



Doubling Down on Wicked Problems: Ocean ArtScience Collaborations for a Sustainable Future

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The UN Decade of Ocean Science for Sustainable Development recognizes the current ocean sustainability crisis and calls for a transformation of ocean science. Many of the key challenges recognized by the UN Decade are examples of wicked problems: intractable and messy situations with high stakeholder divergence. Addressing wicked ocean sustainability problems requires adaptable, iterative, and participatory approaches that can embrace multiple ways of knowing. It also requires a re-imagining of our relationship with the Ocean from extraction and resulting environmental degradation, towards the building of a sense of connection and stewardship. We propose ArtScience as a means to this end by highlighting how transdisciplinary collaborations can help create sustainable ocean futures. We reflect on a recent ArtScience event emerging from Ocean Networks Canada's Artist-in-Residence programme. By situating ArtScience in a broader context of inter- and transdisciplinary collaborations, we demonstrate how ArtScience collaborations can help transform ocean science by envisioning previously unimagined possibilities, and establishing and strengthening relationships with diverse stakeholders through long-term mission-driven or place-based inquiry. We conclude with a call to action to acknowledge the potential these collaborations hold for addressing the challenges of the UN Ocean Decade.

Keywords: transdisciplinary research, ArtScience, collaboration, wicked problems, UN Ocean Decade, SciComm

HIGHLIGHTS

This article highlights the potential contributions of ArtScience collaborations and inquiries to meeting the challenges of the UN Decade of Ocean Science for Sustainable Development (UN Ocean Decade)1. We explore how addressing the wicked problems of sustainable ocean governance with transdisciplinary insights drawn from science and art can contribute to enacting sustainable ocean futures. The co-authors recently participated in an ArtScience event that brought together artists, scientists and friends of the Ocean from five continents and 20 countries. Using the example of this 'Ocean Art - Ocean Science' event as a method of inquiry to advance ocean stewardship, we consider what different collaborations between art and science might look like, and evaluate the

impact of the event on both the audience and on the authors as organizers. We then propose a vision for how ArtScience collaborations can contribute to changing our relationships with the Ocean, by directly engaging with the challenges of the UN Ocean Decade. We conclude with a call to action for funders, decision-makers, researchers and practitioners to direct more resources to ArtScience activities and relationship building to enact the scientific and societal transformations needed to meet the UN Ocean Decade's challenges.

INTRODUCTION

The United Nations General Assembly declared 2021-2030 as the Decade of Ocean Science for Sustainable Development (Intergovernmental Oceanographic Commission, 2018) in response to a crisis in ocean sustainability that constitutes an existential risk (Orb, 2020) for human society. The UN Ocean Decade tagline "The science we need for the ocean we want" is meant to encapsulate how ocean scientists will turn their research efforts to identifying solutions for key ocean sustainability challenges. However, many of these challenges are examples of *wicked problems* (Rittel and Webber, 1973; Edwards, 2010; Groeneveld, 2020), and addressing them effectively will require more than scientific facts. Wicked problems are poorly defined, messy situations with high uncertainty, and with highly divergent perspectives, worldviews, and value systems among relevant stakeholders (Rittel and Webber, 1973; Head, 2008; Xiang, 2013). While ocean science can offer evidence-based strategies for specific interventions, addressing wicked ocean sustainability problems will require adaptable approaches that engage diverse stakeholders to draw on perspectives and practices beyond mainstream Western sciences. In this article, we explore these different ways of knowing and communicating that include storytelling, Indigenous perspectives, and insights produced through transdisciplinary alliances and ArtScience collaborations (Goralnik et al., 2017; Januchowski-Hartley et al., 2018; Clark et al., 2020).

Many questions lie ahead. How can ocean scientists and practitioners best embrace different types of knowledge and promote their necessary co-existence? How can ocean science better engage with broader society to inform and catalyze the collective actions needed to reverse the decline of ocean health? How can we all stay motivated, energized, and optimistic in the face of grave challenges? How can we ensure ocean science is carried out in an equitable, fair, transdisciplinary, and anticolonial way? Accelerating the transfer of scientific evidence to decision-makers and policy developers will be important, as will science education and advocacy. This includes critical engagement with the ongoing processes of privatization, industry impacts and ocean grabbing that endanger a socially just and equitable development of the 'Blue Economy', especially in the global South (Bennett et al., 2015; Bennett et al., 2021). We need to shift from a vision of a placeless Ocean to be exploited (Germond-Duret, 2022), towards a recognition of multiple local realities embedded in their specific

contexts (Graham, 2007). The global community will also need inspiration to pressure relevant industry and governments if we are to achieve a fundamental shift away from exploitation of the Ocean to a relationship that recognizes humanity's deep dependence on the Ocean for planetary health. This is also recognized in the seventh societal outcome for the UN Decade, which identifies the need for the Ocean to be "*inspiring and engaging*" in order to engender positive behavioral changes and expand society's appreciation of the Ocean's economic, social, cultural, and spiritual value. Fundamentally, answering these questions and responding to these challenges means engaging in the difficult work of re-evaluating the way we view and understand the world. It requires reflecting on new methods of inquiry to bring about interventions that could broaden dialogues on ocean stewardship. Beyond facilitating relationship building among various stakeholders, we need methods of inquiry that allow us to reflect on our collective relationship to the Ocean itself. This means being able to surface and explore different types of knowledge and values we associate with the Ocean.

Over the last two decades, there has been a steady increase in collaborations between the arts and science in a range of environments and modes of interaction (Pearce et al., 2018, Chapter 16) (**Figure 1**).

The simplest and most common form of art-science interaction involves scientists seeking support for outreach and communication. In this dimension of engagement, which we term SciComm, art serves as a vehicle for knowledge dissemination (Wilson et al., 2015). Art facilitates public engagement with scientific outputs and ideas. Examples of this dimension might include artistic renderings of tubeworm colonies at deep-sea hydrothermal vents (Gill and Kent, 2021) or visually compelling depictions of marine food webs (Yazzie, 2022). In a second dimension of collaboration, artists seek interactions with scientists to gain unique access to data and information, as new ways of viewing the natural world, without necessarily engaging with the underlying scientific concepts (Roberts, 2006). Examples might be musical compositions that incorporate recordings of marine mammal calls (South, 2021) or sonification of data to generate melodies in a sound art installation (Johnstone, 2016). In addition to these two more common dimensions of engagement, there have been numerous calls for two-way collaborations that acknowledge the inherent similarities in the practices of art and science, and that focus on realizing the full knowledge-growth potential of interactions between those two intellectual cultures (Snow, 1998; Wilson et al., 2015; Januchowski-Hartley et al., 2018; Paterson et al., 2020). For example, sustained interactions with artists can lead scientific researchers to develop new ways of viewing the world, experimenting, and formulating research questions (Clark et al., 2020). The three dimensions outlined here are not mutually exclusive nor should they be seen as stages of development; rather they demarcate a spectrum of communication, action and insight for different purposes. In fact, many, if not most, interactions between artists and scientists have multiple dimensions, whose relative importance may shift over time.

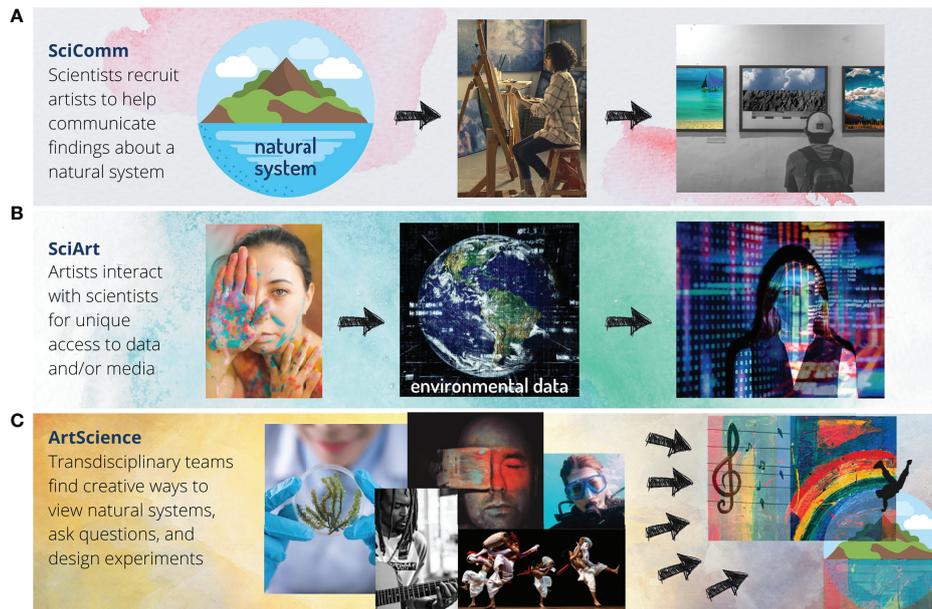


FIGURE 1 | Overview of three different dimensions of art-science collaborations. SciComm (A), is the dimension in which artists interpret scientific findings to communicate with broader audiences. SciArt (B) refers to artists interacting with scientists to gain access to data and scientific knowledge. ArtScience (C) refers to a dimension of art-science collaboration where transdisciplinary teams, including researchers and artists, explore creative approaches for viewing natural systems, asking questions, designing experiments and translating knowledge into action. These dimensions are not mutually exclusive; a single project may include one or more (Created using free content from Canva.com, 2022).

Artist residencies within scientific institutions are increasingly common and have the potential to establish conditions for multi-directional flows of ideas across different dimensions of art-science collaborations (Wilson et al., 2015). However, these residencies often restrict the role of the artist to SciArt or SciComm, that is to say as observers, watchers, or interpreters rather than as active agents in the process of knowledge creation (Wilson et al., 2014). For example, Curtis (2011) points out that even though possible contributions of art to natural resource issues have been identified, they are commonly underutilized. More recently, João Silveira (Silveira, 2021) summarized a range of transdisciplinary fusions between art and science, and highlighted the current unanimity of terms¹ used to describe art-inspired scientific inquiry, and artistic creativity with scientific roots.

Artists are observers of the natural world, and engage its materials, learning from them, as do scientists (Rheinberger, 1997; Rheinberger, 2018; Clark et al., 2020). There is also increasing recognition of a role for artistic expression in knowledge construction (Lawrence, 2005) and of the potential of art to influence pro-environmental behavior (Curtis et al., 2014).

The ArtScience manifesto developed by (Root-Bernstein et al. 2011) stresses the power of connecting and synthesizing artistic and scientific modes of inquiry, and aims to re-humanize and re-

integrate knowledge (Root-Bernstein et al., 2011). Both art and science tend to adhere to a similar type of “uncertainty principle” (p. 319, Yang, 2015a) that Andrew Yang describes as “having faith in uncertainty, finding pleasure in mystery, and learning to cultivate doubt” (p. 319, Yang, 2015a). Being able to manage and work constructively through this uncertainty is especially important when faced with the post-normal character of many of the current wicked ocean sustainability problems. In these situations, the conventional distinctions between politics, values and scientific facts have broken down (Ravetz and Funtowicz, 1993; Sardar, 2010). Instead of predicting narrow outcomes, these situations call for more exploratory approaches that can continually assess and reassess situations while consulting with relevant stakeholders (Healy, 2011). ArtScience collaborations offer such potentially rich pathways to meeting the challenges of the UN Ocean Decade. ArtScience provides a framework that includes elements of inspiration and engagement, as well as reserving space for the emergence of new knowledge and insights without the prescriptive need to create a predefined and narrow set of outcomes (Root-Bernstein et al., 2011). It encourages free exploration, in order to create more situated, contextual and adaptive knowledge and communication (Wilson et al., 2014).

Three authors of this paper (DG, CH and JT) recently participated in an ArtScience event that gathered artists, scientists, and friends of the Ocean from five continents and 20 countries (<https://www.youtube.com/watch?v=f7E8usMmAYM>). Together we explored the different approaches to ArtScience interaction taken by three artists working at the intersection of ocean art and science as part of Ocean Network Canada’s

¹These include ArtScience, STEAM, SciArt, SEAD and others where ArtScience is one of the only terms that includes a justification through the ArtScience Manifest (Root-Bernstein et al., 2011).

Artist-in-Residence program in collaboration with the University of Victoria's Faculty of Fine Arts. We also explored concepts related to ways of knowing, relating, and caring for the Ocean. Through inviting and engaging a diverse audience, we aimed to create an exploratory space for an emerging ocean ArtScience community of practice. The core of our event was the work of three artists-in-residence who used unique access to ocean observing technology, infrastructure, ocean data, and ocean science experts, to produce inspirational works that communicate the Ocean as a place of wonder, and explore the Ocean's complex and dynamic connections to humanity and the cosmos. This paper consolidates and summarizes our reflections during the recorded virtual event, and draws from an audience survey and later exchanges among the authors. Framing our reflections within current ArtScience discussions and ongoing initiatives, we demonstrate how ArtScience can contribute to the necessary transformation of ocean science and address wicked ocean sustainability problems through new ways of thinking and action (Waddock et al., 2015). We conclude with a look ahead to how future collaborations between ocean science and ocean art might inspire innovation and renewal of our entangled and troubled kinship with the Ocean.

The Artist-in-Residence Program at Ocean Networks Canada (ONC)

Conceived in 2018 as a way of strengthening connections between art and science, the ONC Artist-in-Residence program at the University of Victoria (Canada) is a transdisciplinary collaboration between the Ocean Networks Canada ocean observatory facility and the Faculty of Fine Arts. The residency seeks to broaden and cross-fertilize perspectives and critical discourse on today's major issues, such as the environment, technology, Ocean, cultural and biological diversity, and healthy communities. The program comes at a time of crisis in ocean sustainability when there is a need for combining the insights and power of different ways of looking at the world. In the few years since its inception, this program has already yielded a surprising diversity of unexpected benefits, summarized by (Owens et al., 2021), and an ongoing program goal is to increase all dimensions of diversity represented by Artists in Residence.

THREE ARTISTS, THREE WAYS OF VIEWING THE WORLD

Colton Hash (CH) - Digital Media Artist in Residence 2019

CH leads a multidisciplinary practice focusing on the creation of interactive artworks that engage with ecological issues, often using ocean environmental data as material. These works primarily convey ecological relationships that are informed by scientific understanding, personal observation and concerns from within his local community. Reflecting on the relationship between art and science in his work, CH feels that "I am not doing direct science communication and my artworks are not scientific models. I

create art to engage with the vast complexities of our world [...] I'm interested in visual art as a way to develop mental models of ecological systems. This is informed by conversations about the potential of visual arts to ... spark imaginative understanding of ecological issues. Even if that initial understanding is wrong, it can get people thinking and engaged."

Collaborating with scientists from Ocean Networks Canada, CH sought to portray invisible acoustic impacts on the Salish Sea ecosystem from its intensive use as a marine transportation corridor. He created *Acoustic Turbulence* (Figure 2), an interactive artwork depicting animated scenes of large ships traversing through the region. With intuitive controls, viewers can move a virtual camera vertically through the water column to explore visualizations and recordings of the sounds these ships produce. His artwork *Prevalent Echoes* further builds on this work by depicting the cumulative impact of large ships, based on their acoustic footprints.

By portraying relationships between our industrial society and the biosphere, CH seeks to "create space for viewers to consider their own relationships to issues such as industrialization and our impacts on nature" This is especially evident in his immersive installation *Resonant Disintegration* (Figure 3), which features a suspended life-size sculpture of an adolescent orca. This interactive multimedia installation offers an immersive space for viewers to reflect on their relationships to local marine life in the context of climate change. As a performative gesture, CH immersed the sculpture in the Salish Sea near where he lived. The resulting corrosion to him "symbolizes some of the contamination that's in the Ocean, symbolizes things like ocean acidification, but also just binds this material to this specific body of water."

A speaker inside of the sculpture plays recordings of noise pollution from freight vessels passing through the Salish Sea. These vibrations reverberate through the hollow sculpture, and are recorded by a contact mic attached to the metal surface. A programmatically modulated feedback loop causes the sculpture to emanate its own visceral sounds, which reflect the complex vocalizations of cetaceans. The orca is surrounded by a projection of modeled regional climate changes over the remainder of the century, which will affect the entire ecosystem, impacting orcas and their food sources. The movements of viewers in the gallery space are recorded by a motion sensor, which is used to modulate background sounds and the pace of the data visualization. According to CH, the "whole installation is created as a meditative space for viewers to be present [...] Having space to talk about this with others is what we're missing and through my practice, I really strive to uphold multiple ways of knowing such as emotional, intuitive, and spiritual understanding just as much as science and logic."

Each of CH's artworks seeks to bridge disciplines, engaging audiences through accessible installations, while instilling inspiration and appreciation for the issues he addresses. This mode of public engagement with ecological issues through artistic perspectives is intended to contribute toward shifting societal attitudes, although this shift may proceed gradually and be difficult to measure.

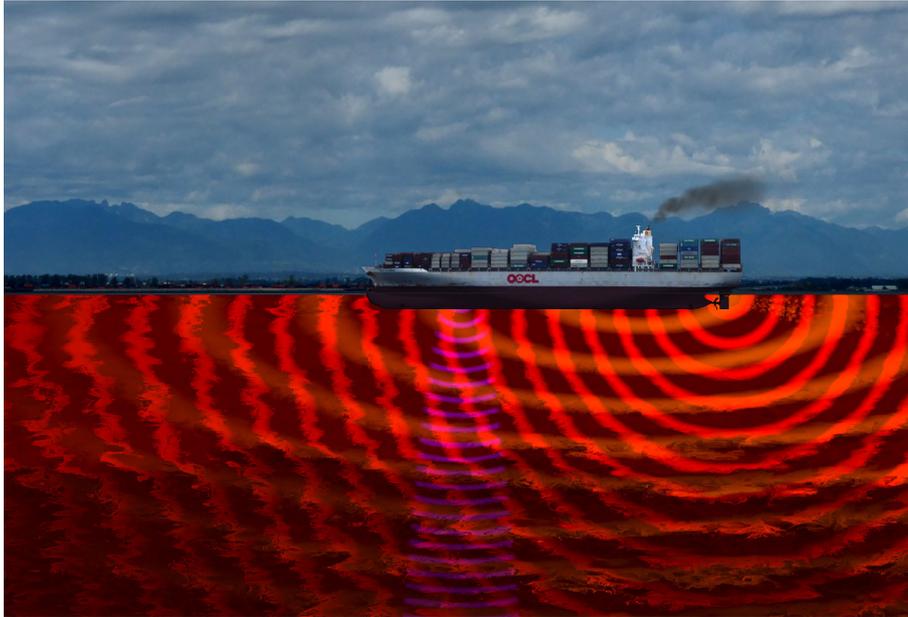


FIGURE 2 | Screen capture from *Acoustic Turbulence*, an interactive data visualization by Colton Hash. This work depicts underwater noise generated from large marine vessels, presenting a gestural presentation of scientific data that is otherwise not experienced, to foster empathetic understanding of acoustic impacts to marine life.

Dennis Gupa (DG) - Applied Theater Practitioner, Artist in Residence 2021

As an applied theater practitioner and theater director, DG asks “how applied theater can deploy local disaster stories, Indigenous ecological knowledge, and embodied practices of ocean stewardship that are not given significant value in climate

change conversations.” Descended from fishers, boat makers, and caretakers of an island in the central Philippines, DG’s relationship to the Ocean is highly influential in his work, and is “an integral part of [his] artistic and academic life.” DG’s collaborations with elders in island communities in the Eastern Samar province demonstrate a stubborn insistence on social

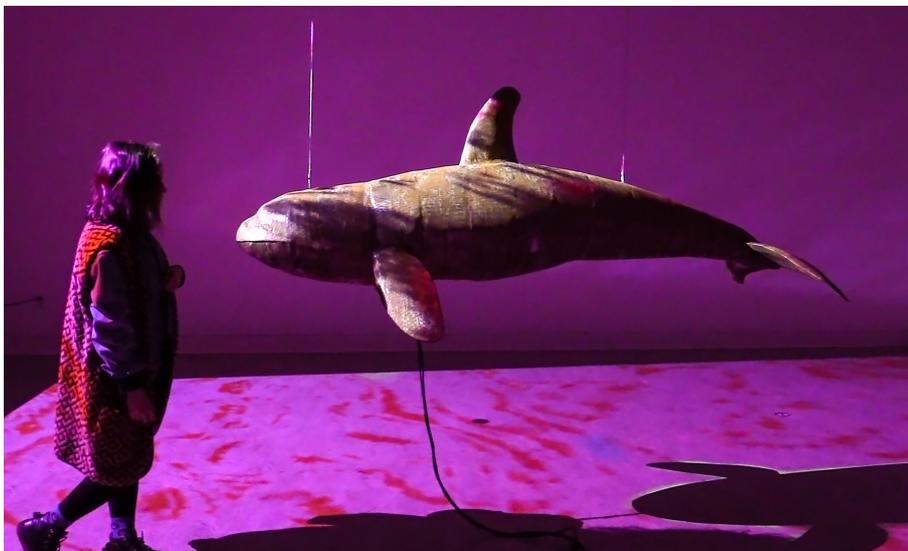


FIGURE 3 | Photo of *Resonant Disintegration*. A life-size form of an adolescent female orca is suspended, inviting viewers to approach and physically engage with the sculpture.

justice in climate-change vulnerable locations that have long histories of natural disasters, often coming from the Ocean in the form of typhoons. These collaborations highlight the role of *Panggal* fishing, a traditional practice that stands as a metaphor and underpins local creativity. *Panggal* are fish traps traditionally made of woven bamboo by residents of some, but not all islands in the Philippines archipelago. For DG, *Panggal* reflects the local community's embodied knowledge of spatial geometry, and the fishers' ability for practical innovation in the practice of ocean stewardship. When he went to Minasangay Island for the first time in 2018, DG heard stories from his relatives about his great-great-grandfather who was a shaman, a keeper of traditional fishing knowledge, and the custodian of the Island.

Super Typhoon Yolanda, the strongest typhoon ever recorded, ravaged the Island when it struck the Philippines on November 8, 2013, claiming more than 6,000 lives. DG explored the human-ocean-typhoon relationship in these communities by using applied theater as a post-disaster response, drawing on local ocean knowledge. The origin of *Panggal* underscores this relationship. The Waray fishers of Tubabao Island knew about the existence of the *Panggal* fishing method on a neighboring island, but the first *Panggal* itself only came to this community after a typhoon struck in the early 1970s. According to Tatay² Frank Abuyen, DG's collaborator, "After a strong typhoon struck our village, we saw *Panggal* [beached] on our seashore. The fishers of Tubabao Island collected these fishing contraptions because they wanted to learn how these devices were crafted. They began dismantling the bamboo strands carefully and assembling them back from their original structure." *Panggal* are released into the sea without any surface buoy to mark their location. Their positions are noted by triangulating between two terrestrial landmarks that the fishers call *tigaman*. After a week or two, the *Panggal* are recovered by the fishers who use the landmarks to locate the original drop position, as shown in **Figure 4**.

DG created community-based theater performances based on the process of crafting a *Panggal*, highlighting the creativity displayed in this Indigenous practice of geo-spatiality. **Table 1** shows the steps of creating *Panggal* and how these steps are used in creating community-based theater performance in Tubabao Island. Adding a geo-spatial (i.e. scientific) dimension to a traditional fishing practice in a performance piece, the work developed a deeper appreciation of local marine culture in the process and in the content of performances. *Panggal* became a method of theatrical creation that guided DG and his collaborators in shaping their community-based theater performances on local climate crises (**Figure 5**).

As DG explains, "In times of climate crises, when disaster and extreme weather disturbances continue to enter in island communities and extreme weather events impact the lives of people and ecology, everyday creativity after the disaster can give us clues about human-ocean relationships that are encoded in itinerant objects like this *Panggal*."

²Tatay - Father or Elder.

Jol Thoms (JT) - Artist, Sound Designer and Researcher

JT's connection to the Ocean has its roots in his artistic practice in remote 'Landscape-Laboratories' where environmental stewardship and the domain of new experimental physics observatories cross and mutate one another. He works often at the perceptual edges of dark matter and neutrino physics and their 'planetary scale' sensing infrastructures that are embedded in mountains, ice shelves, lakes and oceans, where these bodies become explicitly entangled as technologies. JT takes a critical position with respect to Western science's contributions to the disenchantment of the universe, and is interested in the slow construction and inadvertent manipulation of key metaphysical concepts (such as Nature or Technology) that the sciences co-produce with the materials of Earth and Cosmos. For JT, Landscape-Laboratories are sites where planetary features like deserts or bodies of water—these historically sacred and knowing bodies—meet vast institutional and technological assemblages to create new forms of knowing and observing the measurable (but imperceptible) universe. Attempting to define and measure the imperceptible, he considers what other imperceptible and immeasurable experiences are relevant to engage.

JT creates audio/visual compositions, digital prints, sculpture, installation, and writes and publishes experimental theory specific to understanding complex eco-technical sites. His practice questions traditional ideas of nature, technology, cosmos, and the problematic category of the human as he "looks for new relationships, pluralities, and multivocalities as modes and methods to address the complex challenges we face in the 21st century around ecology and inequality. This means also locating agency outside of the sphere or spectrum of the human, in the non- and more-than-human world". His emphasis in these works is therefore towards the lively materiality of the technologies, not just their embeddedness in landscape, but their transformation of aspects of landscape into technical or optical apparatus, blurring the lines between the once considered 'mutually exclusive' domains of technics and nature. According to JT, "[t]hese types of sites are generative for thinking about the implications of quantum physics for our ideas of environment and society—I work with these sites, as modes of thought and as places where nature itself is explicitly knowing, wise, lively, and performative." JT's work is an example of transdisciplinary research that challenges Western modalities of knowing as he is "interested in rethinking a responsible scientific world that does not create or uphold an indifferent universe divided into hierarchies, but rather one that is alive with a cosmic organicism that we can commune with in caring and response-able³ (*sensu* Haraway, 2016) modes. If we again perceived the world as alive it would be much more difficult to exploit and pollute it."

Radio Amnion: Sonic Transmissions of Care in Oceanic Space is one of JT's current projects and involves a collaboration with ONC and the Technical University of Munich's 'SFB1258: Neutrino and Dark Matter Group'. Radio Amnion is a "networked sound sculpture and calibration system that invites artists, musicians,

³Able to respond and responsible for the ability to be able ie: getting active in responding, and generating those abilities through, for example, collective work

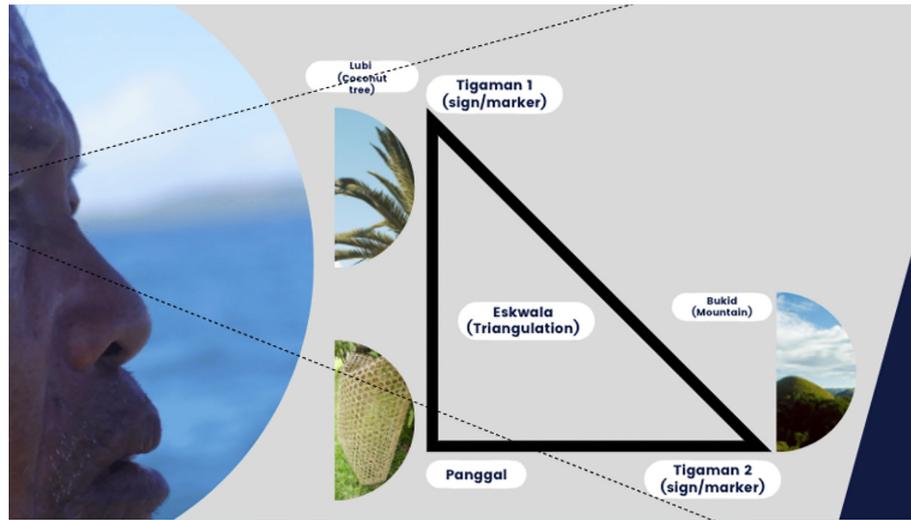


FIGURE 4 | Eskwala (Triangulation) as Indigenous Geo-spatial Knowledge. Tatay Doning looks at the tigaman (markers/signs) on land to recover his Panggal fishing trap. He locates his trap by scanning the land forms from where he is located on the waters and where the Panggal was dropped (Original figure by Dennis Gupa; redesigned by the authors using Canva.com, 2021).

composers, poets, and others to develop new sonic compositions—voicings and soundings of love, care, appreciation and gratitude specifically to and for, the more-than-human realms of this unique Ocean Planet.” These compositions are transmitted during each full moon, *via* a test installation for the proposed P-ONE neutrino telescope at ONC’s Cascadia Basin node—300 kms offshore of Vancouver Island and 2.7 kms deep, as shown in **Figure 6**—thereby “relaying new artists’ compositions into and for the water—sending artistic sensibilities into the vast hydrological cycles of Earth. Deep in the celestial waters that meet deep space, Radio Amnion irrigates ‘connection’ and ‘relation’ among disciplines, practices, and ways of knowing, just in the same way that a [neutrino] telescope at the bottom of the sea reveals connection and relation to the vast distances and bodies of cosmos.” JT remarks that there is an urgency for scientific and artistic practices to meet and form new stories and reciprocities, especially given the climate crisis and science denialism. At the time of publication, 11 original compositions had been transmitted by Radio Amnion between June 2021-April 2022. **Figure 7** shows an illustration accompanying Samuel Hertz’s composition, Four Aquatic Mirroring Devices, which was transmitted 20-22 September 2021.

AUDIENCE RESPONSES DURING THE EVENT

After each of the artists had shared a video showcasing their works, we invited participants to reflect and to share (via Zoom chat) any feelings, thoughts or images that had emerged. For CH’s work, after a video portraying massive tanker and freighter vessels and the recorded underwater sounds emanating from them, we asked the audience specifically to reflect, in anthropomorphized terms, about what the Ocean or living things in the Ocean might experience from their relationship with human civilization. A word cloud generated from these audience responses (**Figure 8**) clearly communicates a sense of *fear, violation, assault, threat, pressure, noise and helplessness*.

For DG’s and JT’s works, we asked the audience to more generally share any images, sensations of feelings that came up for them while watching the videos. In contrast to the response to CH’s video, the audience response to DG’s video communicated a strong sense of hopefulness, stressing words such as *community, future, inspired and kind* (**Figure 9A**). The response to JT’s video went in yet another direction, conveying

TABLE 1 | Panggal-as-Performance Method in Community-based Theater Performance creation.

Steps in Crafting Panggal	Tasks	Task for Community-Based Theater Performance Process
<i>Pagpulod</i>	Gathering of bamboo from the <i>bukid</i> (forest or hills)	Gathering of the stories or objects as materials for the performance
<i>Utod-utod</i>	Cutting of the bamboo into smaller pieces	Selecting of the stories for the performance
<i>Buka-buka</i>	Slicing of the bamboo into thinner parts	Rehearsing each segment of the performance
<i>Pagnawi</i>	Polishing the bamboo to remove its prickles	Technical dress rehearsing
<i>Pagpapaluoy</i>	Soaking the sliced bamboo in sea water	Group discussion to make necessary changes
<i>Larahun</i>	Twining of the bamboo strands as final phase in crafting the fishing trap	The last rehearsal before the performance
<i>Matunod</i>	Using the <i>Panggal</i> to catch the fish on the open sea	The performance



FIGURE 5 | Photos of a community-based theater session (Photos by Dennis Gupta, 2018).

a strong sense of awe, expressed in words like *wonder*, *alien*, *space*, *ice* and *beauty* (**Figure 9B**).

This mode of audience engagement was employed during the live event to extend perspectives on relationality beyond the art-science and artist-artist confines by breaking the “fourth wall” between artists and viewing audience, allowing them to become active participants in the discourse. The word cloud interludes also served as a means of reflection from the audience back to the artists, helping to expand and enrich the ensuing discussion. Here, we rendered a portrayal of open dialogues and conversations that re-enact collective empathy towards ocean stewardship and responsibility that points us into the possible future that JT underscores, a universe beyond hierarchies connected to a living cosmic organism.

REFLECTIONS ON THE IMPACT OF OUR ARTSCIENCE EVENT

Audience Feedback

At the conclusion of the live event, 25 of the 100 audience members completed a survey designed to capture their reactions and perceptions. Participants rated the event’s informativeness and meaningfulness as 4.5/5, offering a range of reasons for their ratings shown in **Table 2**. The survey also asked about key takeaways from the event; notable in the responses was the observation that ArtScience interactions are beneficial and worthy of consideration for joint-venture funding.

The survey included several open-response questions that prompted new insights. One respondent commented that the

audience interactions “brought out the scientist in those of us who are writers and the artist in those who are scientists.” Another respondent remarked on the interplay between uncertainty and perceived certainty. “As a scientist, I know how uncertain science is. We work at the edge of knowledge and do not always know if our explanations are correct. The artists seemed to view that science was more definite than it really is. Exploring this uncertainty of science in art would be interesting and important. It would support that there are different ways of knowing.”

Many of the respondents supported further interactions and collaborations between art and science. One commented, “The meaningful way you have brought together art with science ... should be more widely encouraged.”

Organizers’ Reflections

The event panelists and organizers also completed a more extensive qualitative survey probing their reflections on the impact of the event. Having a shared safe, open and supportive space for ArtScience collaborations emerged as one of the key themes of our reflections. This included physical spaces such as installations, exhibitions and physical facilities for this work, but also space in terms of opportunities for collaborations. Such collaborations should be established as strong, earnest partnerships spanning research, informing policy, education, and public engagement. As art and science have both been forces for societal change, our reflections also stressed the potential cultural and educational relevance of ArtScience projects. As summarized by CH who is “excited by the potential of ArtScience to integrate multiple ways of knowing and stimulate public engagement with complex ecological issues.

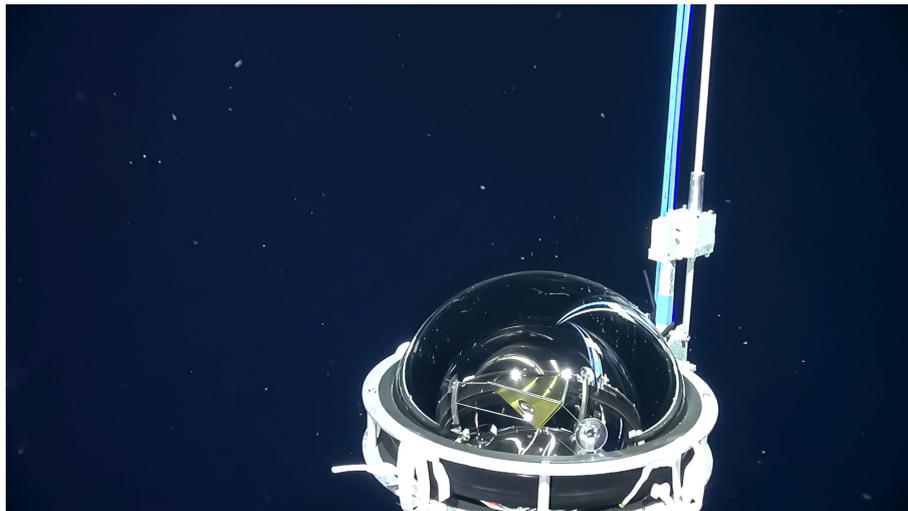


FIGURE 6 | Jol Thoms, 2021: Radio Amnion Sonic Platform. This audio sculpture module was integrated into a neutrino particle detecting test mooring deployed at 2660 m depth in Cascadia Basin (Northeast Pacific) in 2020. It transmits artists' sounds of care for the Ocean during each full moon.

[He] believes that cross-disciplinary research creation can provide collaborative opportunities to foster more nuanced understandings of wicked problems.” By inspiring different modes of thinking and creating empathy, our collaboration had strong emotional impacts on the organizers and led to some changes in perspective. DG recounts his experience

saying that “the gesture of collaboration holds deep significance for contemporary world making and the remaking of human’s long history of occupying the site of power in the natural world. Where are these world’s wicked problems rooted ... that result in violent and damaging effects on our earth? In answering this question, we let us sing songs of justice, dance in

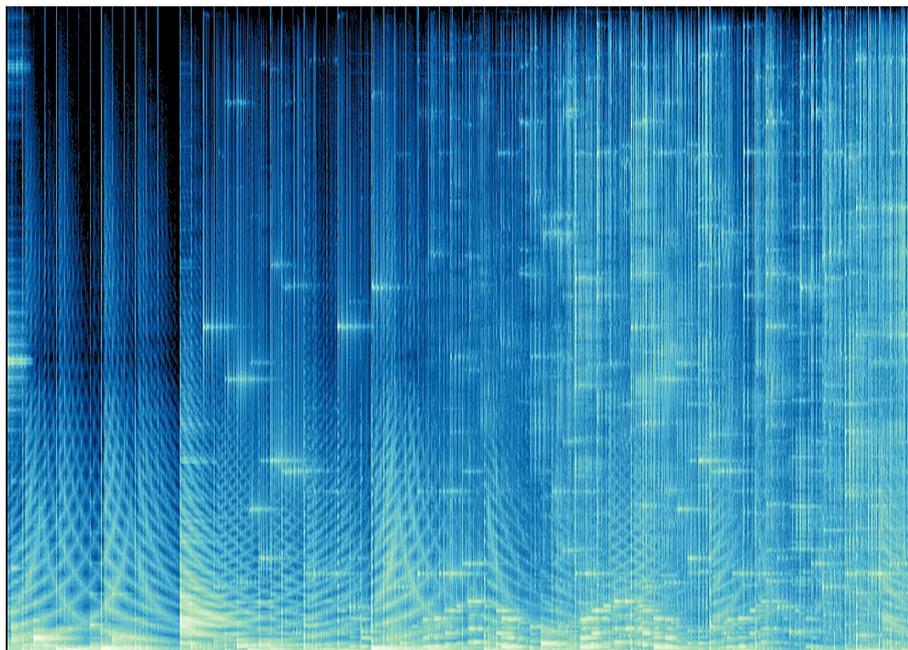


FIGURE 7 | Samuel Hertz, 2021: Mirror 2, from the series Four Aquatic Mirroring Devices by Samuel Hertz for Radio Amnion. The accompanying musical compositions were transmitted to the deep ocean via the Radio Amnion installation in September 2021. Hertz “imagines this relation to water, across bodies, sound and light.... [The] four mirrors offer reflective and refractive ways to understand more-than-physical relationships within and among water, within and among parts that are whole, or wholes, which appear to slide apart”.

the ritual of gratitude, write and read the poetries of renewal, and discover the unknown power of art in healing the wounded world". This reiterates the potential efficacy for ArtScience collaborations to address and contribute to meeting ocean challenges through the combining of different perspectives. However, our reflections also stressed the emotional barriers that will need to be overcome in order for people to feel comfortable to engage with the uncertainty and emergent nature of these collaborations. Although many ArtScience projects have arisen organically at places of long-term, place-based inquiry, mainstreaming ArtScience collaborations will require changes in organizational culture of both disciplines and could manifest through the creation of dedicated institutions or programmes for such collaborations to happen.

DISCUSSION

How Can ArtScience Collaborations Contribute to Sustainable Ocean Futures?

There are no single rational solutions to the wicked ocean sustainability problems that we are facing. By definition, inquiries into wicked problems cannot arrive at conclusive truths (Rittel and Webber, 1973). Instead, they can help us transform situations by reexamining how to make sense of them (Waddock et al., 2015). Engaging with wicked problems requires coherent action and relationship building rather than looking for incremental or disconnected solutions (Head, 2019). ArtScience collaborations can help facilitate dialogue and create relationships and networks among diverse stakeholders, thus enabling the collective determination of the 'right' action at any one moment (Wexler, 2009). ArtScience collaborations can also help develop place-centric collaborative approaches for engagement and help reexamine our relationship with the Ocean overall, both of which are necessary for inspiring and sustaining continued action (Waddock et al., 2015; Crowley and Head, 2017).

Re-Examining Our Relationship With the Ocean

The approaches taken by the three featured artists highlight a way of engaging with the Ocean that is centered on relationality and stresses our inherent connection to this component of our biosphere. This vitalist biocentric perspective views humans as within and as components of Nature. In this view, nature is understood to include not only physical and biological, but also social elements (Inglis, 1993; Kernohan, 2012; Reid et al., 2020). Conceptualizing nature in this way means focusing on the relationships between people and their environment and the responsibilities emerging from those relationships. Relational values highlight this idea of values and associated behavior derived from the idea of a good life living in harmony with nature and each other (Chan et al., 2016). They address some of the main dilemmas found in the current dominant 'goods and services' focused model of ecosystem evaluation. These include the unintended consequences of conservation actions that only focus on a single service (Gómez-Baggethun and Ruiz-Pérez, 2011), and the missing emotional component of cultural

ecosystem services that are crucial for driving action and behavior, but are difficult to capture with this concept (Chan et al., 2012a; Chan et al., 2012b). As relational values reject the perceived dichotomy of valuing the Ocean for instrumental as opposed to intrinsic reasons, this framing can lead to a more nuanced understanding of human-Nature relationships (Chan et al., 2016; Himes and Muraca, 2018). It acknowledges the more entangled and 'wicked' reality of the world we live in by framing values as people's relations (Chan et al., 2016) with their environment and Nature in general. These values contribute to our visions of a 'good life' in ways that challenge and transcend intrinsic or instrumental values (Chan et al., 2016). For example, DG's work demonstrates how traditional fishing methods represent an important adaptive and sustainable response to disasters, thus contributing to people's direct livelihoods, and also constitute an integral part of their cultural identity and connection to their ancestors. As such, the relationship with Nature itself and ways of engaging with the environment including social, physical and biological elements, can contribute to human well-being and feelings of eudaimonia⁴ (Knippenberg et al., 2018; Pritchard et al., 2020). Embracing this relational connection with the Ocean can change the way we interact with it and can inspire action. It acknowledges our dependence on the Ocean in a non-extractivist way, which can enable us to envision sustainable futures where the Ocean is an integral part of resilient and flourishing communities (Worrell and Appleby, 1999; Chan et al., 2016; West et al., 2018).

Meeting the UN Ocean Decade's ten challenges and achieving its seven societal outcomes will require us to catalyze science and embrace 'whole Earth' approaches that include all relevant scientific disciplines and societal stakeholders from the start (Pendleton et al., 2020). Crucially, we will need to continue building empathy between different ways of knowing and relating to the Ocean, in order to re-establish our sense of care and connection with it (Blythe et al., 2021). This is evident in CH's work as he visualizes anthropogenic impacts in the Ocean to elicit empathy and a sense of connection. By inviting the audience to immerse themselves in the Ocean from a different perspective, he creates a space that allows viewers to consider alternative relationships with the Ocean. His evocative works invite us to care about the Ocean and to contemplate what acting with care might look like. Care, the provision of what is necessary for the health, welfare, maintenance, and protection of something, can also represent an embodied practice of acting in ways that express care (West et al., 2018). DG's work demonstrates this. There is a strong connection of care and responsibility in the communities with whom he works. These communities have a long history of natural disasters and responding to ocean hazards. Their relatively recent, typhoon-assisted adoption of the *Panggal* sustainable fishing method, symbolizes this sense of care and reciprocity of living, in their relationship with the Ocean. Combined with knowledge and agency, care can serve as a foundation for a sense of ocean stewardship (Worrell and Appleby, 1999; West et al., 2018; Harden-Davies et al., 2020; Carothers et al., 2021). JT's approach invites us to consider this from yet a different non-human

⁴Happiness.

TABLE 2 | Selected audience explanations for why they found the event meaningful.**Could you give a short explanation on why you found it meaningful or not meaningful?**

Interested in marine risk communication from the perspective of art and storytelling
 I admire art, and love the ocean, so nice to see how to combine the two
 Art can be such a great communicator, so I'm always eager to see new expressions of it
 As a designer and educator, I am always looking to draw new connections between science, human experience, methods of communication, and starting conversations around future possibilities.
 This event provided a completely new perspective on the ocean
 The collaboration of the arts and science on topics facing the future of mankind is very encouraging and inspiring.
 I am interested in data visualization and seeing these artist's works was inspiring and I appreciate how dedicated they are to express what's important to them through their art pieces.

that they engender. ArtScience highlights ways of synthesizing the arts and sciences as well as their associated modes of expression and exploration (Root-Bernstein et al., 2011). ArtScience also provides multiple approaches for combining subjective and objective, sensory and analytical, and personal and public understandings (Glinkowski and Bamford, 2009; Root-Bernstein et al., 2011).

Addressing Wicked Problems Through Continuous Learning and Iterative ArtScience Engagement

One way for Ocean ArtScience to contribute to the UN Ocean Decade is through a focus on place-based or mission-driven inquiries that include all relevant stakeholders in an adaptive process (Yang, 2015b; Pendleton et al., 2020). This culture of engagement will require a conceptual flexibility that existed before the “modern division of art and science” (p. 320, Yang, 2015b), one that seeks to directly communicate with new audiences about wicked problems that snarl ecological balance through practical application and contextual situatedness. Similar approaches to transdisciplinary collaborations have also been suggested in the realms of art, science and design (Tosca et al., 2021). Our proposed process, **Figure 10**, combines the conceptual flexibility of ArtScience with the elements of iterative and adaptive engagement championed in action research, action learning and systems thinking (Checkland, 1981; Jackson, 2003; Coghlan and Brydon-Miller, 2014; Rigg, 2016). Elements of similar, more adaptive management and decision-making have increasingly been suggested in the many wicked and complex social-ecological challenges of current times (Rogers et al., 2013; Bradbury et al., 2019).

We view these types of collaborations as ongoing partnerships based on engagement among artists, scientists and other stakeholders, such as students, community members and policy-makers (Muller et al., 2015). DG's work illustrates this engagement. His exchanges with elders and his collaborators led to the selection of the *Panggal* as a metaphor and focal point for a community-based theater performance. The performance highlighted community concerns around intensifying climate change impacts and was used to engage government officials and other political agents and initiate discussions around decision-making, local resilience, and adaptation. The community-based theater performance served to clarify community concerns internally, and as a communication tool to draw in other stakeholders. This process highlights the role and

potential of ArtScience to act as a performative agent in real-world situations to inspire and catalyze change and meaningful action, which are necessary to meet the challenges of the UN Ocean Decade (Wilson et al., 2014; Waddock et al., 2015). Ocean ArtScience collaborations can also support some of the most crucial elements of the continued sense-making process for engaging with wicked problems, such as collaborative capacity building, and sharing and integrating knowledge in diverse ways (Weber and Khademian, 2008). Focusing on engagement and relationship building as part of an ongoing situated inquiry can also help to alleviate one of the most common issues inherent in ArtScience collaboration—losing sight of the goal of the collaboration by evaluating progress according to the norms and criteria only found in art or in science (Muller et al., 2015). JT's approach that questions our assumptions about technology and landscapes illustrates how continuous reflection upon our norms and values can make room for multiple perspectives.

Examples of what we view as model ArtScience collaborations have emerged organically at sites of long-term, place-based ecological inquiry through a confluence of ecology in the arts and humanities (Swanson, 2015). CH's practice represents this at a personal level. His work is deeply inspired by his relationship to the Salish Sea and has evolved over the time he has spent living in this area. As demonstrated by Clark et al. (2020), intensive, place-based ArtScience projects can be fruitful ground for reshaping narratives and improving our understanding of human-nature relationships and interactions (Clark et al., 2020). DG's work represents an example of expressions that are deeply place-based and contextual, manifesting through relationships between place, researchers, and other stakeholders. Elements of such location-based knowledge and its relevance for sustainable management are also echoed in many Indigenous knowledge systems that inculcate stewardship and socio-environmental relationships to one's landscape, plant and animal communities, human communities, ancestors and ancestral stories, and knowledge systems (Archibald, 2008; Marker, 2015; Reid et al., 2020; Dawson et al., 2021).

Beyond place-based inquiry however, Ocean ArtScience can also be mission-driven by focusing on concrete issues or topics and exploring them from a new perspective. An example of this is the ‘Radical Ocean Futures’ project (<https://radicaloceanfutures.earth/>) of the Stockholm Resilience Centre. This project imagines future Ocean scenarios using a science fiction prototyping approach, which “blends art and science and merges scientific fact with



FIGURE 10 | Proposed process for ArtScience contributions to the challenges of the UN Decade through adaptive and iterative staged engagement process of artists, scientists and other stakeholders in public, education and government sectors as part of an ongoing mission-driven or place-based long-term inquiry. Artists, storytellers and scientists employ art, narrative and science methods to engage diverse audiences, bringing them into the circle of potential impact on a focus area within the larger wicked problem space. Iteratively cycling through stages of planning, action, observation and reflection on a focus area can lead to contextual insights, sense-making and relevant interventions. In this example the wicked problem space, represented by a background field of trash, is the widely adopted linear extract-produce-consume-waste economic model, which has negatively impacted both human health and natural systems. The example focus area at the center of the diagram is the problem of marine plastic pollution (Created using free content from Canva.com, 2022).

creative speculation” (Merrie et al., 2018). They developed four narratives that were expressed in visual and musical ways and used as “tools that can help us to think creatively and imaginatively about our future oceans and assess how unexpected changes, along with human responses to those changes, may play out in a complex world that is, at its heart, surprising” (Merrie et al., 2018).

WHAT IS NEEDED TO ESTABLISH FLOURISHING OCEAN ARTSCIENCE COLLABORATIONS?

One challenge to the wider adoption of Ocean ArtScience collaborations is the tension between the urgency of addressing ocean sustainability challenges and the time required for the

emergence of strong, long-term relationships, and collaborations between the worlds of science and art that will enable an inspired and transformative worldmaking. Engaging requires sustained effort (Peters, 2017). The short lifespan of some ArtScience initiatives can even reinforce preconceived ideas that question their usefulness for generating new insights (Yang, 2015b). This tension is also evident in the outcomes of the qualitative survey among the organizers, which highlighted the need to create and support dedicated spaces for ArtScience collaborations to flourish instead of relying only on the organic process of serendipitous relationship development. There have been programs in the past that aimed to create dedicated spaces, time, and funding for ArtScience collaborations, such as the Wellcome’s Trust Sciart programme (Glinkowski and Bamford, 2009). However, even in the UN Ocean Decade, the current conception of the role of the arts so far appears to be limited to

SciComm, where the arts contribute to the “inspiring and engaging ocean” societal outcome. Therefore, this should be raised at relevant international meetings and fora such as the UN Ocean Conferences where the potential transdisciplinary contributions of ArtScience collaboration can be highlighted. An example of recent progress is the European Commission’s funding of the JCR Sci Art project⁵ that will promote transdisciplinary exchange around the concept of “NaturArchy : Towards a Natural Contract”.

If ArtScience collaborations are to make more substantive contributions to ocean sustainability, they will require resources for authentic relationship building and the development of networks and communities of practice. Considering the relentless nature of the wicked problems we are facing, creating long-lived, transdisciplinary communities beyond individual participants will be important (Weber and Khademian, 2008). While building authentic relationships and communities is inherently ‘messy’ to some degree, there are established methods that can help navigate common pitfalls. Interested groups could take inspiration from other process-driven research and engagement frameworks such as action research, systems thinking, and respectful anticolonial engagement with Indigenous methodologies (Smith, 1999; Rogers et al., 2013; Bradbury et al., 2019; Rosiek et al., 2020). As shown by the various approaches taken by our three artists, beyond specific tools and methodologies, the role of empathy in cooperation is transformational. This was also highlighted in findings from the Long-Term Ecological Research Network in the United States, describing how empathy lies at the heart of successful collaborations among the arts, humanities and science (Goralnik et al., 2017).

Empathy is essential, but we reiterate that organizational commitment is equally fundamental. Sustained Artist Residency programs can provide context and continuity for transdisciplinary relationship building to take hold. Whether functioning as interlocutor, performer, writer, exhibitor or convener, embedded Artists-in-Residence within ocean science institutions can actively engage with researchers in wicked problem spaces such as human-induced change in the Ocean, and the compounding societal risks posed by intensifying ocean-based hazards. In a world engulfed by wicked problems, local and Indigenous communities on the margins of social, economic and political decision-making often bear the brunt of climate-related crises. No matter the specific focus of collaboration, though, ArtScience can only flourish when organizations provide spaces and resources to support such work and the development of communities of ArtScience practitioners. This could include funding and administrative support for residency programs and direct support to artists, but also moral, political and social investment in imagining new ways of relating and collaborating. There are more wicked ocean problems to address as we explore the potential of this practice and gravitas of a commitment to a sustainable ocean future. We call upon ocean observation, art, science and technology organizations to resource

Ocean ArtScience, both as a meaningful contribution to the UN Ocean Decade and as an investment in transdisciplinary research.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

DG, CH, and JTh were panelists at ONC’s ArtScience event that was moderated by JJ and co-organized by DO, KJ, and JThr. DO conducted and analyzed the audience survey. JJ led the writing of this paper, conducted and analyzed the organizer’s survey and suggested the initial framing building on the outcomes of the event. All authors discussed the resulting conceptualizations and contributed to writing and editing the paper. KJ ensured the final editing and overall alignment. Each artist created the figures in their section, DO designed **Figures 1, 8–10**. All authors contributed to the article and approved the submitted version.

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⁵https://joint-research-centre.ec.europa.eu/knowledge-research/centre-advanced-studies/jrc-sciart-project_en

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