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Care-fully?: The Question of "Knowledge Co-production" in Arctic Science

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Abstract

Understanding and redressing the climate crisis in the Arctic demands acknowledging and translating perspectives from frontline communities, environmental scientists, Indigenous knowledge bearers, and social scientists. As a first approximation to the question of how Arctic scientists conceptualize and enact "knowledge co-production," we analyze how they write about it in their academic publications through a systematic literature review. Based on the results, we identify the lack of clear definition and practical engagement with "co-production" understood as a practice of integrating knowledges and methodological approaches from various disciplines and cultures. We raise concerns regarding researchers' claims of co-production without understanding what it means, which is particularly harmful for Arctic communities whose knowledge practices scientists have long marginalized and exploited. In response, we argue that feminist STS scholarship provides crucial guidance on how to create and sustain meaningful relationships for knowledge co-production. These relationships can potentially subvert power inequities that have prevented many Arctic science teams from breaking out of traditional disciplinary silos to create new forms of knowledge exchange, particularly those based on notions of care for collaborators, communities, and equity.

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collaborative research, co-production of knowledge, care, Arctic research, Indigenous knowledge

Introduction

> We appreciate the recognition in the [National Science Foundation's request for proposals] of the need for research in a rapidly changing Arctic to take a co-production of knowledge (CPK) approach. However, there was no meaningful effort at CPK as far as we have seen for these proposals. Given the rapid pace of changes, the importance of ensuring equitable inclusion of both Indigenous Peoples' knowledge and science in addressing research questions, and concerns about our changing environment, cannot be overstated.
> —Public letter from Kawerak Inc. to the National Science Foundation, 2020

Leaders of Kawerak Inc., a non-profit consortium that represents twenty tribes of Alaska's Bering Strait region, wrote this letter to the primary funder of basic research in the United States, the National Science Foundation (NSF), to express the widespread frustration of Alaska Natives with non-Indigenous researchers who arrive uninvited in their communities to study various questions, ranging from ecology and geophysics to public policy, epidemiology, and infrastructure. The NSF increased this flow of scientists by selecting the Arctic as one of its ten research foci or "Big Questions" beginning in 2016. In 2019, the first year of the Navigating the New Arctic (NNA) funding program, the NSF funded 30 million US dollars' worth of new research into the Arctic's "natural, social, and built systems" in the context of rapid climate change (NSF 2018). As social scientists on one NNA-funded research team, we ask in this paper how Arctic researchers understand "co-production of knowledge," as an NSF-promoted approach to integrating knowledges across social and epistemic boundaries.

This tension between NSF-funded researchers and local communities indexes the demand for carefully entering relationships of reciprocal obligation to create meaningful collaborative ties (Murillo 2022; Yua et al. 2022), particularly for communities that have long been subjected to exploitative research as Indigenous Arctic communities have (Erickson 2020; Lanzarotta 2020; Turner 2008; Wiseman 2016). We suggest that scientists' ongoing attempts to understand and implement co-productive methodologies (efforts recently ballooned with NSF funding) offer insights into how collaborative knowledge production can reproduce—or, perhaps, upend—colonial and imperial power relations. For example, we call attention to alternative approaches beyond the NSF's and

scientists' portrayals of co-production, including those founded on Indigenous thought, feminist STS, decolonialism, and frameworks of care.

The NSF advocates for collaborative knowledge production In general through its recent focus on ten "Big Questions," which are important social and epistemic problems whose study relies on what the NSF calls "convergence research." Convergence research involves researchers from several disciplines collaborating to produce "integrated knowledge" that transcends the collaborators' disciplines. Convergence research is implicitly conceptualized as researcher- and discipline-focused, which leaves out other kinds of knowledge. This omission is very troubling for the rights of people and communities whose knowledge practices have been historically marginalized or excluded by the technosciences.

In response to Arctic communities' complaints about exploitative, extractive research, the NSF's NNA program has tried to reduce this exclusion by including Indigenous knowledges as a component of convergence, specifically through the methodology of co-production of knowledge. To STS scholars, "co-production" more familiarly means Sheila Jasanoff's (2004) conception of the simultaneous construction of nature and society. But this is not the meaning that the NSF ascribes to co-production, as shown in the NNA program's first request for proposals: "Community collaborations and knowledge co-production with Arctic Indigenous communities are encouraged in both [funding] tracks, when appropriate. NSF identifies co-production of knowledge as: Research in which local and Indigenous people and organizations fully engage in the complete research process from the development of questions, to the collection, use and stewardship of data, and interpretation and application of results" (NSF 2018).

This language signaled new institutional support for collaborative research with Indigenous communities, in the form of "knowledge co-production." However, the letter from Kawerak Inc. (2020) accused the teams funded under this request of not actually doing co-production. Worse, the 2019 revised request for proposals takes a less encouraging tone: "Knowledge co-production with Arctic Indigenous communities is encouraged *only* when appropriate and *must be strongly justified* and supported in the proposal text and project budget" (NSF 2019, emphasis added). Despite the implication that co-production is acceptable but not necessary, the 2019 request includes a new paragraph explaining what co-production means and where to find resources about how to do it. Thus, the NSF proposes one approach for researchers to integrate multiple kinds of knowledge, including Indigenous knowledges and various academic disciplinary knowledges, to understand the environmental, infrastructural, and social effects of climate change through collaborative methodologies. Yet communities, like those represented by Kawerak Inc., are not experiencing what they want co-production to be. What, then, is going wrong?

Whereas the technosciences are formed through boundary-making practices that operate as exclusionary forces, co-production calls for researchers to move beyond epistemic boundaries and disciplinary silos. In response, NNA-funded teams have been attempting—and struggling—to change long-established methods of data extraction without community involvement by "integrating" Indigenous, scientific, and social scientific knowledges. There are many reasons for the challenge, such as entrenched practices of gatekeeping and competition in the technosciences, the unfamiliarity of "co-production" for many researchers, and overall resistance to change in scientific practices and to knowledge practices that do not align with naturalist epistemologies. It is possible that a major funder's promotion of "co-production" ends up incentivizing researchers to identify it with an administrative burden, rather than a crucial effort in relationship-building and reparation. This study thus raises broader questions of how funder advocacy for a particular framework may affect communities, researchers, and knowledge.

In this paper we investigate possible roots of this problem by examining how Arctic researchers portray what co-production means to their peers through scholarly publications. For instance, we found that many authors argue that co-production is "too difficult" to do in practice due to a variety of factors (e.g., misaligned timelines between research cycles and subsistence lifestyles, community members' lack of access to research funding, failure to find research questions of mutual interest, unequal commitment to a project, limited internet access for communities, etc.). In response to these kinds of excuses for not pursuing equitable collaborations, STS researchers in feminist and Indigenous studies call for intersectional and pluriversal forms of knowledge production that demand basing collaboration on recognition of power relations between scientists and their "others" (e.g., Collins and Bilge 2020; Escobar 2018; Haraway 1988; Harding 2004; Murphy 2015; Viseu 2015). Climate research in the Arctic provides a valuable window into these changing processes of research practice. Specifically, it builds on long legacies of extractive, colonial, and imperial research; relies on access to Indigenous lands and knowledges; and carries crucial implications for understanding and mitigating climate change for communities in the Arctic as well as around the world. Furthermore, the NSF's encouragement of co-production offers a currently unrealized but potentially key opportunity for building towards more Indigenous-led research by empowering Arctic communities to conduct their own research agendas.

This paper uses Arctic researchers' conceptions of knowledge co-production to raise broader questions about what it means to exchange knowledge by collaborating across sociocultural, political, and epistemic divides. We first consider the politics of "knowledge integration" from the perspectives of STS scholars, Indigenous scholars and communities, and feminists. We ask how Arctic research teams interpret co-production, based on document analysis of how they write about it in academic publications. Our results show widespread lack of

comprehension and limited application of co-production as a theory and practice. The NSF's current attempt to include Arctic communities in research is so far yielding few thoughtful interpretations or strategies of co-production. We suggest that considering other approaches beyond co-production can inform epistemic practices that strive to challenge exploitative ties between Indigenous and non-Indigenous knowledge producers. In particular, feminist frameworks of care call attention to and can help address many of the problems we see in research teams' portrayals of co-production, such as by recognizing and reforming power structures, empowering excluded knowledge makers, and celebrating marginalized knowledges such as those drawn from affect, experience, and Indigenous cultures. Taking these care-based approaches as foundations for research collaborations could enable more equitable and respectful relations between Indigenous and non-Indigenous peoples as well as between scientists and social scientists, and researchers and the public.

Theories of "Knowledge Integration"

The question of how to conduct collaborative research has been at the forefront of contemporary STS scholarship, alongside a growing body of literature on community-based and citizen science (e.g., Dosemagen et al. 2022; Kimura and Kinchy 2016; S.A. Wylie et al. 2014). One of the key assumptions in this debate is that sociotechnical and environmental crises—such as socioeconomic inequity, environmental injustice, infrastructural failure—are best addressed through collaborative approaches that foster pluriversal epistemologies. "Pluriversality" means designing practices where many worlds fit, as taught to us by the Zapatistas (Escobar 2018). This inclusive concept is informed by and well aligned with feminism and decolonial thought in STS (Escobar 2018; Haraway 1988, 2016; Harding 1992; Turkle and Papert 1990; A. Wylie 2015). In particular, decolonial thought stemming from Indigenous, Mestiza, and transnational feminist scholarship articulates how calls for "diversity" and "pluralism" can harmfully obscure power relations by claiming symmetry or flattened hierarchies between kinds of knowledge and knowledge makers (Cusicanqui 2012; Liboiron 2021; Mohanty 2003; TallBear 2014). Instead, different kinds of knowledge should be recognized as valuable *for* their histories, power dimensions, and social contexts, rather than being dismissed as too cultural to be credible. Accordingly, theoretical and methodological frameworks should guide potential collaborators to recognize power differentials and redress entrenched exploitative relationships to create teams with distributed decision-making power and more equitable conditions for research.

STS scholars have historically proposed various approaches to understanding collaborative and competitive dynamics in the technosciences, including classics such as Star and Griesemer's (1989) "boundary objects," Lave and Wenger's (1991) "situated learning" in communities of practice, Collins and Evans's (2007) "interactional expertise," Galison's (1997) "trading zones," Callon's (2009) "hybrid

forums," Viseu's (2015) conception of "collaboration as care" (see Carrigan and C.D. Wylie, introduction, this issue), and "sociotechnical integration research" (e.g., Richter et al. 2017). Foundational studies in STS did not problematize intersectional inequities of color, gender, and power, probably because they concentrated on Euro-American laboratories with scientists of similar racial, ethnic, and socioeconomic backgrounds.

STS scholars have since challenged these established lines of inquiry by applying some of their critiques of science to their own discipline. For example, Helen Watson-Verran and David Turnbull (1995) argued that science is an example of Indigenous knowledge. Their explanation is that both systems are inherently local to their contexts, contrary to the stereotypes of science as universal, rational, and objective and of Indigenous knowledge as cultural, locally bounded, and, thus, unscientific (Watson-Verran and Turnbull 1995, 114). As such, they argue, "one way of capitalizing on the strength of social studies of science, and of avoiding the reflexive dilemma, is to devise ways in which alternative knowledge systems can be made to interrogate each other" (139).

However, Indigenous scholars object to the idea of their knowledge being used to augment, improve, or otherwise serve Western knowledge. They are the sole rights bearers to their knowledges, while Watson-Verran and Turnbull—and perhaps the NSF—seem to assume outsiders' right to access Indigenous knowledges and knowledge holders for the purposes of advancing the technosciences. Comparing Indigenous knowledges with Western knowledge can be demeaning, especially if researchers test Indigenous conceptions of nature against Western ones as a standard of legitimate knowledge. As Sherry Ortner used to say in class to one of us, "we [anthropologists] were all relativists until we discovered power."

Calls for collaboration assume the importance of multiple forms of knowing and practicing science. This assumption comes from various perspectives, such as the NSF's concept of convergence to feminists' celebration of situated ways of knowing (e.g., women's experiences, scientific sensibilities, shared stories) to STS scholars' calls for the potential for pluralism to strengthen knowledge (e.g., Douglas 2004; Escobar 2018; Galison 1997; A. Wylie 2015; C.D. Wylie 2019). Yet questions remain about who benefits from knowledge sharing. As Alison Jones and Kuni Jenkins point out, "*indigenous* access into the realms of meaning of the dominant Other is hardly required; members of marginalized/colonized groups are immersed in it daily. It is the colonizer, wishing to hear, who calls for dialogue" (2008, 12, emphasis original). In this view, then, it is empowered researchers (e.g., Western academics) who benefit from collaboration, not necessarily marginalized groups (e.g., Indigenous knowledge bearers).

Indigenous communities around the world have been wary of collaboration with Western scientists. They have historically and powerfully challenged the assumption that Indigenous knowledge practices are comparable or compatible with Western science (Nadasdy 1999; Ríos, Dion, and Leonard 2020). They have also warned against the instrumentalization of Indigenous knowledges to benefit Western understandings and policies through recurrent forms of extraction. Instead, some communities have called for national funders to pay for Indigenous communities to conduct their own research (e.g., Inuit Tapiriit Kanatami 2018). Supporting community-led research would entail investing in Indigenous access to scientific labs, equipment, and research careers as well as promoting Indigenous research methodologies (Reano 2020; Smith 1999; TallBear 2014; Wilson 2008). From this debate we learn that one way to contribute towards Indigenous research sovereignty could be through collaborative methodologies that center care for relationships with special attention to the institutional power dynamics that have long invisibilized Indigenous communities, their knowledges, and, subsequently, their research priorities.

Proponents of interdisciplinary collaboration through frameworks of care likewise argue that recognizing power dynamics among knowledges and knowledge holders is essential to address other inequities (Hackett and Rhoten 2011; Lyle 2017; Smolka et al. 2021). One way to do this is to identify shared "matters of care" among diverse groups, to align their values and thereby establish care-based motivations for working together (Puig de la Bellacasa 2011). However, identifying shared values should not mean erasing the differences between groups (Jones and Jenkins 2008). Rather, *care-full* collaborations—our term—should acknowledge collaborators' diverse experiences, worldviews, and right to self-determination. This is one form of *caring about* and *caring for* each other as everyday practices of knowledge production, which also includes recognizing everyone's labor (and especially undervalued and invisible labor, such as Arctic logistical support organizations composed of Indigenous science workers), emotion and affect, and ways of knowing (e.g., Boenig-Liptsin et al. 2022; Branch and Duché 2022; Murphy 2015; Viseu 2015).

Indigenous communities have proposed frameworks for integrating multiple forms of knowing in ways that serve their values and needs, in contrast to institutional technoscientific practices (in the Alaskan context, e.g., see Erickson 2020; Itchuaqiyaq 2023; Rudolf 2023). One example is the framework of "two-eyed seeing," in which people learn to apply Indigenous and Western worldviews simultaneously and equally—one through each eye—to interpret nature holistically (Bartlett, Marshall, and Marshall 2012). Developed by Albert Marshall, an Elder of Mi'kmaw First Nations, this framework has been applied in several contexts including science education, natural resource management, policymaking, and collaborative research. A similar framework is the "three-track" methodology, developed by an environmental scientist, Stephane McLachlan,

whom two Indigenous communities in Canada hired to facilitate their interactions with government scientists to address industrial water pollution (Blacker 2021). This methodology involves Indigenous knowledge, Western scientific knowledge, and a middle track between the two comprised of relevant, accessible information selected by practitioners from each knowledge system. McLachlan emphasized the importance of not *subsuming* Indigenous knowledge into Western knowledge, but rather keeping the two separate with a middle ground made of beliefs and practices that the communities and the government scientists curated for the other group to understand. This approach supports Indigenous communities in protecting their knowledge practices fully from outsiders, who might exploit or dismiss it as so often happens in "settler science" projects (Blacker 2021). Instead, the Indigenous communities chose *what*, *how*, and *when* they wanted to share in order to accomplish the goals they negotiated in common with the government scientists, which, in this case, meant identifying carcinogens in this environment and their health effects. Three-track methodology is Indigenous-led, even when conducted by a non-Indigenous facilitator hired by a tribe, as McLachlan was.

There is a growing body of literature on Indigenous research methodologies written by Indigenous scholars and calling for research led by Indigenous communities (e.g., Grande 2008; Liboiron 2021; Smith 1999; Wilson 2008). For example, the concept of "Indigenous data sovereignty" extends Indigenous rights of self-determination and territorial autonomy to include any data collected from that land or culture (Carroll, Rodriguez-Lonebear, and Martinez 2019; Rainie et al. 2017). This assertion of Indigenous stewardship of data highlights the colonialism of past and current research in which non-Indigenous researchers collect data from Indigenous places and people and then leave, without providing any explanation, compensation, recognition, or benefit for the Indigenous communities (e.g., Inuit Tapiriit Kanatami 2018). Conversely, Indigenous data sovereignty identifies data extraction as an extension of the historic exploitation of resources from Indigenous communities, including through commercialization and appropriation of traditional knowledge through bioprospecting, also known as "biopiracy" (Brown 2003; Hayden 2004).

Crucially, the NSF does not conceptualize co-production as Indigenous-led. Rather, like co-learning, co-creation, community-engaged research, participatory research, and other similar frameworks, co-production seems to imply close partnership between scientists and non-scientists. As the NSF put it in their 2021 NNA request for proposals, "A co-produced approach includes research in which local and Indigenous peoples and organizations fully engage in the complete research process cycle from the development of research questions; to the collection, use and stewardship of data; and the interpretation, application, and dissemination of results" (NSF 2021). Communities and researchers often have different assumptions of what community engagement in the research process means, on a spectrum from being invited to comment on researchers' project plan

to creating a project plan with researchers. This positioning is echoed in Kawerak Inc.'s (2020) letter to the NSF to protest researchers' failure to include them as true, reciprocal partners in NNA projects.

The NSF's expectation that NNA projects investigate "natural, social, and built systems" through convergence and co-production led a research team to add us as social scientists to their existing proposal. These researchers had submitted a prior proposal to study Arctic infrastructures with a team of architects, environmental scientists, community partners (from local Indigenous and government authorities), and researchers at federal labs. That proposal was not funded, due in part to reviewers' criticism of an underdeveloped plan for co-production across disciplines and with residents. In response, the team invited the first author, Caitlin D. Wylie, a social scientist who studies collaboration among research workers (e.g., scientists, technicians, students, volunteers), to guide the team's co-production. Wylie expanded this facilitation role to be founded upon a study of the team's co-production, to contribute to knowledge about integrative knowledge making as well as to inform our team's attempts to co-produce ethically in practice. The team also invited the second author, Luis Felipe R. Murillo, a social scientist with technical expertise in open technologies for community-based environmental research. Murillo expanded this role to include the study and design of data management systems that prioritize community demands for digital sovereignty. The experience of working as social scientists in the context of Arctic science led to our initial puzzlement over how co-production was conceived and conducted in NNA projects more broadly, thus inspiring this study.

Methodology

We draw from our expertise in the study of technoscientific practices to examine how Arctic researchers portray "co-production" in their publications. Accordingly, we conducted a systematic literature review using Web of Science, the primary publication database for environmental scientists. We focus on science-centered publications to better understand the particular context of the NNA program and our project. As a result, the dataset is incomplete but still representative. Web of Science largely omits publications in non-science journals, as well as all unpublished and unwritten perspectives. For example, Indigenous communities often share knowledge on co-production directly, such as through guidelines for researchers, websites, conference talks, or letters like Kawerak Inc.'s (e.g., see Wilkens and Datchoua-Tirvaudey's list [2022, 135]). They also publish their ideas in academic journals in a variety of disciplines outside of science, as well as write influential policy documents for funders and governments (e.g., Inuit Tapiriit Kanatami 2018). These sources deserve attention in future studies to understand how Arctic residents perceive co-production and other forms of research. Our focus here is to investigate how Arctic scientists understand co-production, as a

proxy for the effect that the NSF's promotion of co-production has had thus far on theories and practices of research collaboration.

On May 3, 2022, we searched for "coproduction + Arctic" and "co-production + Arctic" (due to inconsistencies in the spelling of co-production), which together returned 112 papers. Of these, we excluded 41 papers for mentioning co-production only in the references or authors' biographies, meaning carbon monoxide ("CO production") or the joint production of a film, or being duplicates. This cleaning left a dataset of 71 papers. We loaded these papers into Zotero and exported a spreadsheet of their metadata (i.e., author names, paper title, journal title, year published, abstract). Wylie did preliminary analysis of several papers' abstracts to identify other features to allow us to compare the papers' portrayals of co-production: each paper's "co-production" definition, reference, example, and whether it critiques co-production; study location; discipline of journal; disciplines of authors; and whether any authors identify as Indigenous or representatives of Indigenous groups. Wylie then analyzed the papers with the help of an undergraduate research assistant. Murillo contributed to the Zotero library, read the papers independently, and performed a second pass on the analysis performed by Wylie and the research assistant for the identification of themes. Finally, the whole team performed a third and final pass of qualitative analysis that informed the findings we present below.

Findings

Here we paint an initial picture of co-production publications as a dataset with descriptive statistics, and then discuss qualitative patterns we have identified. Most of the 71 papers were published between 2016 and 2022, with only 9 (13 percent) published before then, with the earliest in 2003. These 9 perhaps informed the NSF's adoption of the term *co-production* for their first NNA request for proposals in 2018. Probably as a result of that request, 2019 and 2020 saw steep increases in numbers of papers mentioning co-production. The most common geographic region of the papers' studies is North America (51 percent, United States and/or Canada) and the next largest group of papers (29 percent) reports on studies that took place in multiple countries. This trend suggests that co-production is largely—but not entirely—a North American concept thus far. The papers were published in 38 different journals (plus four books or edited volumes), which we categorized as scientific (42 percent), social scientific or policy-focused (36 percent), or interdisciplinary (22 percent). This is a relatively even split between the three categories, with a slight bias towards science due to our search on a science-focused database.

We used the same categories for each paper's author team—that is, whether the authors are all scientists or all social scientists based on their affiliations or, when we were unsure, their professional websites. If not, then we labeled that paper's authorship "interdisciplinary." Fifty-eight percent of the papers had

interdisciplinary author teams, 28 percent had all scientists, and 14 percent all social scientists. This trend suggests that social scientists alone are not the primary authors of the term *co-production*; rather, co-production is likely to entail social scientists working with scientists. In comparison, there are more author teams of all scientists than all social scientists, suggesting that at least some scientists feel comfortable writing about co-production *without* a co-author from the social sciences (or another discipline or a non-academic position, including representatives of Indigenous communities). This situation might partly explain the wide range of conceptions of co-production in this dataset, if scientists are adopting (or, more likely, name-dropping without understanding) this term without an expert to guide them. Likewise, only 31 percent of papers had an author whom we could identify as Indigenous or as employed to represent an Indigenous group. For a concept that is closely tied to respect for Indigenous communities' knowledge and sovereignty, this percentage is surprisingly low. It may reflect researchers' struggle to learn how to collaborate with Arctic communities, who have been flooded with requests for partnerships since the NNA program began. We surmise that the representation of Indigenous communities as co-authors is an important component of co-production because it forces researchers to give their local partners power over researchers' most valued output, publications.

How do these papers define co-production? First of all, not all of them do. Many papers only use it as a keyword, in the abstract, or in the text without elaboration. Eight papers (11 percent) used the term without a definition, and four (6 percent) only implied definitions in context. The other 59 papers provided some explanation of the term (83 percent), though only 18 papers (25 percent) referenced definitions given by other sources. Few papers provided any discussion of the implications of those definitions or why they were chosen. This low engagement with the term may suggest that these authors assume that everyone knows what co-production means or imply that it is not worth discussing. The variety of the provided definitions, though, suggests otherwise.

We defined three categories of the explicit definitions that the fifty-nine papers provide for co-production. The first is Jasanoff's (2004) theory of co-production—namely, that how we produce science and society (especially policymaking and governance) through our beliefs, values, and actions are inextricably linked. For example, a few papers applied Jasanoff's concept to argue that resource management policy is co-produced with scientific knowledge. We wonder if these researchers were trying to use co-production in the NSF's sense and came across Jasanoff's work. While the two concepts could be related, we are uncertain about their linkage, if any.

The second category of definitions is a generic implication of pluralism through collaboration with various "stakeholders" (that colonial term that circulates with

effective erasure of its history), including academic disciplines and/or community partners. Papers that exemplify this meaning include projects in which wildlife ecologists consulted local policymakers about species management, and sea ice scientists and snowmobile users who mapped safe ice routes together.

The third category is a subset of the second one with a more specific focus on the integration of Indigenous and technoscientific knowledges. This definition is, we surmise, what the NSF intended. It is also the commonly understood definition among proponents of collaborative scientific research to benefit Indigenous communities, although, as we've seen, this conception is not as sovereignty-serving as Indigenous-led research. These papers do not always capture this notion in the way that the NSF or Indigenous community members intend; some are patronizing or downright discriminatory with respect to Indigenous knowledge. For example, Devin Waugh and co-authors wrote, "The research found that Inuvialuit beluga harvesters possess detailed rational knowledge of beluga, particularly regarding hunting techniques and food preparation…Inuvialuit knowledge is limited to anecdotal reasoning drawing on generalized observations of beluga and the accounts of others" (2018, 242). The insidious link here between traditional knowledge and irrationality has been demolished long ago even by Euro-American anthropologists from culturalist and rationalist traditions (Lévi-Strauss 1966; Radin 1927). The authors' seeming surprise at the hunters' "detailed rational knowledge" is made worse by their dismissal of that knowledge as "anecdotal." Those "anecdotes," of course, derive from Indigenous communities' thousands of years of observation and experimentation, passed on as narratives that constitute the community memory that underlies both Indigenous and, as Watson-Verran and Turnbull (1995) point out, scientific knowledges. Social scientists, such as ourselves, are also accustomed to the classification of our findings as "anecdotal," which, sociologically speaking, stems from a language practice to establish a boundary between those who get to speak truth in the realm of science and those who do not (Ferreira da Silva 2022).

Despite a few conspicuous failures in understanding co-production as creating knowledge with Indigenous communities, most papers in this category argued for co-production as a key methodology to achieve diverse goals. For some teams, these goals were to improve science by enriching it with insights from Indigenous knowledge, such as expertise about a locality from lived experience and/or oral-history-preserved information. This approach reflects an openness to co-production with a more pluriversal approach to the socioenvironmental challenges that the Arctic faces. However, it can also justify extractive research that advances the sciences with no benefits for Arctic communities. Other teams hoped to improve the success of their proposed policy initiatives, such as managing natural resources and wildlife, by partnering with Indigenous and other residents to collectively craft policy that meets everyone's needs or, more

cynically, to invite residents' input as a token to improve their compliance. The goals that best serve equitable, care-full collaboration were those that focus on co-production as a means to create reciprocal ties with Indigenous communities.

These three definitions of co-production—respectively, as Jasanoff's co-construction of knowledge and society, as generic collaboration, or as collaboration specifically between researchers and Indigenous communities—are different in meaning, practice, and epistemic and ethical implications. They reflect Arctic researchers' confusion about the term and about how the NSF wants them to do research. These papers generally argue that co-production is a good solution to problems of incomplete scientific knowledge, ineffective policy, and the long history of exploitation of Arctic communities in the name of research. Some papers also imply researchers' resistance to collaborating with residents, such as in barbed comments dismissing Indigenous knowledge, complaints about communities' notions of time and priorities as conflicting with research project cycles, and blame for communities who do not engage with a research team as that team wants. These complaints reinforce the infrastructure of naturalist knowledge making as a neocolonial enterprise. Indigenous communities complain too about the challenges of co-production, as in Kawerak Inc.'s (2020) letter, and advocate for more Indigenous-led research. The previous norm of data extraction with no community participation is not an option in their view, while scientists who complain about how hard it is to work with communities seem to assume that it is, in fact, acceptable to opt out.

Only 11 of the papers (15 percent) include critique of co-production as a theory or a practice. The other 60 papers (85 percent) mention it without discussion or promote it as good without explaining why. This trend suggests an unquestioning uptake of the term by Arctic scientists, probably due to the NSF's use of the term. While this finding demonstrates the power that funders have to influence scholars' adoption of theoretical and methodological frameworks, it worries us that researchers are not being careful to understand the concept before they (claim to) use it. Understanding the term must be the first step before researchers attempt to enact co-production. It's likely that this unthoughtful use of funder-promoted concepts is a problem in all contexts of research collaboration between Western and Indigenous knowledge makers, beyond climate research in the Arctic.

Those eleven papers offer diverse critiques and to varying extents, but they usefully shed some light on concerns among practitioners of co-production. Several papers argue that the effects of long-standing power inequities between Indigenous communities and researchers threaten co-production's success and even feasibility (e.g., Armitage et al. 2011; Falardeau, Raudsepp-Hearne, and Bennett 2019; Yua et al. 2022). Camilla Brattland and Tero Mustonen even found that "the projects that seem to fulfill Arctic expectations of traditional knowledge

co-production with science (projects with high legitimacy) seem to have the least impact on policy" (2018, 375) in the case of salmon management in Norway and Finland. This disappointing trend demonstrates, they argue, that "expectations at the international policy level towards traditional knowledge integration with science are at times unrealistically high" (375). These papers do not intend to reject co-production by emphasizing the neocolonial power relations involved. Rather, they warn of these relations' importance so that researchers will approach co-production with power in mind and thus act accordingly to respect and empower Indigenous partners and Arctic communities.

Many of these papers propose practical advice for doing co-production. For example, Ellam Yua et al. (2022, 3) provide a detailed framework for co-production with Arctic Indigenous communities, illustrated by a diagram of concentric rings of concepts (e.g., trust and respect, sovereignty, relationships) and actions (e.g., problem definition, reciprocity, control of information) that center on knowledge systems and are all enveloped by equity. Similarly, Jan Wilkens and Alvine Datchoua-Tirvaudey offer a step-by-step framework "to co-produce mutually beneficial research" (2022, 140) with Arctic Indigenous communities. Their process focuses on researcher training, such as reading communities' protocols and research guidance as well as academic work on co-production; learning communities' research needs to co-design shared questions; and checking with communities during the research process to allow methodological adaptations and respectful sharing of useful results. M.D. Robards et al. likewise propose five characteristics of effective co-production: "1) evolving communities of practice, 2) iterative processes for defining problems and solutions…3) presence of boundary organizations, such as a government agency, university, or co-management council…4) the consistent provision of sufficient funds and labor that may transcend any one specific project goal or funding cycle, and 5) long temporal scales" (2018, 203). As a more specific intervention, Sue Moore and Donna Hauser (2019) propose using the seasonal cycles of Arctic environments and cultures as a way to structure relationships between communities and researchers who want to study marine mammals together. Similarly, Shari Fox et al. (2020) use the concept of "human-relevant environmental variables" to guide co-productive research about Arctic weather, as a way to conceptually bridge Indigenous and scientific knowledges. L.L. Loseto et al. (2020) argue that a crucial and missing component of co-production is Indigenous participation in peer review and journal editing. Accordingly, they propose steps towards more inclusion of Indigenous knowledge and knowledge holders in academic journals.

Other critiques aim at institutions' promotion of co-production. For example, Evgeniia Sidorova (2020) criticizes the Arctic Council, an intergovernmental organization of Arctic countries, for providing mere "lip service" about co-production rather than meaningfully incorporating it into its research and policy

work. On the other hand, Nicole Klenk and Katie Meehan (2015) warn that funders and institutions should not require co-production. They worry that "the integration imperative conceals the friction, antagonism, and power inherent in knowledge co-production, which in turn can exclude innovative and experimental ways of understanding and adapting to climate change" (Klenk and Meehan 2015, 160). In this view, forcing researchers and residents to (try to) co-produce knowledge can obscure fraught power dynamics and prevent the creation of more equitable methodologies. Instead, Klenk and Meehan propose three approaches that decenter Western knowledge and do not strive to integrate multiple forms of knowing: triangulation, the multiple evidence-based approach, and scenario building (160).

These eleven papers' calls for conceptual focus on power dynamics alongside practical suggestions for addressing power relations is what seems to be needed for future co-productive work in the Arctic. Rather than accepting co-production as self-evident or an inherent good, we identify the necessity for *care-fully* and collectively addressing what co-production means for all team members in everyday research practices.

Conclusion

In this article we took a first step in examining "knowledge co-production" based on how Arctic researchers write about their conceptions of interdisciplinary collaborative research. Most of the papers we analyzed (58 percent) were written by scholars from different disciplines, suggesting that research teams recognize the need for various kinds of knowledge. But only 31 percent of the papers include Indigenous or Indigenous organization-affiliated authors. This is a start, but much more *care-work* is needed to support Indigenous scholars and community organizations. In anthropology, for example, some authors include the community they study in a paper's author list. Some might consider it mere virtue signaling, but it can powerfully indicate and contribute to social ties of trust and reciprocity. One paper in our dataset offered an inspiring challenge to norms of scientific authorship by listing Ellam Yua as lead author, which is a Yup'ik term meaning "the spirit or person of the universe" (Yua et al. 2022, 4). The authors explain that "by acknowledging the work of Ellam Yua via inclusion as an author, we illustrate both the importance of Indigenous lived experiences and respect for interconnections between everything that makes up the Arctic" (4–5). Approaches like this help researchers problematize entrenched norms about what counts as a meaningful contribution and who counts as contributors in producing knowledge, such as about the fast-changing Arctic.

This study opens up broader and urgent questions for scholars of STS and feminist thought as well as technoscience researchers and funders. For example, how do research funders' promotions of particular frameworks for collaboration affect how researchers in a variety of disciplines and contexts design and conduct

projects of socio-environmental import? Accordingly, how might care inform collaborative research across established sociotechnical and epistemic borders? Studies grounded in various genealogies of feminist STS offer crucial insights into the ethical and epistemic importance of embracing positionality and pluriversality through everyday research practices. Other important sources of guidance for scientists are methodologies of action research, which integrate community work with social research based on community-informed agendas, as well as ongoing STS debates about public engagement in research. We suggest learning from these approaches as forms of care-full engagement with knowledge bearers of minoritized communities, thereby fostering relationships that recognize a legacy of active abuse and exclusion perpetrated by technoscientific projects in the Arctic with a view toward reparation and solidarity building through research collaboration.

From the emergent literature on co-production, unfortunately, we learn that researchers' understanding and practical experience with the term is rather weak. Yet there are practical demands that every researcher must attend to before "parachuting" into a community to pitch a project. These demands include equitable distribution of funds and decision-making power between researchers and communities, as well as valuing multiple ways of knowing such as by following longer and more flexible timelines for project outputs (e.g., Erickson 2020; Robards et al. 2018). First Nations in Canada, for instance, emphasize the importance of researchers being *invited* by a community. These kinds of approaches can build the respectful, meaningful, and reciprocal relationships that marginalized communities call for (Tsosie et al. 2022). This line of work is slower and harder than a researcher defining a project alone or with colleagues with the same disciplinary background. It is also more epistemically plural and socially meaningful. This orientation is crucial for care-full research. What we see lacking in published mentions of co-production, in sum, is what we find in the calls for plural epistemologies that rely on feminist and Indigenous solidarity for knowledge making.

We hope our findings call attention to Arctic researchers' need for more thoughtful engagement with co-production in theory and practice. Not every research team needs to reinvent what co-production means; however, every team should think care-fully in listening sessions with community members about how co-production should translate into concrete research tasks. From scholarship in feminist and Indigenous STS, knowledge co-production opens the opportunity for acknowledging and deconstructing what Denise Ferreira da Silva (2022) has called the "intrastructures" of technoscientific epistemologies that dismiss particular knowledge practices as "anecdotal" and "unsystematic" and therefore not credible. Intrastructures organize at a microscale how symbolic power is exercised through the classification and active exclusion of what counts as truth-telling (veridiction) in scientific discourse. We learn from this line of scholarship that

recognizing cultural and epistemic violence committed by past researchers is step *number zero* in the process of challenging entrenched assumptions built into knowledge hierarchies. Studying how we strive for this change in perspective will yield key insights into how researchers and residents can work together in pursuit of social-justice-serving research. Studies of co-production can thereby also inform feminist ideas about how theories and practices of care can help researchers navigate other epistemic and cultural divisions, beyond science and Indigeneity and below the Arctic. Co-producing knowledge about complex sociotechnical problems through care-full collaboration across various kinds of boundaries can help us work towards a more equitable present and future through scientific practices.

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