



Synthesis

A values-centered relational science model: supporting Indigenous rights and reconciliation in research

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ABSTRACT. Addressing complex social-ecological issues requires all relevant sources of knowledge and data, especially those held by communities who remain close to the land. Centuries of oppression, extractive research practices, and misrepresentation have hindered balanced knowledge exchange with Indigenous communities and inhibited innovation and problem-solving capacity in all scientific fields. A recent shift in the research landscape reflects a growing interest in engaging across diverse communities and ways of knowing. Scientific discussions increasingly highlight the inherent value of Indigenous environmental ethics frameworks and processes as the original roadmaps for sustainable development planning, including their potential in addressing the climate crisis and related social and environmental concerns. Momentum in this shift is also propelled by an increasing body of research evidencing the role of Indigenous land stewardship for maintaining ecological health and biodiversity. However, a key challenge straining this movement lies rooted in colonial residue and ongoing actions that suppress and co-opt Indigenous knowledge systems. Scientists working with incomplete datasets privilege a handful of narratives, conceptual understandings, languages, and historical contexts, while failing to engage thousands of collective bodies of intergenerational, place-based knowledge systems. The current dominant colonial paradigm in scientific research risks continued harmful impacts to Indigenous communities that sustain diverse knowledge systems. Here, we outline how ethical standards in researcher practice can be raised in order to reconcile colonial legacies and ongoing settler colonial practices. We synthesize across Indigenous and community-based research protocols and frameworks, transferring knowledge across disciplines, and ground truthing methods and processes in our own practice, to present a relational science working model for supporting Indigenous rights and reconciliation in research. We maintain that core Indigenous values of integrity, respect, humility, and reciprocity should shape researcher responsibilities and methods applied in order to raise ethical standards and long-term relational accountability regarding Indigenous lands, rights, communities, and our shared futures.

Key Words: *colonial science, community-based participatory research; decolonizing methodologies; ethics; humility; Indigenous communities; Indigenous data sovereignty; Indigenous knowledge systems; Indigenous methodologies; Indigenous research governance; Indigenous rights; integrity; reciprocity; reconciliation; relational science; respect; values*

INTRODUCTION

Indigenous knowledge systems, recognized as collective and dynamic bodies of knowledge generated over centuries of observation (Cajete 2000, International Council for Science 2002, Nakashima and Roué 2002, Berkes 2008, 2009a, Burkett 2013), continue to guide a wide range of environmental practices, such as sustainable agriculture (Altieri 2004, Johnson et al. 2021), watershed management (Kagawa and Vitousek 2012), and intentional burning (including “good fire” or cultural burning) for fire and land management (Kimmerer and Lake 2001, McKemey et al. 2020, Christianson et al. 2022). Effectively addressing complex social-ecological issues, such as climate change and environmental justice, will require all relevant sources of knowledge and data, especially those held by Indigenous communities who remain close to the land (Nakashima et al. 2012). However, long-standing, colonial-rooted imbalances in power relations reinforce a problematic scientific research paradigm that perpetuates disparities in knowledge generation and access, inhibiting diverse knowledge exchanges, innovation, and problem-solving potential (Battiste and Youngblood Henderson 2000, Simpson 2004, Battiste 2008). As a result, many environmental scientists work with incomplete datasets, neglecting the vast and longstanding bodies of knowledge held within Indigenous knowledge systems that have sustained social and ecological well-being. Compounding this issue is the

concerning evidence that, even when Indigenous knowledge systems are documented, Indigenous communities often lack access to their externally held data, contributing to unchecked inaccuracies in data and ethical violations of Indigenous Peoples’ rights (Quigley 2001, Harris and Jim 2010, David-Chavez and Gavin 2018). To address these concerns, this synthesis article provides researchers and community members with a working model that aligns cultural and institutional principles for research integrity.

Our research is grounded within experiential practice to provide a holistic conceptual map and working model applicable to Indigenous research initiatives. In building this working model for research integrity, we draw from leading ethical guidelines across disciplines and institutions, including education (Carjuzaa and Fenimore-Smith 2010), public health (Straits et al. 2012), geography (Grossman et al. 2010), as well as Indigenous institutions and initiatives (e.g., Akwesasne Task Force on the Environment 1996, KSDPP 2007, Assembly of First Nations 2009, Argumedo and Communities of the Potato Park 2011, South African San Institute 2017, AIATSIS 2020, Karuk - UC Berkeley Collaborative 2020). The resulting working model provides a guiding path for diverse research projects and collaborations led by and engaging with Indigenous Peoples. In order to introduce this model this article (i) provides a concise history including patterns and paradigms in science research by,

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on, and with Indigenous communities; (ii) highlights research frameworks, approaches, and concepts across disciplines as resources for improving ethical standards in science research; (iii) defines core values, researcher responsibilities, and actionable methods necessary for integrity in research with Indigenous communities; and (iv) visualizes a working model that brings these resources together. This effort is also informed by a case study and lessons learned from field-testing this working model. We draw on this case study by presenting anecdotes describing challenges and effective means of implementing a values-centered relational science model in practice.

Our authoring team draws on decades of lived and professional experience working within Indigenous community contexts, within the U.S., including the U.S. Caribbean, where our case study takes place (co-led by D. David-Chavez and N. Ortiz), Aotearoa New Zealand, Peru, Nicaragua, Vanuatu, and with international Indigenous collaborative efforts. Our authoring team includes four Indigenous authors (Arawak Taíno/Boricua, Ahtna from Native Village of Kluti-Kaah, and Laguna Pueblo) and a non-Indigenous scholar drawing from experience in international Indigenous research partnerships. We draw from various roles and areas of expertise held across our authoring team, including Indigenous science research and education, biocultural conservation, Indigenous evaluation, Indigenous data sovereignty, and as community practitioners stewarding and sustaining Indigenous knowledge systems and practices.

In our development of a culturally and ethically informed model for relational science research, our approach included cross-disciplinary synthesis of literature. This literature synthesis is complemented through ground-truthing of methods as detailed through the practice of reflexive written and visual journaling during the community-led field study described within numerous anecdotes in this article (by D. David-Chavez). We also engaged numerous iterations of review focused on validating and refining the model through public presentations, training, and workshop activities shared with community members and scholars engaging in Indigenous-focused research initiatives.

History, patterns, and paradigms in science research with Indigenous Peoples

Below we outline notable shifts and patterns in research inquiry and practice across time. Although not as comprehensive as more in-depth historical accounts (e.g., Whitt 2009), this reflection on historic patterns in scientific research by, on, and with Indigenous communities clarifies our understanding of the major paradigms driving and shaping present research relations that our article and working model seek to reconcile. As culturally informed research recognizes, “historical views (including ignorance of history) and societal norms influence the ways researchers interact with people and their communities” (Caldwell et al. 2005:5). Here we unpack events informing these relationships and ongoing normative shifts in Indigenous-focused research.

Indigenous science research

The earliest and longest record of research begins with Indigenous systematic inquiry in the form of longitudinal studies spanning generations past and into the present. Indigenous Peoples have formed, tested, adapted, and refined diverse knowledge systems based largely upon careful observation of Earth’s natural systems and geophysical processes alongside related cultural, spiritual, and social-ecological systems of interaction (Kawagley 1993,

Berkes et al. 2000, Cajete 2000, Berkes 2008). Although Indigenous Peoples have been forced to endure severe and traumatic disruptions to their knowledge and lifeways, Indigenous knowledge systems persist into the present (Yellow Horse Brave Heart and DeBruyn 1998, Stone 2002, Fernández-Llamazares et al. 2021).

Colonial science research

Colonial science research likewise persists into the present. This form of research seats authority in knowledge generation and validation in colonial institutions (including academia). This research approach often describes Indigenous communities as vulnerable, disadvantaged, and at risk of extinction, despite the continued resistance and resilience of thousands of communities. This deficit framing can be used to enable the extraction of knowledge systems and the emphasis of studies of/on (rather than by/with) Indigenous Peoples for institutional knowledge gain (Battiste and Youngblood Henderson 2000, Smith 2012). Exploitative research methods driven by the colonial science paradigm have also allowed for non-consensual medical experiments and biopiracy, generating harmful outcomes for Indigenous communities around the world (Mead 1994, Laird and Lisinge 2002, Mello and Wolf 2010, Shiva 2016).

Though attempts to reconcile such human rights violations exist, such as through establishment of the Belmont Principles (United States National Commission for the Protection of Human Subjects of Biomedical, Behavioral Research 1978), and the Nagoya Protocol on Access and Benefit Sharing (Convention on Biological Diversity 2011), pervasive harms persist. Many extractive colonial paradigm-driven studies regard issues affecting Indigenous communities solely within the deficit narrative of their symptoms (e.g., social conditions of poverty, health disparities, etc.) without recognizing how these conditions reflect acts of genocide and systemic oppression that created them (Meadows et al. 2003, Ermine et al. 2004, Simpson 2004, Tuck 2009, Walter and Andersen 2013, van Uitregt 2021). The colonial science research paradigm also reinforces artificial binaries between what is validated as “Western” science knowledge (a disproportionately small handful of perspectives and sources) and a multitude of diverse ways of knowing (including scientific ways of knowing) from thousands of Indigenous communities around the world. Rather than effectively recognizing Indigenous research and knowledge systems as adaptive and pluralistic (i.e., weaving together multiple strands of knowing), they often remain dismissively aggregated and othered as “ethno-,” “folk,” or “traditional” knowledge (Agrawal 1995, Kimmerer 2002, Tengö et al. 2013).

Present transitional era and paradigm shift

Although Indigenous knowledge systems have supported human flourishing and sustainable lifeways for millennia, and though interest in Indigenous knowledge has existed since the inception of colonization, this interest has culminated in recent years with broader recognition across scientific research and policy forums. These include the Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and recent U.S. federal agency guidance, recognizing the value of Indigenous knowledge systems for addressing complex social-ecological issues such as climate change and conserving biodiversity (Thaman et al. 2013, Tengö et al. 2014, Gavin et al. 2015, Garnett

et al. 2018, IPCC 2022, Executive Office of the President 2021, Prabhakar and Mallory 2022). Yet, for the science community to engage Indigenous knowledge systems ethically and effectively, legacies built upon 500+ years of unethical practices require critical intervention. For example, evidence shows that research engaging with Indigenous knowledge systems reflect an imbalance in power distribution, often perpetuating extractive research practices (David-Chavez and Gavin 2018). Specifically, research and data practices and ensuing policy regarding Indigenous communities remain largely shaped by external agendas, resulting in a lack of relevant, timely, usable, and accurate data for decision makers within Indigenous communities (Schultz and Rainie 2014, Walter et al. 2021). Compounding these issues, research is generally conducted by external, often non-Indigenous researchers lacking cultural context, and often inadequately trained. When external interests and policies determine which data are collected and who can access them, and these data in turn inform policy development, results show consistent failure in terms of effective Indigenous policy across colonized nations (Walter and Carroll 2021).

Amidst longstanding ethical misconduct and ineffective research standards, hope arises through the emergence of protocols protecting Indigenous community rights developing across a multitude of geographic scales and institutional contexts. These include developments within institutions (e.g., Grossman et al. 2010, Liboiron et al. 2020), in communities and within regions (KSDPP 2007, South African San Institute 2017, Kūlana Noi'i Working Group 2021), by nation-states, including Indigenous nations (CTKW 2014, Rainie et al. 2017a), and within international forums (United Nations General Assembly 2007, Convention on Biological Diversity 2011, United Nations Framework Convention on Climate Change 2013, Research Data Alliance International Indigenous Data Sovereignty Interest Group 2019). These initiatives represent a necessary disruption to colonial science paradigms and a new pattern within research in which Indigenous communities and allies are (re)engaging in research efforts that reaffirm and strengthen Indigenous lifeways and principles of ethics (Ermine et al. 2004). This growing movement primarily led by Indigenous scholars and researchers, many of whom represent the first generation in their families with access to leadership roles in scientific research and higher education, also focuses on honoring and strengthening inherent rights to sovereignty and Indigenous governance in research and data practices (Kukutai and Taylor 2016a, Carroll et al. 2019). Threads of this movement include the affirmation of Indigenous data sovereignty: "the right of Native nations to govern the collection, ownership, and application of [their] own data" (Rainie et al. 2017a). Indigenous data sovereignty is expressed through the articulation of Indigenous Peoples' values, rights, and interests regarding Indigenous data governance (Rainie et al. 2017b, Carroll et al. 2019, David-Chavez et al. 2019, Jennings et al. 2023), Indigenous research sovereignty (Hudson et al. 2023, Leonard et al. 2023), and regarding research governance (Garba et al. 2023), in ways that honor ethical and relational responsibilities.

Within this growing movement, we see a need for continued transformative shift from the colonial science research paradigm toward trust and relational accountability across cultural communities. We also see an opportunity to achieve this through aligning cultural and institutional protocols and principles for

integrity. More broadly across the science community, this movement represents an ongoing transition in the academic landscape toward research practice that is interdisciplinary (including theory and methods from multiple disciplines), and transdisciplinary (including community practitioners), bringing together strengths from across the sciences, humanities, and Indigenous knowledge bases for application-oriented research (Mausser et al. 2013, Pálsson et al. 2013, Wilmer et al. 2021; Belmont Forum 2016, *unpublished report*). The following section advances these efforts through a cross-disciplinary and cross-cultural literature synthesis, outlining opportunities for improving research standards.

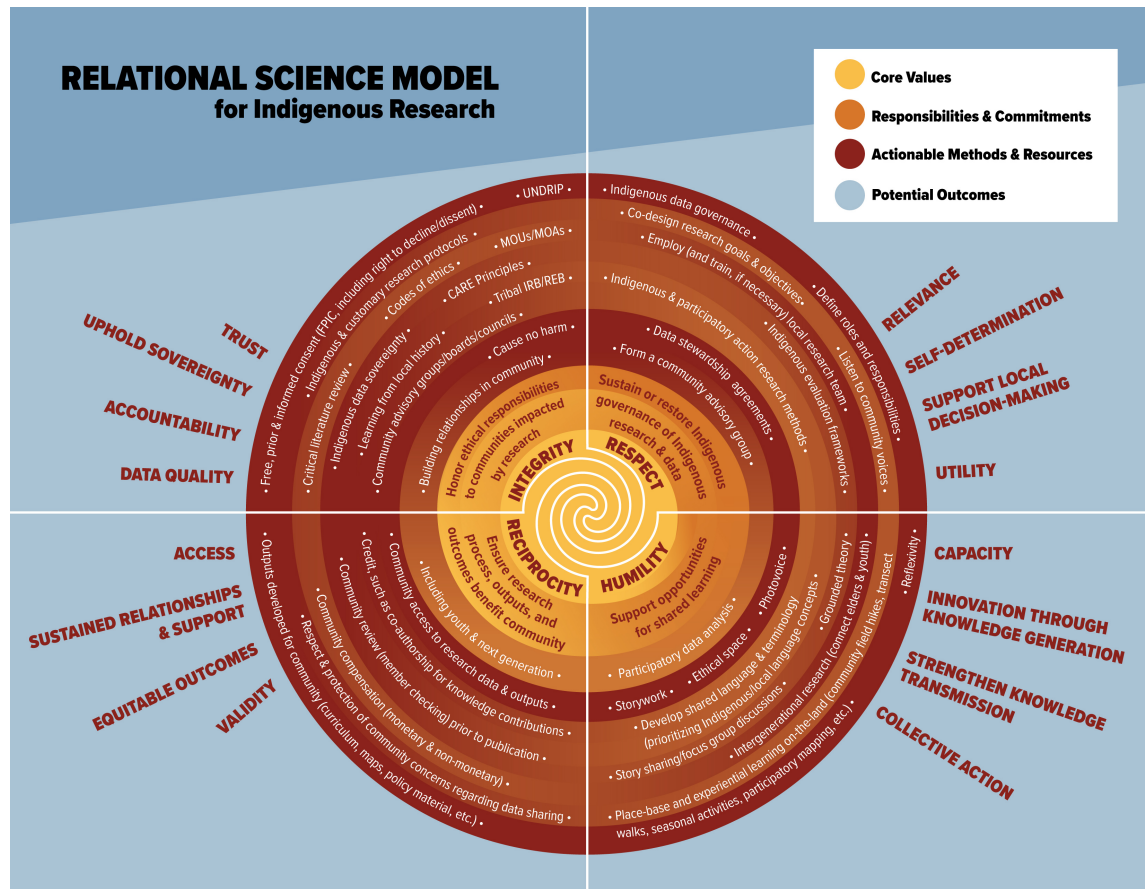
An interdisciplinary review of relational accountability in research

In this synthesis of literature, we extend our scope into and beyond environmental sciences, linking to relevant research frameworks, effective practices, approaches, and concepts more broadly applied in research with Indigenous communities. In doing so, we draw from and emphasize Indigenous and community-based participatory research methodologies as critical resources for explicitly addressing the historic harms outlined in this article. Sources within this synthesis draw from several of the authors' experiences as Indigenous scholars and community members (David-Chavez, Ortiz, Valdez, Carroll), also through learning from parallel experiences shared by Indigenous scholars and researchers (e.g., Masta 2018, Reano 2020, Tachera 2021, Hird et al. 2023), and through experience working within Indigenous communities. The supplementary table included with this article (Appendix 1) includes a summary of the key theoretical contributions including research frameworks, methodological approaches, and relevant concepts, which have informed our practice and contributed to the conceptualization of a relational science model.

In this work we sought to understand the distinct historical, colonial, place-based, and socio-cultural contexts surrounding a given research study, and how these factors relate to the unique strengths and challenges that Indigenous community members carry into a research setting. Indigenous and decolonizing methodologies provide the processes to engage with these contexts (Chilisa 2012, Smith 2012, Walter and Andersen 2013, Kovach 2021). A long-term relational accountability to land and community, including more-than-human communities (animals, plants, and natural entities), and future generations, forms a foundational basis across Indigenous methodologies (Weber-Pillwax 1999, Denzin et al. 2008, Wilson 2008, Kovach 2021, Chilisa 2012, Wilson-Hokowhitu 2019, Yunkaporta 2020). Opaskwayak Cree scholar Shawn Wilson defines relational accountability in the context of research, stating that "in essence this means that the methodology needs to be based in a community context (be relational) and has to demonstrate respect, reciprocity and responsibility (be accountable as it is put into action)" (2008:99).

Given these qualities, we recognize how Indigenous and decolonizing methodologies complement and deepen the principles developed in community-based participatory research and participatory action research frameworks, which provide tools supporting collaboration with and benefit to communities as partners or leaders in the research process (Fisher and Ball 2003, Kindon et al. 2007, Cochran et al. 2008, LaVeaux and

Fig. 1. A relational science model.



Christopher 2009, Smith 2012, Caxaj 2015, Easby 2016). These include numerous Indigenous-led, decolonizing, and anticolonial frameworks and concepts therein, such as those detailed in Appendix 1, originating from Aotearoa New Zealand (Smith 1997, 2015, Parr 2002, Pohatu 2013, Pihama et al. 2015), Australia (AIATSIS 2020), Canada (Kirkness and Barnhardt 2001, Bartlett et al. 2012, Peltier 2018), South Africa (Mkabela 2005, Muwanga-Zake 2009), Peru (Huambachano 2018), Guatemala (Estrada 2005), the U.S. (Louis 2007, Carjuzaa and Fenimore-Smith 2010, Reano 2020, Montgomery and Blanchard 2021), and other regions of the world addressing colonial/imperial harms. Each of these methodologies and frameworks demonstrate innovative and culturally grounded pathways toward improving relational accountability in research practice while centering Indigenous values and rights. Fundamental relational values and principles interwoven across these research frameworks and methodologies effectively guided our efforts in mapping out and field testing a working model for Indigenous rights and relational accountability in science research as described below.

A WORKING MODEL FOR RELATIONAL SCIENCE RESEARCH

Here we present a working model for centering Indigenous rights and relational values that considers both institutional and cultural protocols regarding science research: a relational science model. The relational science model centers relationships and relational

accountability through the basis of four core relational values prominent across numerous cultural contexts: integrity, respect, humility, and reciprocity (Fig. 1). The concept of relational values, as derived from our responsibilities and relationships to the world around us, proves helpful given how these values transcend across cultural and geographic boundaries (Chan et al. 2016). In the sections to follow, we define each value, translate these into responsibilities for culturally responsive researchers, and provide examples of ground-truthed, actionable methods and resources to support locally driven and mutually beneficial research processes. Brief anecdotes recorded through reflexive journaling of the primary researcher (David-Chavez) and verified by her community research partner and co-author (Ortiz) detail examples of relational science values in practice. This section of our article also provides practical recommendations for local community driven research initiatives that are built upon, and that help to nurture sustained relationships between researchers and communities. Additionally, we acknowledge numerous challenges of shifting from a colonial to a relational science research paradigm.

This relational science model (Fig. 1) originated from a reflexive visual mapping exercise of the primary researcher, who sought a higher standard of ethical and relational practice while facilitating a climate and science education-focused field study within her own Indigenous Caribbean community. She drew from many of

the theories, concepts, and methodologies describe in Appendix 1, as well as the guidance of mentors, including Tewa Indigenous science education leader, Dr. Gregory Cajete, and Indigenous education and evaluation expert, co-author Dr. Shelly Valdez. The study anecdotes describe efforts in the two rural mountain communities of Cidra and Comerío of Borikén (Puerto Rico) occurring in 2016–2018 as facilitated by David-Chavez and Ortiz. Based on the interests of our community advisory group, this intergenerational, youth, and community-led study explored Indigenous knowledge systems regarding seasonal cycles of time for planting and harvesting, as well as observed and projected changes over generations. We also assessed youth interest and attitudes toward science and Indigenous knowledge in the community across two public elementary schools (for further detail see David-Chavez and Ortiz 2018, David-Chavez 2020).

One of the core questions asked in this effort was, how do we carry the values stewarding Indigenous knowledge systems into the research process itself to guide and define the research methods and agenda? Beliefs and value paradigms underlie any methods applied in research, yet they are not always explicit, nor acknowledged in colonial era science research models (Hikuroa et al. 2011, Liboiron 2021, Emanuel and Bird 2022). By explicitly centering relational values, we are emphasizing the fundamental importance of building, nurturing, and sustaining relationships between researchers and community to enable more ethical and effective science research practice (Gardner-Vandy et al. 2021, Kūlana Noi'i Working Group 2021). Although the relational science model was developed within a specific place and context, we emphasize that the language, processes, and methods developed here can be adapted to numerous contexts that aim to shift from external to local-driven research. This includes adaptation of the four core values (including through Indigenous language concepts), and expanding to include additional values, such as the six Rs (Tsosie et al. 2022) or seven Rs (Montgomery and Blanchard 2021), to suit research contexts. Therefore, we present this as a living working model, with an understanding that the emerging movements and innovations generating from Indigenous communities and intercultural collaborations will continue to inform, adapt, and refine what we have developed here.

Core value: integrity

Responsibilities and commitments

Integrity as a research value is demonstrated through a researcher's commitment to understanding and honoring moral and ethical responsibilities to the communities impacted by the research. In order to uphold this commitment and underlying value of integrity, it is necessary for researchers to first recognize the rights and responsibilities that come with research practice (OFIFC 2016). These understandings may come from pre-existing customary governing bodies, protocols, codes of ethics, tribal research consultation frameworks, or tribal institutional review boards/research ethics boards (IRBs/REBs), which may be in various stages of formal development and recognition (Sahota 2007, Kelley et al. 2013).

Protocols governing Indigenous knowledge systems and data generated from them also vary across communities requiring researchers to seek a nuanced understanding of the background context that includes existing governance mechanisms and

customary protocols. In some instances, ethical responsibilities related to Indigenous community rights are formally and clearly defined for community members, researchers, and administrators, whereas in other contexts they may not be. Further, even with access to formalized principles for conduct, such as those defined for signatory nations within the UN Declaration on the Rights of Indigenous Peoples (UNDRIP), governing bodies may not be legally bound nor have existing protections or resources for enforcing ethical protocols for research (Kinnison 2011). For example, in the U.S., even for federally enforced consultation policies relevant to environmental science research, such as the National Environmental Policy Act of 1969 (NEPA) and the National Historic Preservation Act of 1966 (NHPA), "agencies are required only to conduct consultations and take them into account, but their decision-making is not necessarily constrained by the feedback received during these consultations" (Kinnison 2011:1310). In instances where formal protocols for ethical research integrity have not yet been defined, we emphasize the importance that these be developed under the authority of the Indigenous communities in which the research will take place (Lambert 2014). For example, researchers and community members may formalize their commitment to ethical integrity through establishing memorandums of agreement or understanding (MOAs/MOUs) and/or data use agreements (Ball and Janyst 2008, Cummins et al. 2010, Morton Ninomiya and Pollock 2017). In addition to tribal IRB/REBs or formal governing councils, research integrity may be guided through forming community advisory groups, boards, or steering councils to oversee and approve the research process (KSDPP 2007, Sahota 2007).

Many of these protocols emphasize responsibilities aligning with UNDRIP articles such as free, prior and informed consent (FPIC), which requires community approval and access to information that they deem necessary for decision making regarding proposed research or developments within their communities (United Nations General Assembly 2007, Forest Stewardship Council 2012). In developing relationships and clarifying responsibilities outlined amongst these types of frameworks, understanding consent is a fundamental first step to research engagements. This includes recognizing the levels of representation researchers and community members aim to achieve. For example, Bantu scholar Bagele Chilisa observes four levels of consent: "individual consent, community consent, group consent, and collective consent" (2012:196), with an emphasis on intricate webs of relationships and responsibilities that then inform our individual actions. Likewise, researchers recognize gaps in existing ethical frameworks defining consent protocols for "human subjects" research. These have involved recommendations for inclusion of "respect for communities" as a key principle in the Belmont Report (Weijer and Anderson 2002), and the expansion of Belmont principles (respect for persons, justice, beneficence) for transdisciplinary research settings to include representation, self-determination, reciprocity, and deference (Wilmer et al. 2021). Issues within levels of consent may occur when authority is placed in governing bodies that are geographically, socially, and/or culturally disconnected from research site communities. As conservation scientist Anne Toomey describes, "official approval as authorized by an indigenous leadership council to conduct their research does not

ensure local support” (2016). Indigenous concerns emphasize the importance of consent protocols driven by community values and principles, as described by renowned Māori scholar Linda Tuhiwai Smith as the “bleeding of knowledge away from collective protection through individual participation in research, with knowledge moving to scientists and organizations” (Smith 2008:99). In addition to seeking meaningful and clear approvals across various levels of leadership within communities, it is also central to uphold and respect the right for Indigenous Peoples to dissent or decline engagement or data sharing at any stage of the research and data cycle (Assembly of First Nations 2009, CTKW 2014).

Responsibilities in research are not limited to on-the-ground engagement practices, as they also extend into the generation and stewardship of data. UNDRIP Article 31 states that, “Indigenous peoples ... have the right to maintain, control, protect and develop their intellectual property,” including “traditional knowledge ... manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, [and] oral traditions ...” (United Nations General Assembly 2007:9). Upholding this responsibility, also referenced as the commitment to “cause no harm” (Cochran et al. 2008, CTKW 2014), requires honoring community-determined restrictions on when and where sensitive knowledge should be shared or restricted (Suina 1992, Battiste 2008). As Williams and Hardison illustrate, “when traditional knowledge is shared, it is often accompanied by stewardship obligations within communities with expectations that outsiders also carry these obligations when knowledge is shared” (2013:534).

Indigenous data sovereignty provides a necessary framework for upholding these principles in practice to support research integrity. Through applying an Indigenous data sovereignty framework, Indigenous scholars, researchers, and allies are transforming both qualitative and quantitative research data practices to center the inherent rights of Indigenous Peoples to govern data stewardship in their communities (Kukutai and Taylor 2016b, Māori Data Sovereignty Network 2016, Walter et al. 2018, Bull et al. 2019, Walter and Suina 2019). One such framework that aims to resolve tensions between the push for open data and protections for Indigenous knowledge systems and peoples is the CARE Principles for Indigenous Data Governance (Collective Benefit, Authority to Control, Responsibility, and Ethics). The CARE Principles extend and complement the FAIR Guiding Principles for scientific data management and stewardship (Findable, Accessible, Interoperable, Reusable) by elevating “people- and purpose-oriented” principles rather than “data-centric” principles (Research Data Alliance International Indigenous Data Sovereignty Interest Group 2019, Carroll et al. 2020, 2021).

Actionable methods

In terms of actionable methods identified in the field study ground-truthing this model, preliminary relationship-building and exchanges through time spent together in-community proved helpful in identifying existing cultural and institutional protocols for integrity and building relationships of trust. This included discussions held at accessible gathering places, including local public schools and outdoor cultural sites, with community

members and leaders (both formal and informal). These conversations deepened the researchers’ understanding of local historical context and power dynamics in the community. Researchers worked with community members to co-design the IRB protocol and oral consent script and employed a confidentiality agreement developed by the local Nagueake Community-School Survival Program for protecting intellectual property rights (Oficina de Asuntos Comunitarios Indigenas 2016, *unpublished manuscript*). Where formal advisory bodies did not exist for Indigenous and rural community members, we extended a public invitation to form a community advisory group to provide research oversight. Embedded power dynamics within the community arose as one major challenge when forming the advisory group, which we addressed through centering marginalized voices, such as Indigenous farmers and land stewards, grandparents, youth, and local rural educators to inform and guide the study. This required an intentional shift from framing university-trained researchers and political leaders as the “experts,” which the research facilitators have observed can result in community members withholding their own voices when such figures are present at research meetings or workshops. Although we followed necessary formal protocols and met with political leaders individually, ongoing oversight and guidance remained with the local community advisory group, and workshop activities were facilitated to ensure inclusion of all advisory members’ voices and priorities in the research. These field experiences also emphasized the importance of building trust and relationships prior to formally collecting data to clarify moral and ethical responsibilities, and to identify the appropriate tools for honoring these responsibilities. Rather than considering these steps as optional or supplemental methods, we emphasize that they are a critical and integral phase of the research process itself and necessary for maintaining integrity and relational accountability.

Core value: respect

Responsibilities and commitments

Respect, as an underlying research value, requires a commitment on the part of researchers toward sustaining or restoring Indigenous governance of research and data impacting Indigenous communities. Addressing respect within the research process requires listening, observing, and responding to unique strengths, challenges, and needs of communities (Matson et al. 2021). Potawatomi scholar, Kyle Powys Whyte, maintains that “scientists who seek to exchange knowledge with Indigenous peoples should not only understand what Indigenous knowledge systems can do for them, but also have a sense of the significance of these knowledge systems for Indigenous governance today” (2018:57). This respect requires developing a space and format, where Indigenous governance remains supported in terms of research design, goals and objectives, and project evaluation, both during and after a research project occurs. Indigenous research and data governance mechanisms that enable this can include, for example, working with a community advisory body, formal agreements, community co-design of research goals and objectives, clarity regarding all parties’ unique roles and responsibilities, use of Indigenous-defined metadata labels (Jennings et al. 2023, Anderson and Christen 2019), as well as methods detailed below.

Actionable methods

Although ground-truthing actionable methods for upholding respect, we recognized the value of drawing from Indigenous and participatory action research methodologies to support a shift from externally governed research design to Indigenous-led and locally co-created efforts. Indigenous evaluation frameworks (LaFrance and Nichols 2009, 2010, Chilisa et al. 2016) and participatory workshop activities provided space for listening to community voices and identifying priority needs and potential research questions to build our project goals and objectives around. For example, using a “thematic wall,” Indigenous evaluation activity co-developed by one of the authors (Valdez; see David-Chavez et al. 2020 for activity description), we invited community advisory group members to determine and rank areas of interest in the context of Indigenous knowledge and climate resilience to focus our research study on. This locally self-determined process also earned support on behalf of the community given that the topic was generated from their own interests. One outcome of this process was enhanced capacity for community engagement in high level research forums, including a youth-led research presentation for the International Institute of Tropical Forestry scientists, contributions at Fourth National Climate Assessment (NCA4) regional stakeholders meeting, and a technical contribution to the NCA4 report (Gould et al. 2018).

Local power structures, norms of communication, social roles, interpersonal relationships, and gender dynamics, required attention and understanding to engage local voices that may otherwise remain marginalized. We found it helpful to assess potential barriers (time, location, literacy, etc.), learned through listening to insights of local communities members, and to innovate methods (pairing youth with elders, including visual/non-text data forms, participatory workshop activities, etc.) that would ensure inclusion and decision-making authority on behalf of local community members. Employment or formal governance roles for local community members on the research team provides additional support for sustained Indigenous governance in research, including through technical training. Local employment, especially of local youth, can support knowledge and resource transfer flows to rather than away from the community, and support long-term decision-making capacity (Assembly of First Nations 2009, NCAI 2012, Karuk - UC Berkeley Collaborative 2020).

Core value: humility

Responsibilities and commitments

Humility as a research value supports opportunities for shared learning by acknowledging the underlying premise that all those engaged in the research bring unique strengths, expertise, and experiential insights that when brought together generate new knowledge. This approach contrasts with longstanding academic science methods in which “we are told what to know and how to know it, unrelated to our lives and of the knowledge we have gained from our experiences” (Cajete 2015:68), as based on long-held assumptions that one way of knowing science, developed from the colonial science paradigm is somehow superior to Indigenous knowledge systems (Alatas 2000, Dei 2008, Smith 2012, Cajete 2015). When these assumptions and “ontological (worldview) supremacy” (Hird et al. 2023) become enacted,

Indigenous knowledge systems are forced to “integrate” into dominant colonial ways of knowing science, or are validated through external criteria to accept them as a form of “science” (Nadasdy 1999, McGregor 2004). Yet, we affirm the understanding that Indigenous knowledge systems hold validity within their own right, including as scientific ways of knowing (Aikenhead and Jegede 1999, Van Eijck and Roth 2007, Assembly of First Nations 2009, Grossman et al. 2010).

Longstanding biases from the colonial science paradigm have generated significant harms and ongoing challenges for Indigenous Peoples. As exemplified in the Canadian Royal Commission on Aboriginal Peoples’ document outlining ethical guidelines in research, with the majority of past research initiated and implemented by non-Indigenous researchers, “Aboriginal people have had almost no opportunity to correct misinformation or to challenge ethnocentric and racist interpretations” (1993:1). Colonial science research and education paradigms, and the assumptions and power disparities inherent to them, impede opportunities for balanced knowledge exchanges, while also undermining Indigenous Peoples’ sovereignty and self-determination. In turn, researchers have documented how these systems actively threaten intergenerational transmission of Indigenous knowledge systems as opposed to knowledge generated and stewarded within local community contexts (McCarter et al. 2014, Tang and Gavin 2016, Fernández-Llamazares et al. 2021).

Alternately, engaging multiple ways of knowing through processes that enhance balanced, respectful exchanges can lead to improved data interpretation and understanding (Parrado-Rosselli 2007). In the health sciences, some researchers are looking to participatory research processes as a means of restoring trust, recognizing that “mutual learning is essential to acknowledging and reconciling past abuses inflicted upon tribal communities by researchers” (Christopher et al. 2008:1404). Numerous frameworks, such as The Multiple Evidence Base framework, originating from the United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Tengö et al. 2013, 2014), and the multiple epistemologies approach developed in science education settings (Bang and Medin 2010, Balgopal et al. 2017) recognize pre-existing power dynamics while providing methods for balanced engagement and synergy across diverse cultural contexts.

Where complementary threads of knowledge weave together, innovation through shared knowledge generation may follow. These exchanges require overcoming inherent biases and assumptions about the “other,” while also supporting expressions of Indigenous sovereignty, self-determination, and related governance needs (Whyte 2018, Latulippe and Klenk 2020). Shared knowledge generation, also referenced as co-production of knowledge, recognizes that “knowledge is a dynamic process,” that it is essential for local land and natural resource stewardship, as well as for fostering place-based learning communities (Davidson-Hunt and O’Flaherty 2007:293). Such knowledge exchanges can support multi-directional capacity-building (Toomey 2016), or rather “capacity sharing” in which community researchers and those working within academic institutions teach one another (Pijogge and Liboiron 2021). This multidirectional

flow of knowledge also reflects social learning, or sharing of experiences (Berkes 2009b), which can serve as a means of supporting “collective action and reflection” toward sustainable futures (Keen et al. 2005:3). Concepts such as postcolonial Indian scholar Homi K. Bhabha’s “Third Space Theory” (1994) and “ethical space” as articulated in an Indigenous context by Willie Ermine of the Sturgeon Lake First Nation (2004, 2007), help us to observe and engage with spaces that support dialogue between worlds, rather than holding one above the other. In this way, diverse worldviews and experiences can interact and form relationships, share learning, innovation, and work collectively to address social and political tensions or conflicts.

Actionable methods

In the accompanying field study ground-truthing this model, numerous methods served as resources for shared learning, such as critical reflexivity (Chilisa 2012, Mao et al. 2016), informal discussions held on community field hikes, place-based and culturally responsive education methods, “storywork” through story sharing/focus groups, participatory mapping, and Photovoice (documentary photography; Archibald 2008, Castleden et al. 2008, Semken and Freeman 2008, Little Bear 2009). Supporting an adaptive research design allowed for on-site experiential learning and informal knowledge exchanges, which we documented through use of audio recorders, photography, handheld GPS units, and descriptive field notes. Some of our community field meetings, for example, occurred on rural Indigenous trail systems accessed through the memories and machetes of local land stewards (David-Chavez 2020). For community members, who because of availability or mobility were unable to join on field hikes, research facilitators (David-Chavez and Ortiz) travelled to their homes or farmlands to gather feedback and review research materials and data interpretation.

We also emphasized the importance of finding a shared language. This required listening carefully to how scientific processes were described in the local language and centering these, rather than colonial/academic language terms, to retain to our best ability the unique philosophies and concepts embedded within them (Little Bear 2000). This process required the inclusion of local community members on the research team who could best translate regional dialect and helped us to understand deep place-based knowledge systems, and to identify where diverse knowledge systems overlapped (Berkes 2009b). Previous studies likewise advocate for beginning with Indigenous language and concepts first, and then following with academic science concepts to support culturally relevant informal science education grounded in Native ways of knowing (Brayboy and Castagno 2008, Mack et al. 2012). One challenge within this process, in the twice-colonized region of Borikén where our field study was held, was a hesitation in engaging Indigenous knowledge systems that have long been stigmatized and associated with negative stereotypes from social racism, including discriminatory and misrepresentative messaging generated in urban contexts and in the media. This concern also arose at a high level, government-sponsored “stakeholder” meeting assessing climate impacts in the U.S. Caribbean, where the sole smallholder farmer in attendance disclosed with us his experience of Indigenous agricultural knowledge being looked down on in these scientific meetings as “folk knowledge.”

Nevertheless, centering local language and concepts extended into youth workshops and a field camp held during the field study as well, in which we began with local stories describing biological indicators for shifts in weather patterns commonly passed down in Indigenous and rural families as sources for sparking scientific inquiry. We encouraged youth in developing their own research questions for youth-elder interviews following this activity and provided research training and tools for data collection to honor local knowledge as our primary data source. We engaged additional data sources, such as climate model projection maps and agricultural calendars, as secondary data sources to enhance our learning.

Youth researchers presented their findings to state and federal agency scientists in ways that explicitly valued local community members and elders as primary knowledge sources, challenging colonial patterns of neglect and dismissal of Indigenous knowledge systems. The youths’ ability to weave together diverse knowledge systems also highlights the strength of approaches such as co-learning and integrative science facilitated through “Two-Eyed Seeing,” a concept described by Mi’kmaq Nation Elders, Albert and Murdena Marshall as bringing together multiple perspectives from Indigenous and western/mainstream worldviews to address challenges affecting the current and future well-being of our communities (Bartlett et al. 2012). Likewise, the process of beginning with community stories held by elders and knowledge keepers as points of scientific inquiry and supporting the youth to share their own research stories expanding beyond colonial scientific narratives, highlighted the strengths and opportunities of applying Indigenous storywork as methodology and community narratives as key data sources (Archibald et al. 2019, Yunkaporta 2020).

Core value: reciprocity

Responsibilities and commitments

Reciprocity as a research value focuses on how researchers will ensure Indigenous community members can access benefits from research outputs and outcomes. In the colonial paradigm, extractive research methods focus on providing benefits and credits to external institutions and peoples, often overlooking broader impacts for Indigenous communities (Smith 2012, David-Chavez and Gavin 2018, Emanuel and Bird 2022). In our relational science model, we look to multiple forms of reciprocity between researchers and Indigenous communities building up to, during, and following the time cycle of a research project. In terms of research impacts, reciprocity extends to multiple generations both within human and more-than-human communities. For example, the Kūlana Noi’i Working Group in Hawai’i (2021) guidance regarding practices for building sustained, reciprocal, and equitable partnerships between researchers and community recognizes that research decisions carry long-term impacts that will eventually reach future descendants of present community members. Looking critically within the research process, we identify pathways beyond the dominant model of knowledge extraction and non-binding consultation. A helpful recommendation is building formal community research governance roles into the project infrastructure in the grant writing phase to support pathways for compensation reciprocity, including identifying funds for equitable consultation rates and honorarium funds in

respect of the time, resources, and guidance shared (Ermine et al. 2004, Assembly of First Nations 2009, Tachera 2021, Kovach 2021).

Further, we emphasize the importance of supporting opportunities for local youth to know and draw from their Indigenous knowledge systems and other relevant diverse ways of knowing. As described in the Indigenous Stewardship Model, developed in collaboration with the Oglala Sioux Tribe, “ultimately, children will become the stewards of the land” (Ross et al. 2011:254). Findings from additional studies in environmental change, stewardship, and conservation research also highlight the importance of engaging local youth in the research, strengthening relationships and pathways for knowledge sharing between Indigenous knowledge keepers and youth (Flint et al. 2011, Baines and Zarger 2012, Gill et al. 2014, Tang and Gavin 2016, Reo et al. 2017). The Mataatua Declaration on Cultural and Intellectual Property Rights of Indigenous Peoples also affirms that, “the first beneficiaries of indigenous knowledge (cultural and intellectual property rights) must be the direct indigenous descendants of such knowledge” (Commission on Human Rights Subcommission of Prevention of Discrimination and Protection of Minorities Working Group on Indigenous Populations 1993:2).

Additionally, reciprocity as demonstrated in research practice can be expressed through provision of data and outputs that are accessible and desired by Indigenous communities. Standard research outputs (such as peer-reviewed journal articles, data reports, etc.) may not be as readily useful or accessible as other community-centered forms of data/outputs, such as curriculum, policy materials, maps, local/tribal news articles, etc. (Sowerwine et al. 2019). Community review of any research outputs is also recognized as necessary and vital toward building rapport and sustained reciprocal relationships between researchers and community members, while helping to improve data validity (Louis 2007, Wong et al. 2020). Community authorship provides one pathway supporting sustained opportunities for checking accuracy and validity of data interpretations and outputs by primary subject matter experts, while also providing due credit for knowledge contributions. For an example of this process in action, Métis/Michif scholar Max Liboiron and their Civic Laboratory for Environmental Action Research (CLEAR) science lab, provide a process for determining authorship centered in equity, accountability, and good land and community relations (Liboiron et al. 2017, CLEAR Lab 2021).

Actionable methods

In terms of ground-truthing actionable methods for reciprocity, our study focused on making the local community the primary beneficiaries of the research outputs and outcomes. In doing so, our field study also received benefit by improving the trustworthiness and validity of our data and strengthening relationships toward long-term support of our project goals. By inviting community members as research partners and in forming our community advisory group we could more readily identify pathways for exercising reciprocity throughout the evolution of the project. Toward the beginning, this included, for example, making space, time, and resources available for a blessing, and grandparents and grandchildren planting of yuca/cassava (*Manihot esculenta*) and maíz/corn (*Zea mays*) at one of the local

schools serving as a field site, as requested by our community advisory group members. Although limitations on federal doctoral research funding created challenges for providing monetary compensation to reciprocate the time and energy provided by community members, we did overcome this challenge somewhat through the generosity of members of the research team and organizations. Through these avenues, we were able to provide support for local transportation, meals, gift exchange, workshop materials, local businesses, and travel coordination for community members to attend and present at professional conferences.

Throughout our project, we built numerous opportunities for community members to participate in and share benefits of the research process and knowledge creation. These included community workshops, story sharing/focus group discussions, and local presentations that included family members of youth, local school personnel, and community leaders. These presentations provided a method of sharing and reviewing data with the community prior to publishing or presenting to academic and scientific institutions and agencies. This process provided means for sustained member checking, as applied in qualitative research, where community members reviewed raw data and interpretive themes to enhance the validity and accuracy of findings (Lincoln and Guba 1985, Creswell and Miller 2000). Further, working with community members in key research roles (including as co-authors, and advisory members), provided sustained, culturally relevant, critical review of our process and outputs. In doing so, we more readily identified outputs that could serve community interests and access needs (e.g., educational materials, reports for local agencies and policy makers, Indigenous calendars, and artistic renderings of data). Co-developing and co-authoring research outputs with community members also helped to ensure that community-generated data was appropriately credited to the original data stewards. Through these intentional practices of reciprocity, researchers can work to strengthen and maintain relational accountability to community throughout the entirety of the research process, from co-creation to shared knowledge generation, for collective benefit.

DISCUSSION AND CONCLUSION

In this article, we detailed some of the opportunities and insights available when applying values such as integrity, respect, humility, and reciprocity to restore long-term relational accountability toward Indigenous communities, lands, and futures. The value of the relational science model we present includes synthesis across disciplines, bringing together theory and practice regarding research ethics in Indigenous communities for a holistic working model adaptable to multiple disciplines and research contexts. The relational science model provides a visual map to guide responsible research integrity and practice with Indigenous nations and communities, while the case study anecdotes provide examples of specific actionable methods and resources that can be applied in implementing the model. We offer this working model, case study, and supplemental table of theoretical contributions (Appendix 1) as a pathway toward normalizing higher ethical standards in research practice. Rather than sustaining the dominant colonial research paradigm that promotes extractive research practices, this model addresses the need for research regarding Indigenous communities to be led and designed by members of those communities (Hepi et al. 2007).

Based on our findings from applying and ground-truthing this relational science working model, we recognize further potential for engaging in research that shifts from eroding to enhancing Indigenous sovereignty, governance, and maintenance of Indigenous knowledge systems and lifeways. One of the key areas requiring further attention toward addressing historical challenges in research is raising awareness among non-Indigenous communities regarding Indigenous histories (including past harms), Indigenous knowledge contributions, and inherent rights to sovereignty and self-determination, both in terms of the research process and in terms of past, current, and future data responsibilities. In the context of this research, we emphasize the right to environmental self-determination in environmental justice (Tsosie 2007), as applied toward “restorative justice ... for the longstanding environmental and cultural damage from a history of colonialism” (Sproat 2016:160). We likewise recognize the need for growing this awareness and consequent actions addressing power relations, sovereignty, as well as anticolonial and decolonizing pathways within colonial educational systems where researchers receive their foundational training (Freire 2000, Brayboy 2005, Dei 2008, Tuck and Yang 2012, Patel 2014, Brayboy et al. 2015, Grande 2015, Sabati 2019).

Among the many areas where these efforts could be immediately applied include support for Indigenous communities to develop and implement formal research protocols and codes of ethics where they are not currently available, to further define and operationalize Indigenous data governance policies and practices, and to advocate for greater support in terms of funding and capacity for Indigenous-led research and authorship. In this paper we have highlighted numerous disciplinary and geographic areas where Indigenous Peoples have already developed research principles and codes of ethics that may be useful starting points.

Addressing the issue of incomplete datasets in science requires holding space and making time for the primary sources of that data: the Indigenous communities who carry the untold narratives, deep place-based concepts, and relevant research questions. We look forward to the innovation and problem-solving potential that has not yet had opportunity to grow from beneath the thick colonial residue that has settled into the science community for so long. We also consider the youth and the challenges they will seek to address in the future, in hopes that this relational science working model will serve as a map to guide a new generation of culturally grounded scientific leaders.

Author Contributions:

David-Chavez (multicultural Arawak Taíno) maintained primary responsibility for conceptual development, research design, data collection, data analyses, data interpretation, and writing. Valdez (Laguna Pueblo) and Gavin contributed with conceptual design, writing, and research mentorship through all stages of the process. Carroll (Ahtna, Native Village of Kluti-Kaah) contributed with conceptual development, writing, and mentorship. Ortiz (Boricual Arawak Taíno) co-led the field study referenced in this article as a community research partner guiding research design, data collection, data analysis, data interpretation, and reviewed our manuscript.

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Data Availability:

Theoretical contributions informing the development of this Synthesis manuscript are included in supplemental data file (Appendix 1).

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Appendix 1. Theoretical and conceptual contributions supporting a values-centered relational science model.

This table highlights contributions spanning across geographic, disciplinary, and community contexts which can serve to guide and inform a relational science model. Source references emphasize theory, concepts, and methodologies relevant to environmental research and stewardship *in, with, and by* Indigenous communities. There may be earlier works on these topics less focused on these contexts excluded from this listing. Though not comprehensive, this may serve as a helpful source of guidance for scholars, researchers, and practitioners working to engage in relational science practice.

	Theoretical contributions	Source references	Description
1	African-relational evaluation	(Chilisa et al., 2016)	A model rooted in African worldviews, aimed at decolonizing power structures in evaluation through "Indigenization," as defined through African-people centered methodologies, values, and practices.
2	Āta (growing respectful relationships)	(Pohatu, 2005)	A Māori concept applied in Kaupapa Māori theory for social service practitioners to guide understandings and processes for developing respectful relationships, including negotiating boundaries, and critical reflection.
3	Biocultural conservation	(Gavin et al., 2015)	Practice of conservation based on the foundation of understanding relationships between biodiversity and cultural diversity, focused towards sustaining both ecological and sociocultural elements, including the ways in which these systems interact with and depend on one another.
4	Capacity sharing	(Pijogge & Liboiron, 2020)	In contrast to capacity building (unidirectional concept) "capacity sharing" is a process in which community researchers and those working within academic institutions teach one another.
5	CARE Principles for Indigenous Data Governance	(Carroll et al., 2020; Research Data Alliance International Indigenous Data Sovereignty Interest Group, 2019)	Principles for Indigenous data governance, focused on people and purpose, rather than solely data, including Collective Benefit, Authority to Control, Responsibility, and Ethics. The CARE principles were also developed to extend and complement the FAIR principles for scientific data management and stewardship (Findable, Accessible, Interoperable, Reusable).

6	Ceiba (Tree of Life) methodology	(Estrada, 2005)	A culturally-based research methodology drawing from Mayan "values, visions and stories" which extends the Ceiba ("Tree of Life") metaphor from Maya sacred cosmology (Popol Vuh) as a means to connect past and future contexts in the research, while valuing multiple ways of knowing and supporting respectful relations.
7	Community-based participatory research	(LaVeaux & Christopher, 2009)	A research approach focused on collaborative partnerships working with and learning from community, aiming for mutual benefit of all collaborators, with an emphasis on promoting positive social change in community.
8	Culturally competent research	(Caldwell et al., 2005)	A set of 20 guiding principles for collaborative and participatory research and program evaluation, as developed from a multidisciplinary network of researchers and practitioners at the First Symposium of the Work Group on American Indian Research and Program Evaluation Methodology, which emphasize respect for tribal sovereignty and diversity across Native nations and communities.
9	Decolonizing methodologies	(Smith, 2012)	Research methodology which critically engages and unsettles colonial research practices, including underlying assumptions, philosophies, and past harms in relation to research on Indigenous peoples and in Indigenous communities to re-envision pathways for Indigenous research.
10	Eco-Critical Race Theory	(Montgomery & Blanchard, 2021)	Includes six principles as foundations for challenging settler-colonial narratives and engaging intersectional identities and experiences towards the aim of addressing environmental and racial oppression.
11	Ethical space	(Ermine, 2007; Ermine et al., 2004) (adapted from Poole, 1972)	A bridging concept, recognizing a space where contrasting worldviews (in this case Indigenous and Western) can engage in dialogue, identify, and address tensions and determine ethical means for interacting and connecting.

12	Etuaptmumk (Two-Eyed Seeing)	(Bartlett et al., 2012; Peltier, 2018)	A Mi'kmaw concept representing learning to see in a way that draws from the strengths of multiple perspectives (drawing from both Indigenous ways of knowing and mainstream science) to bring forth lasting action, also applied in Indigenous research methodology and participatory action research to support co-creation of knowledge that is responsive to multiple cultural contexts.
13	Indigenous data governance	(Carroll et al., 2019; David-Chavez et al., 2019; Rainie et al., 2017b)	Mechanisms for exercising Indigenous data sovereignty in relation to Indigenous data (including environmental, cultural, social, political, and genetic data), supporting self-determined decision-making across data cycles and ecosystems (including data creation, analysis, stewardship, access, use).
14	Indigenous data sovereignty (Maiam nayri Wingara; Te Mana Raraunga)	(Kukutai & Taylor, 2016; Māori Data Sovereignty Network, 2016; NCAI, 2018; Rainie et al., 2017a; Walter et al., 2018; Walter & Suina, 2018)	Derived from the inherent rights and interests of Indigenous Nations and peoples, both at the collective and individual level, in relation to Indigenous data, including the rights to govern data collection, protection, ownership, and applications.
15	Indigenous evaluation framework	(LaFrance & Nichols, 2009); (also see African relational evaluation, Chilisa et al., 2015)	An evaluation framework formed from Indigenous ways of knowing and four core cultural values shared across Indigenous communities--"People of a Place," "Centrality of Community and Family," "Recognizing our Gifts," and "Sovereignty," as developed by the American Indian Higher Education Consortium (AIHEC).
16	Indigenous methodologies	(Chilisa, 2012; Denzin et al., 2008; Kovach, 2010; Louis, 2007; Weber-Pillwax, 1999; Wilson, 2008)	Research approaches developed from Indigenous worldviews, value systems, and lived experiences
17	Indigenous Stewardship Model	(Ross et al., 2011)	An Indigenous-led process for collaborative natural resource management developed in the Oglála Lakȝóta Oyáte (Oglala Sioux Tribal Nation).
18	Kaupapa Māori	(Pihama et al., 2015; Smith, 1997)	A theoretical foundation for research drawing from and prioritizing Māori Indigenous values, beliefs, rights, and practices within the research agenda,

remaining especially conscious of who benefits in the research process.

19	Khipu Model	(Huambachano, 2018)	An Indigenous research framework intended as a tool for knowledge sovereignty in knowledge production, drawing from Andean Khipu as a metaphor and framework to represent threads of knowing, being, and doing in research. Draws from Quechua and Māori worldviews and knowledges, including the khipu as a metaphor representing threads of knowing, being, and doing in research, from a biocultural protocol for working inclusively with Quechua communities, and a participatory action research approach with community as research partners.
20	Kūlana Noi'i (Research Standards)	(Kūlana Noi'i Working Group, 2021)	A Hawaiian, place-based and value centered guiding resource for building equity and reciprocity in research and community relations, as developed from the experiences of local partnerships and practitioner working groups focused on natural resource stewardship.
21	Mo'okū'auhau	(Wilson-Hokowhitu, 2019)	A Kanaka 'Ōiwi (Native Hawaiian) concept of genealogical lineage applied as a theory and practice to address historical challenges and shape research methodologies that honor and draw from the relationships, places, and events that led to where we are today, in order to shape our futures.
22	Multiple epistemologies	(Balgopal et al., 2017; Bang & Medin, 2010)	An approach developed in science education research that provides methods for integrating diverse ways of knowing without delegitimizing one over another, including opportunities for overcoming cultural barriers that suppress contributions from marginalized cultural communities.

23	Multiple Evidence Base Framework	(Tengö et al., 2013)	A framework presented by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) which recognizes different ways of knowing (local knowledge, Indigenous knowledge, social and natural science knowledge, etc.) as equally valid and complementary sources of evidence, that can work in synergy to enhance our understanding of governing ecosystems and biodiversity in ways that support human lifeways
24	Nayri kati (Indigenous quantitative methodology)	(Walter & Andersen, 2013)	A palawa (Tasmanian Aboriginal) language concept meaning “good numbers” articulating an Indigenous quantitative methodology explicit in generating statistical data from the standpoint of Indigenous values, knowledges, and evaluative needs, rather than the deficit framing of Indigenous peoples generated from non-Indigenous (Euro-Australian) value systems.
25	Participatory action research	(Caxaj, 2015; Kindon et al., 2007)	A research approach grounded in the experiences, stories, and knowledges of marginalized peoples, and meaningful community-researcher partnerships focused on collective action and change.
26	Participatory research	(Cochran et al., 2008)	A research approach which engages participants in the research process, which faces its own unique challenges in Indigenous communities, and which provides unique opportunities when community-researcher partnerships work to develop trust (including ending harm), to redefine roles and address power dynamics, and to build institutional support.
27	Píkyav	(Karuk - UC Berkeley Collaborative, 2020; Sowerwine et al., 2019)	A Karuk language concept meaning "to repair" or "to fix" applied as a protocol and collaborative process, as formed from a tribal-university agreement. The policy of Practicing Píkyav is developed to guide community-based participatory research, and eco-cultural restoration and revitalization efforts with a purpose of protecting intellectual and cultural property and honoring tribal sovereignty rights.

28	Place-based learning communities	(Davidson-Hunt & Michael O’Flaherty, 2007)	A research approach and process for building context-specific networks that engage Indigenous peoples and researchers as collaborators, in which they exchange in dialogue towards cross-cultural understandings and shared knowledge production for addressing local concerns and phenomena (such as, local natural resource management priorities)
29	Praxis	(Freire, 2000), (original publication 1972)	A means for transforming structures to improve our world through a process of reflection and action, in other words bringing together theory and action to create change.
30	Red pedagogy	(Grande, 2008, 2015)	A space of encounter between Indigenous and non-Indigenous critical theory, focused towards decolonizing educational reform through an Indigenous-led re-envisioning.
31	Shared knowledge generation (co-production of knowledge)	(Berkes, 2009; Latulippe & Klenk, 2020)	Human exchanges over time resulting in the generation of new shared knowledge, for which outcomes may vary depending on the nature of relationships and collaboration between diverse knowledge-holders (e.g., Indigenous-led, extractive, transactional, etc.).
32	Social learning	(Berkes, 2009; Keen et al., 2005)	Learning through sharing of experiences, which can serve as a means of supporting collective action and reflection towards sustainable futures.
33	Storywork	(Archibald, 2008; Archibald et al., 2019)	An Indigenous and decolonizing framework and methodology for inviting storytelling into education and research, that draws on the principles of "reverence, respect, responsibility, reciprocity, wholism, interrelatedness, and synergy," as a process for holistic meaning-making learned from contextualized, lived experiences.
34	Te Mātāhauariki Methodology Creative Relationship Framework	(Parr, 2002)	A framework developed by the Te Mātāhauariki legal education-focused institute to support Maōri and Pakeha (Indigenous and non-Indigenous) cross cultural relationships through

			understanding, awareness, and communication.
35	The 4Rs (Respect, Relevance, Reciprocity, Responsibility)	(Carjuzaa & Fenimore-Smith, 2010; Kirkness & Barnhardt, 2001), (original publication 1991)	A framework for reforming universities to improve how they respond to and support Indigenous students and communities, which emphasizes "Respect of First Nations cultural integrity," "Relevance to First Nations perspectives and experience," "Reciprocal relationships," and "Responsibility through participation."
36	The Six Rs of Indigenous Research (Respect, Relationship, Representation, Relevance, Responsibility, Reciprocity)	(Tsosie et al., 2022)	A framework informed by the 4 R's (Kirkness and Barnhardt, 2001), and Tribal Critical Race Theory (Brayboy, 2005) designed to be applied when using Indigenous research methodologies.
37	The 7Rs of Indigenous Research (Respect, Relevance, Reciprocity, Responsibility, Relatedness, Relationships, Redistribution)	(Montgomery & Blanchard, 2021)	A framework extending the 4 R's (Kirkness and Barnhardt, 2001) working to addresses disparities within mainstream colonial science. Defines practices for sustaining and protecting Indigenous knowledges while supporting equitable partnerships and knowledge sharing between Indigenous and non-Indigenous entities.
38	Third Space	(Bhabha, 1994)	An "inbetween" theoretical space for unsettling historic power relations and norms, which supports fluidity and hybridity of culture that can occur when multiple identities/cultures interact.
39	Tribal Critical Race Theory (TribalCrit)	(Brayboy, 2005)	A theoretical framework that recognizes the roles of colonialism, imperialism, and assimilation in the political/legal relationships and educational policies between American Indians and the U.S. government, and which emphasizes experiential knowledge in the form of stories/narratives as valuable data sources and substance forming theory.

40	Tribal Participatory Research Model	(Fisher & Ball, 2003)	A model developed to guide collaboration between social science researchers and American Indian or Alaskan Native communities towards the outcome of positive social change and empowerment, expressed through the application of tribal oversight, engaging facilitators, providing community training and employment opportunities, and developing culturally specific methods for assessment and intervention.
41	Ubuntu	(Mkabela, 2005; Muwanga-Zake, 2009)	An African Indigenous ethical philosophy and value system, defining a collective human responsibility for maintaining harmony and balance in relationships with one's community (including non-human community) applied to guide an Afrocentric research paradigm in South African communities.

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