

Concept Paper

Decolonizing Digital Citizen Science: Applying the Bridge Framework for Climate Change Preparedness and Adaptation

Jasmin Bhawra 

DEPTH Lab, Johnson Shoyama Graduate School of Public Policy, University of Saskatchewan, Saskatoon, SK S7N 5B8, Canada; jasmin.bhawra@usask.ca

Abstract: Research has historically exploited Indigenous communities, particularly in the medical and health sciences, due to the dominance of discriminatory colonial systems. In many regions across Canada and worldwide, historical and continued injustices have worsened health among Indigenous Peoples. Global health crises such as climate change are most adversely impacting Indigenous communities, as their strong connection to the land means that even subtle changes in the environment can disproportionately affect local food and health systems. As we explore strategies for climate change preparedness and adaptation, Indigenous Peoples have a wealth of Traditional Knowledge to tackle specific climate and related health issues. If combined with digital citizen science, data collection by citizens within a community could provide relevant and timely information about specific jurisdictions. Digital devices such as smartphones, which have widespread ownership, can enable equitable participation in citizen science projects to obtain big data for mitigating and managing climate change impacts. Informed by a Two-Eyed Seeing approach, a decolonized lens to digital citizen science can advance climate change adaptation and preparedness efforts. This paper describes the 'Bridge Framework' for decolonizing digital citizen science using a case study with a subarctic Indigenous community in Saskatchewan, Canada.

Keywords: decolonizing research; citizen science; digital health; health equity; data sovereignty; self-governance; indigenous health; two-eyed seeing; climate change; food security



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1. Introduction

Climate change is a global health crisis and one of the most pressing issues of our time [1–3]. Research has well established the myriad impacts of climate change, including the direct and indirect risks that extreme heat, poor air quality, and adverse weather events pose for human health in particular [3–7]. As identified in the 2021 Intergovernmental Panel on Climate Change (IPCC) Report, rapid and swift action is required to mitigate the devastating effects of climate change [7]. This urgency was reiterated by nations across the world at the 2021 United Nations Climate Change Conference, where key goals were set to minimize the impacts of climate change [8]. Apart from limiting the rise of global temperature to 1.5 degrees Celsius, one of the key goals is to protect communities and natural habitats by implementing adaptation strategies including building defences, warning systems, and resilient infrastructure. Another key goal is to accelerate action through collaboration between governments, business, and civil society [8]. Citizen science can play a significant role in achieving these goals, as it can be used to not only leverage big data that can inform rapid responses [9,10], but also to bring decision-makers and civil society together to co-create solutions [11,12].

Citizen science refers to active citizen participation in research, from data collection to the knowledge dissemination stage [11,13–15]. Digital citizen science is an emerging area whereby digital tools, such as smartphones, are used to capture data and engage with citizens in real time [11,16]. Digital tools have immense potential to advance citizen

science research, as rapid-response interventions and knowledge sharing can be administered in near real time [9,10,17]. Combined with artificial intelligence, there is increasing sophistication that can be built into digital platforms to enable time-, user-, event- or location-triggered prompts for citizens' feedback [9,10,16,17]. Digital technology has an even greater role to play in time-sensitive crises such as climate change preparedness and adaptation.

While there is an immense global effort to mobilize against rapid climate change, the communities most negatively impacted are often not well represented in these critical conversations, if at all. In many regions across Canada and worldwide, Indigenous and racialized communities live in the most severely impacted areas, and as a result experience worse health outcomes [18–23]. On the collective territories or land we call 'Canada', Indigenous Peoples include First Nations, Inuit, and Métis communities, with each group representing unique cultures, languages, beliefs and histories [24]. Indigenous communities are one of the most adversely affected by climate change because their strong connection to the land means that even subtle changes in the environment can have a disproportionately greater impact on their food systems, economy, and livelihoods [21,22,25,26]. In 2022, a new report released by the IPCC, "Climate Change 2022: Impacts, Adaptation, and Vulnerability", importantly acknowledged the role of colonization in perpetuating the climate change problem, as well as the lack of representation from the most vulnerable population groups in determining solutions [27]. If the goals of the IPCC and United Nations Climate Change Conference are to be achieved, consistent and equitable engagement with Indigenous communities is critical to managing climate change [28–31].

Given the disproportionate impact of climate change on Indigenous Peoples, the voices and knowledge of communities who have been experiencing the closest and most frequent effects must be amplified [27]. In exploring opportunities for climate change preparedness and adaptation, integrating Traditional Knowledge (this term is capitalized out of respect for the cumulative body of knowledge, practices, and beliefs that Indigenous Peoples have developed and maintained over time) with Western research methods such as citizen science could provide unique and timely solutions to mitigate climate and related health issues [32,33]. However, traditional citizen science approaches stem from Western ideology, with many projects placing the focus on individual participation and data collection rather than the community as a whole [12,34]. Nevertheless, digital citizen science, in particular, has great potential to aid meaningful climate change preparedness efforts in Indigenous communities, if decolonized and viewed as a collective community effort working towards common goals [10,33].

Researchers, scientists, and thought leaders in this space have paved the way for decolonizing research methods [35–39], and it is important that we apply these principles if we are to address the climate crisis equitably. Decolonizing research methods involves unlearning the hierarchy attributed to Western research methods and respecting Traditional Indigenous Knowledges as valid climate change solutions. Decolonizing digital citizen science has great potential to improve research on climate change preparedness and adaptation.

This paper describes a framework for decolonizing digital citizen science for climate change preparedness and adaptation. Applying three core theoretical approaches (decolonizing research methods, citizen science, Two-Eyed Seeing), the 'Bridge Framework' can contribute to decolonizing citizen science projects. A case example is provided of a subarctic Métis community in Canada to illustrate the application of decolonizing citizen science for a project focused on climate change impacts on food systems—the Food Equity and Environmental Data Sovereignty (FEEDS) Project [40]—where Indigenous self-governance and data sovereignty are prioritized.

2. Theoretical Approach

A framework for decolonizing digital citizen science was informed by three key theoretical approaches: decolonizing research methods, citizen science, and Two-Eyed

Seeing. Decolonizing research is the first step, and when combined with a Two-Eyed Seeing approach, allows researchers to apply citizen science to any project with the mindset of collaboration, determining a collective vision, and eliminating or reversing power imbalances between researchers and citizens or communities.

2.1. Decolonizing Research

Decolonizing research de-centres the focus from the aims of non-Indigenous researchers to the needs of Indigenous Peoples [35]. It is a process that requires unlearning Western-centric research practices, from data collection and analysis to participant engagement and knowledge sharing, in order to dissociate research from its colonial roots [34,37,38]. While community-based participatory research is commonly applied to community-focused research [41], this does not necessarily mean that projects are community-driven or take a “decolonizing” lens. Decolonizing research requires an active stance—it is an iterative process whereby each aspect of research and engagement is unpacked to understand the potential colonial underpinnings, and reassessed with a decolonized lens. Engaging in this process warrants dedicated time and reflection, and while I describe my experience in the FEEDS Project as a case study below, the topic cannot be done justice in a single paper. Decolonizing methods can be explored in depth through the works of scholars including Dr. Linda Tuhiwai Smith [35].

2.2. Citizen Science

Citizen science refers to public participation in data collection and knowledge dissemination for research [11,13,42]. Traditionally, citizen science research is conducted voluntarily (i.e., unpaid), and scientists lead projects with input from citizens. This approach enables citizens to contribute or collaborate on all aspects of the research process and promotes open participation which enables citizens to be active collaborators on research projects [11,15,17]. With the expansion of smartphone ownership, information is increasingly being shared through digital and social media. Citizen science has great potential to contribute to climate change adaptation and mitigation strategies, as citizens can report on and respond to the effects of climate change in real time with the help of digital tools. A current deficit of this approach, however, has been the lack of representation of Indigenous, racialized and low-income groups [15,43,44]—many of whom experience the adverse effects of climate change most frequently and severely [2,28]. The individualistic approach of citizen science limits its application for community-driven initiatives if not adapted using a decolonized and Two-Eyed Seeing approach, whereby citizens are viewed as members of a larger community for project participation.

2.3. Two-Eyed Seeing

Two-Eyed Seeing is a term coined by M'ikmaw Elder, Albert Marshall, which refers to learning to see from one eye with the strengths of Indigenous Knowledges, and the other eye with the strengths of Western knowledges [45–47]. This approach is based on the principle that neither type of knowledge is superior to the other, and instead, learning to see with both eyes encourages creativity and inclusivity in how problems and solutions are oriented. A Two-Eyed Seeing approach, when combined with decolonizing citizen science, can promote self-governance by allowing researchers and communities to find local solutions to global problems [11]. For example, the FEEDS Project aims to develop a digital platform for real-time decision-making to mitigate adverse climate change-related impacts on human health in the communities most affected. This project highlights Traditional Indigenous Knowledge about the environment and food systems, Indigenous research methods, and Western digital citizen science methods to promote culturally relevant approaches for climate change preparedness and adaptation [40].

3. A Framework for Decolonizing Digital Citizen Science

Decolonizing digital citizen science is a process that requires understanding and identifying the various ways in which citizen science has stemmed from a colonial perspective, and reimagining how the strengths of this method can be applied with a Two-Eyed Seeing approach [45–47]. Figure 1 describes a framework for decolonizing citizen science whereby a self-decolonizing journey, community engagement and capacity building, integrated knowledge translation, and co-creating solutions with communities are key pillars that can lead to Indigenous self-governance—a process that has particular benefits for climate change preparedness and adaptation. The ultimate goal of engaging in decolonizing citizen science is to facilitate healing, self-determination, and self-governance [35].

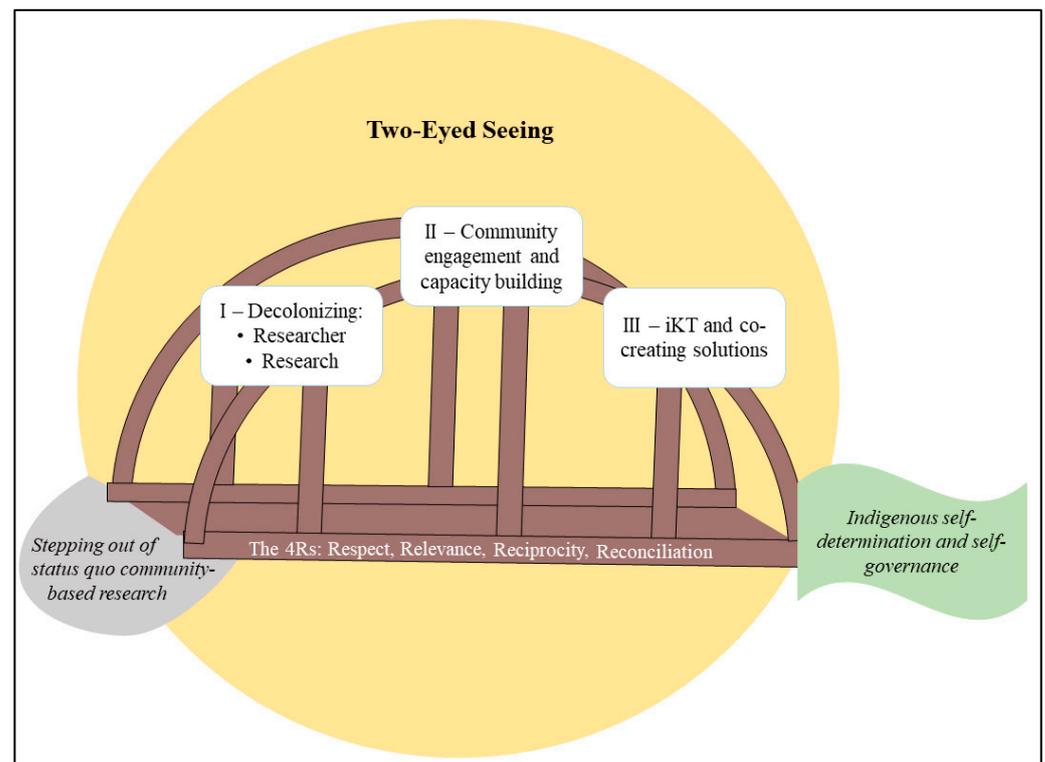


Figure 1. The Bridge Framework for decolonizing digital citizen science.

3.1. Self-Decolonization

As a settler scholar and daughter of immigrants with Indian ancestry—a country formerly colonized by the British—witnessing the intergenerational impacts of colonization stemmed my interest in understanding the long-term impacts of these systems on health. My undergraduate education introduced me to the concepts of social and ecological determinants of health, where Indigenous Peoples in Canada were consistently noted as experiencing disproportionate health and social disadvantages. While the connection between these issues and colonization was not immediately clear to me, I worked closely with off-reserve Indigenous communities during my graduate studies which elucidated the myriad of impacts that colonization continued to have on holistic health. Over the past 10 years, I have partnered with First Nations and Métis communities in Ontario and Saskatchewan, Canada on a range of projects focused on food security and mental health, and have had the great privilege of learning from Knowledge Keepers and Elders in these communities. These experiences emphasized the importance of acknowledging the extent to which our systems—and therefore our ways of thinking and doing—are colonized, so that we may begin to reimagine how our approach to health research and community engagement could shift if we took a decolonized approach.

Decolonizing research is a complex process, as most research endeavours are embedded in colonial systems or institutions. However, if we are to make meaningful progress in improving health outcomes among (formerly) colonized communities—particularly those who have suffered unspeakable injustice as a result—decolonization is a necessary first step.

We cannot let the history of harmful colonial impacts be water under the proverbial bridge. In partnering with Indigenous communities, relationships must be built based on respect, collaboration, and common goals [48,49]. On my decolonizing journey over the past decade, I learned that engaging in decolonizing citizen science research is a process that begins with decolonizing as a self-reflective practice for researchers. Decolonizing involves non-Indigenous researchers listening and learning from the colonial history and experiences of Indigenous Peoples. This practice requires identifying and deconstructing Western-centric research training, which can be initiated through grounding in self-awareness and reflection; listening to stories of lived experience; and engaging with scholars championing these areas.

3.2. Community Engagement and Capacity Building

Consistent and meaningful community engagement and capacity building is an important next step for not only decolonizing research but also for self-determination to take place as described in Tuhiwai Smith's Indigenous Research Agenda [35]. This agenda provides a set of approaches that can be incorporated into research methods or practices to facilitate self-determination. Self-determination is described not only as a goal, but also as a process that requires transformation, decolonization, healing, and mobilization of Indigenous Peoples [35]. As part of this process, researchers must appreciate how each community is unique and has different histories, experiences, understandings of the world, and teachings. Community engagement is an important part of this learning and can take place in various forms. However, a critical aspect of this engagement is identifying where and how capacity can be built to ensure long-term project sustainability and longevity. Ultimately, self-determination and governance rely on community capacity.

3.3. Integrated Knowledge Translation and Co-Creating Solutions

Integrated knowledge translation (iKT) refers to collaboration between researchers and knowledge users to address a research issue [50,51]. Taking principles from community-based participatory research, iKT involves the co-production of knowledge as knowledge users work with researchers throughout the research process [51]. This approach not only provides the necessary context for designing and implementing a research project, but also ensures that the knowledge generated and shared throughout a research project is continually disseminated to all relevant stakeholders [51]. For community-based initiatives, the consultation also ensures that the project plan, implementation, and knowledge dissemination are both culturally appropriate and relevant given the specific context, resources, and infrastructure available to a given project or community.

Throughout a project, co-creating solutions to identified problems is an essential component of designing policies, programs, and strategies that will succeed. Emphasizing co-creation ensures that solutions do not come from the 'top' down [41,43,47]. Communities are the experts and beneficiaries of a given research project, and thus must lead in guiding solutions. The process of iKT should take place before, during, and after co-creating solutions, as this encourages timely idea sharing, dissemination, and implementation of solutions. Activities may include organizing community events, use of social media, or sharing knowledge via KT symposia [52].

3.4. The 4Rs

Decolonizing digital citizen science cannot take place without respect for Indigenous Knowledges and cultures, and between researchers and community members [35,39,43]. The foundation for the bridge to decolonizing citizen science for Indigenous self-governance

therefore must be the 4Rs—Respect, Relevance, Reciprocity, and Reconciliation [53,54]. This includes respect for Indigenous cultures and Peoples, reciprocity in relationships between non-Indigenous settlers and Indigenous Peoples, a reconciliatory approach to building partnerships, capacity, understanding, and healing and ensuring the relevance of our approaches to engagement, iKT, and co-creating solutions.

In conducting digital citizen science projects, the First Nations OCAP principles [55] are also critical to acknowledge and apply. These include ownership of knowledge and data, control over all aspects of research, access to information about one's own community, and possession or control of data [55]. These principles ensure First Nations and other Indigenous Peoples the right to their own information and respect the fact that they are stewards of their information, in the same way that they are stewards over their own lands. They also reflect commitments to use and share information in a way that maximizes the benefit to a community, while minimizing harm.

Both the 4Rs and OCAP principles are critical to decolonizing research. As described in Darder's (2019) principles of decolonizing Indigenous education framework, decolonization requires centring Indigenous voices and naming coloniality [56]. Removal of hierarchical structures is also a key component, as Western research norms for funding structures, rigid timelines, and research participation can limit the application of decolonized citizen science and a Two-Eyed Seeing approach. Collaboration at every stage of research, from project conceptualization to knowledge dissemination, is necessary for self-determination and self-governance.

3.5. The Bridge

The Bridge Framework is enabled by Two-Eyed Seeing, which is symbolized by a circle that encompasses the bridge that facilitates the change from status quo in community-based research to Indigenous self-governance—a pathway that is particularly important in leveraging the strengths of both Indigenous and Western Ways of Knowing in addressing a specific problem such as climate change [31,40]. From a digital citizen science perspective, self-governance cannot be feasible without data sovereignty as big data generated by citizens playing a central role in informing decision-making [11]. Thus, the framework ultimately leads to both self-governance and data sovereignty.

Collaborations between non-Indigenous or settler scientists and Indigenous communities, which are particularly critical for climate change preparedness and adaptation, may benefit from a Two-Eyed Seeing approach to leverage tools, expertise, and technology [45,47]. Decolonizing digital citizen science is an essential step in achieving the goals of the IPCC and the 2021 United Nations Climate Change Conference [8,27]. The Bridge Framework is currently being used to implement climate change preparedness and adaptation strategies in partnership with Indigenous communities [40].

4. A Bridge Framework Project—Food Equity and Environmental Data Sovereignty (FEEDS)

Guided by the decolonizing citizen science Bridge Framework, the FEEDS Project was conceptualized in collaboration with the Métis jurisdiction of Île-à-la-Crosse, Saskatchewan, Canada. The Northern Village of Île-à-la-Crosse, also referred to as Sakitawak—the Cree name translating to “the place where the river flows out” [57]—is a subarctic community with road access in northwest Saskatchewan. Given its location on the lake of Île-à-la-Crosse, Sakitawak was a strategic location for the fur trade. It is the second-oldest community in Saskatchewan, established in 1778, with a population of 1300 [57]. The community is predominantly Métis (77%), and Northern Michif is the traditional language [58]. In Île-à-la-Crosse, commercial fishing, forestry, wild rice harvesting, schools, and the hospital are key sources of employment. With respect to digital access and connectivity, the majority of citizens aged 13 years and older own smartphones and have mobile or WiFi data plans. The presence of a cellular tower in Île-à-la-Crosse provides reliable and easy access to mobile data. FEEDS is a sustainable digital platform that enables early detection and warning of

climate change impacts on food sovereignty, food security, and solastalgia [40]. Ultimately, the digital platform will provide access to real-time data to facilitate timely decision-making and knowledge dissemination for climate change preparedness and mitigation in the community.

4.1. Applying Citizen Science to the FEEDS Project

In applying the Bridge Framework, FEEDS incorporates the Smart Framework's principles of integrating citizen science, community-based participatory research, and systems science for population health research [11]. Citizen science, in particular, has played an important role in the ecological sciences to collect data on a range of issues including wildlife movement patterns and climate change-related environmental hazards [13,14]. Citizen science, when combined with digital tools, has great potential to generate big data to address complex public health crises if citizens' data can be anonymized and applied by communities [11,40]. In addition to capturing environmental and health-related data (e.g., weather, permafrost degradation, fire hazards, human movement, etc.), the FEEDS Project uses a custom-built app to engage and enable citizens to report on environmental hazards, changes in biodiversity or wildlife, and related food and mental health issues in their communities [40]. Big data is relayed in real time to a digital dashboard, where citizens and decision-makers have access to valuable information which can be used to mitigate health-related risks of climate change [40].

4.2. Decolonizing Citizen Science for the FEEDS Project

A series of steps were followed from the Bridge Framework for the FEEDS Project. First, all lead researchers have a strong history of working with Indigenous communities and applying a decolonizing lens to their research approaches. The lead researchers have facilitated consistent engagement between the researcher team and community to ensure that the whole team (researchers, decision-makers, Elders) work together in applying a Two-Eyed Seeing approach for addressing community health issues. This process has involved researchers actively learning from Indigenous community leaders. Many thought leaders in the space of decolonizing research methods [35,38,39] describe the importance of decolonization as a process that is not 'complete' at any given point but continues to evolve over time.

For instance, as the Principal Investigator of the FEEDS Project, my personal journey of decolonizing myself as a researcher has involved formal training workshops led by Indigenous scholars, conversations with Elders and community members, reading and learning about Indigenous histories in Canada, and unpacking my family's own complicated history with colonization as a second-generation immigrant with Indian ancestry—an ongoing process that started 10 years ago when I began collaborating with Indigenous partners [59,60].

Decolonization is an especially critical consideration for research related to climate change impacts on health and food systems, as issues of land and food sovereignty, as well as holistic wellness (i.e., the connectedness between environmental and human health, which includes social, physical, mental, spiritual, and emotional wellbeing) [61]. As global conversations are taking place on climate change preparedness, colonial power dynamics are clearly on display. The lack of attention to decolonization may hinder our collective efforts to curb climate change while we can.

4.3. Community Engagement and Capacity Building

Understanding the distinct community of Île-à-la-Croix started with building a relationship with several community members and leaders more than a year before the project was conceptualized. This community engagement was informed by the 4Rs and OCAP [53,55], where based on guidance from community leaders, community members were approached with respect and ceremony (i.e., gifting of tobacco). Common values and goals were discussed as part of building a relationship based on reciprocity, reconciliation,

and relevant project planning. The OCAP principles strongly informed conversations about data ownership and control, hence centring data privacy and sovereignty as part of the digital platform design. These conversations over the course of several months elucidated various priority areas for the community, including climate change impacts on food systems and mental health [62].

FEEDS was then established, and in order to facilitate focused discussions about these topics, a Citizen Scientist Advisory Council was created comprising Elders, Traditional Knowledge Keepers, key community decision-makers, youth, and FEEDS researchers [40]. The Council governs the FEEDS Project, and importantly, represents community members' interests to guide the governance of project development, implementation, and evaluation. All Council members are provided with CAD 150 as honoraria for each meeting to respect their time and guidance. The Council also leads the citizen recruitment strategy whereby citizen scientists can be actively engaged in the research process from data collection to knowledge translation [40].

The emphasis of these engagements is on listening to community needs and developing a long-term relationship that would not only ensure cultural safety, but also facilitate community capacity building. The Citizen Scientist Advisory Council is leading capacity-building efforts to ensure long-term project sustainability. One example of a distinct initiative that stemmed from the focus on sustainable project capacity is the development of a digital literacy program where youth learn research and data skills and teach adults and Elders in the community. Improvements to digital literacy were identified as critical for the success of not only the FEEDS Project but also for improving digital connectivity and independence in decision-making for community members.

4.4. Integrated Knowledge Translation and Co-Creating Solutions

It is a common misconception that knowledge translation happens after the project starts. Using the Bridge Framework, we ensured that knowledge transfer between Indigenous Knowledge Keepers, Elders, decision-makers, and researchers happened during the community engagement, which eventually led to the conceptualization of FEEDS, i.e., integrated knowledge translation and co-creation of solutions.

Given the complex history between researchers and communities and the exploitation of Indigenous Peoples and their data [23,63], self-governance and data sovereignty are of utmost importance for the FEEDS Project. Citizen scientists in the community co-create the project objectives, and these objectives evolve as community needs may change. Citizens are stewards of their own data and can engage with researchers and decision-makers in real time to shape solutions for the community [40]. For example, citizens can anonymously engage with researchers or decision-makers in the smartphone app via a user-triggered messaging system. This system provides greater flexibility and control for citizens to engage outside of traditional data collection periods and facilitates timely data access to relevant stakeholders. Equity is emphasized further in the researcher-community relationship, as Citizen Scientist Advisory Council members are co-authors on publications, and collaborate on other knowledge dissemination materials and events.

Meaningful community engagement requires awareness and management of hierarchies that inevitably enter a research or project dynamic. In order to facilitate this, capacity building is necessary to manage power dynamics, and ultimately ensure the sustainability of the project in the long term.

5. Discussion

The Bridge Framework was developed to facilitate decolonizing of digital citizen science. Self-decolonization, community engagement and capacity building, iKT, and co-creation of solutions form the pillars of the Bridge Framework, which lead towards Indigenous self-governance and data sovereignty when grounded by the 4Rs. A Two-Eyed Seeing approach encompasses the entire Bridge Framework as it enables researchers to

identify the strengths of both Western and Traditional Knowledges for addressing imminent issues such as climate change.

5.1. Two-Eyed Seeing as an Underlying Approach to Decolonizing Research

The application of a Two-Eyed Seeing approach is critical to decolonizing digital citizen science. This approach requires working closely with Indigenous communities to ensure alignment of research and community priorities, and culturally appropriate knowledge dissemination [35,38,43]. In collaboration with communities, learning where and how specific Western methods or technologies can complement Traditional Indigenous Knowledges and methods is important to advancing our efforts for climate change adaptation and mitigation. For instance, in the FEEDS Project, Traditional Knowledge about the history of climate and weather events, environmental hazards, and shifts in the land, wildlife, and plants serve as indicators of climate change. These shifts have impacted traditional food acquisition practices, food access, and mental and physical health in the communities most adversely impacted [28–31]. In some communities, climate change has led to “positive” effects on food systems, including longer growing seasons [64,65].

Many Indigenous communities, particularly those in rural and remote areas, bear the brunt of climate change impacts [18–22]; however, this also means that these communities have developed invaluable knowledge about climate change adaptation, preparedness, and management [28–30]. Geographic isolation poses a barrier to timely data collection and knowledge sharing in many communities, and digital tools—especially those most widely available, i.e., smartphones—can help with rapid data collection and response [9,11]. Île-à-la-Crosse is better situated than many Indigenous communities in terms of data and WiFi access, which makes the application of this technology more feasible than it may be in other communities. While the experiences of each community regarding climate change impacts on food sovereignty, food security, and mental health differ, the use of digital tools may help bridge some gaps in health equity that result from a lack of access to resources, technology, and support [9,11,16].

It is also important to recognize that the Two-Eyed Seeing approach is not essential to the success of a community project, as an Indigenous-focused lens brings sufficient breadth and depth of knowledge to tackle the complex social and health issues facing Indigenous communities globally. However, where appropriate, Two-Eyed Seeing can be applied to projects where the use of multiple research methods is beneficial. In this context, decolonization has been less commonly referenced as a critical step in applying Two-Eyed Seeing, but decolonization is required if we are to make meaningful change in our systems of research—particularly towards the goals of Indigenous self-governance and data sovereignty [35,39].

5.2. The Potential of Digital Citizen Science for Indigenous Self-Governance and Data Sovereignty

Digital citizen science has transformed citizen science by providing opportunities to collect big data in real time without geographic limitations. For projects using citizen-owned smartphones, widespread data and WiFi access have increased opportunities for citizens to participate in projects globally [9,14,16]. Citizen science projects have typically taken an individualistic approach, whereby citizens gather and share data on their perspectives and observations about a specific area. If we are to bring a decolonized and Indigenous-focused lens to citizen science, the focus must be on the community. Community-oriented data collection, analysis, and knowledge sharing will shift the application of research findings and promote greater participation from marginalized groups [28,43].

For Indigenous communities, in particular, self-determination and self-governance have been long-standing issues because traditional research methods have posed barriers to data access and ownership [35]. Community-based digital citizen science can give communities ownership of their own data so that they have the power to act on this information in the best interests of their community members.

Digital citizen science can be conducted in collaboration with researchers; however, it can also be entirely community-driven using external or self-developed digital platforms [10]. We must consider moving away from traditional models—as academics and researchers we cannot continue to centre our project agendas on academic goalposts. Communities should have the option to reach out for collaborations where this expertise is needed, but keep control over their data and their futures.

In addition to data ownership in research, data sovereignty has become a topic of increasing concern as our numerous digital devices collect data from our social media platforms and applications [66]. Data sovereignty refers to meaningful control or ownership of one's data [66]. Given that citizen science is typically voluntary, there are often unclear parameters around data ownership, privacy, and security [16,67]. A decolonized approach to digital citizen science requires dedicated conversations around data sovereignty, including the development of digital platforms that incorporate nuanced access to citizen and community data [9,11].

5.3. The Role of Digital Tools in Climate Change Adaptation and Preparedness

Digital tools and technology have an important role to play in rapid-response research, particularly climate change research focused in rural and remote areas. Digital devices, such as smartphones, can enhance citizens' access to specific resources or projects to connect with others about issues in their communities. These devices can serve as tools of equity [11], whereby all citizens with either a smartphone or digital connectivity can access essential information or engage on issues of interest. In the FEEDS Project, a custom-built smartphone app is being designed to capture information on specific priority areas, barriers, and opportunities for climate change preparedness and adaptation [40]. Qualitative data collection, which typically takes place in the form of key informant interviews and sharing circles, is also being adapted for digital storytelling following the lead of the Citizen Scientist Advisory Council.

In addition to amplifying citizen voices, digital data collection generates big data which can lead to collaborations across disciplines (i.e., environment, health, social justice) that are necessary for work on climate change adaptation and preparedness. In the FEEDS Project, big data collected by the community (quantitative and qualitative data from smartphones) will be linked to existing databases—including weather data (i.e., Environment and Climate Change Canada) and climate change trackers (i.e., Arctic observatories)—as the combination of historical and prospective data collection will enhance prediction models that can improve local climate preparedness strategies.

This cross-disciplinary collaboration with communities can lead to rapid-response interventions and the design of long-term strategies for climate change preparedness and adaptation. In order for our global efforts to succeed, local participation of multiple sectors is required to design and implement sustainable solutions. Digital tools can help with not only acquiring necessary data to inform this decision-making but also timely knowledge sharing both within and across communities that may be experiencing similar impacts of climate change.

5.4. Challenges and Opportunities in Decolonizing Citizen Science Research

Digital citizen science can aid in timely data collection, rapid-response interventions, and real-time engagement and knowledge dissemination. However, the lack of structured citizen recruitment and data management in most projects can lead to challenges with data quality, ownership, and security [15,67]. Study samples are especially important for research-driven projects; however, structured sampling strategies are not always possible in citizen science projects. Whether the project is community-based or focused on climate change impacts on health, randomized sampling strategies, for instance, may not be ethical or even logistically feasible [68]. In the FEEDS Project, key decision-makers and Knowledge Keepers in the community were first approached to identify appropriate modes of recruitment [39]. An effort is being made to enrol citizens from various sociodemographic (i.e.,

gender, age) and digital literacy categories. Based on the existing venues for communication in the community, the project is being promoted through social media, the Mayor's office, the school board email list, and the local radio station. The Advisory Council advised against randomizing citizen recruitment given the project's focus on climate change impacts on mental health, so that community participation in the project remained open.

Data quality is a challenge for digital citizen science projects as data collection may be less structured (i.e., user-triggered) for some components, and data analysis may need to be more flexible given intermittent data flow. A key consideration for projects focused on urgent, time-sensitive crises like climate change is that the focus cannot and should not be solely on research as a process. If the purpose of conducting this research is to aid in climate change preparedness and adaptation strategies, breaking conventional research protocols is often necessary to address issues in real time, or translate knowledge sooner than an anticipated wave of data collection is completed.

Data ownership is an important component of digital citizen science projects, as it relates to citizen and community data sovereignty. The FEEDS Project is building a system whereby citizen data are anonymous and encrypted to ensure that the OCAP principles of ownership, access, control, and possession over data are followed. The digital dashboard which displays community-level data is shared with decision-makers in real time, and the Mayor's office decides which stakeholders have access to different types of data [40]. The opportunity for real-time data access and communication increases the community's capacity to self-govern.

Of utmost importance for all digital data-based projects is data security and privacy. In order to protect citizens' identity and information, anonymizing data is an essential first step. Some projects, including FEEDS, rely on citizens identifying themselves to receive help; however, this must be made optional so that citizens have control over their information. To further ensure confidentiality, data encryption and limited access to personally identifiable information must be built into digital platform designs. The FEEDS Project also employs a pause feature whereby citizens can disable monitoring for a set duration of time. Secure server space, whether affiliated with a research institute or located locally within a community is part of the essential infrastructure for data security and privacy [9,17].

In addition to data-related concerns, research has identified lower participation of marginalized and lower socioeconomic status groups in citizen science projects [12,43]. Lower participation may be a result of deficits in study recruitment, a history of exploitation that discourages specific groups from engaging in research, and mistrust of research, among other reasons [23,35,43]. Given that these groups are also most likely to be adversely affected by issues like climate change, their participation is critical in digital citizen science projects. Promoting inclusivity and collaboration in this research relies heavily on processes like decolonizing and community-based partnerships, especially if we are to work together as a global society for climate change preparedness, adaptation, and mitigation.

6. Conclusions

Decolonizing citizen science has great potential to respond rapidly to global crises such as climate change. The FEEDS Project provides an example of how citizen science can not only be reimagined with a decolonized lens, but also how data sovereignty and self-governance can be promoted as part of community-driven research.

Decolonizing citizen science is critical to partnering with Indigenous communities in the digital age, and it can also facilitate equity among other marginalized populations and developing countries that have historically been impacted by colonization. The Bridge Framework is one small step in the decolonization of digital citizen science to conduct ethical research with Indigenous and marginalized communities in the 21st century. Digital citizen science, if decolonized, can play a significant role in protecting communities and natural habitats by accelerating action through collaboration between governments and civil society.

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