Consilience: The Journal of Sustainable Development
Vol. 19, Iss. 1 (2018), Pp. 183–195

Dance and Mixed-Media Performance for Building Scientific Understanding and Environmental Respect

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Abstract

Art and science are essential for sustainable development, and art-science interactions can advance both fields and enhance their impact. This is supported by historical, personal, and contemporary examples. Dance and performing arts are especially powerful when representing the physical world studied by environmental science, and for encouraging change in thoughts and actions related to the environment. The ways in which artistic approaches differ from the scientific are helpful in encouraging innovation and scientific discovery. Obstacles to such collaborations are discussed, as well as potential solutions and best practices. One such practice is measuring impacts of interdisciplinary collaborations, and a methodology is proposed to do so. Study of these interactions will enable strategic art-science partnerships and encourage wider acceptance of interdisciplinary innovation.

1. Introduction

1.1. A framework for sustainable development

The advancement of humankind requires adoption of new technologies, solutions that are safe and appropriate, understanding long-term impacts, and commitment to protecting natural resources even as economies grow. All of these require a strong and effective scientific discipline. Science is connected to all of the Sustainable Development Goals in some form.
Here I consider that the aim of development is supporting healthy lives and thriving communities for as many generations as we can imagine. Lives should be long and fulfilling; communities, including families, institutions, and countries, should be peaceful and supportive. And why do I use the word *imagined*? It is impossible to fully know what future generations require. Some have used this observation to modify early definitions of development and have suggested we leave future generations with the resources we ourselves received. But I contend that we can do better. Conducting thought experiments on what might be helpful to leave behind may be a more appropriate method than leaving exactly what we received or trying to "preserve" the environment. Even nature doesn't naturally preserve itself. It is dynamic. Such thought experiments may also enable us to identify additional unintended consequences of current actions. It is this forward-thinking aspect of science, and the creative processes often found in art, that can enable us to approach this type of development.

1.2. Awareness and transformation

It is good to use art to raise awareness, but that is not enough. The arts are not a tool for other disciplines to contribute to development. The arts are part of sustainable development; thriving communities create art. Even struggling communities create art; it is a part of human existence as old as records exist. Art born of struggle is often an essential component of bringing about change. In fact, many artists believe that art should always change the way an observer feels, thinks, or acts in the future. In this paper I will focus mostly on this aspect of art- its transformative potential. Though they are valid ventures, I do not dwell here on aesthetics, art that makes us question what qualifies as art, or "art for art's sake". Specifically, I consider art that can create change related to science and the environment and contend that science is better suited for raising awareness than art is. Science informs and increases our body of knowledge about the world. Art can both turn that information into transformation and help advance the scientific field by helping scientists discover in new ways.

2. Art and Science

2.1. The art-science schism

Italian artist Lucio Fontana said, "We refuse to think of science and art as two distinct phenomena… artists anticipate scientific deeds, scientific deeds always provoke artistic deeds" (Hamilton 2001). The art-science split is theorized to have

deepened both by the environs of the Industrial Revolution and when, in 1837, the scientific Royal Academy moved out of the London Somerset House which it shared with the arts-focused Royal Society. Scientists were then first called as such, and what was lost at the art-science split was "the colour, depth and shape of the interrelationships between artists and natural philosophers", as they had been called before (Hamilton 2001).

Rather than merging, it is possible that the two have continued diverging, and modern technology may play a role. For engineers, drawing used to be a more important skill than it is today. In the past, calculating trajectories, ideation and design, and creating plans were done by hand drawings. Compare that with my mechanical engineering education in the 21st century. I spent two weeks of one class practicing hand drawing objects with appropriate perspective, shading, and clarity, versus six entire courses focused computer languages and modeling programs. The type of "art" an engineer is required to learn has changed.

With that historical perspective, increasing technology could further divide art from science. But there are other ways in which technology is becoming a bridge between the two, some of which are discussed in this paper.

A seminal and oft-quoted work discussing the division between art and science focuses mainly on the cultural difference between those who practice both fields (Snow 1993). While the schism remains, many of the characteristics of the two groups have changed. Some distinctions may have even flipped from one group to the other, such as political affiliations and level of optimism for the future. This paper discusses some of the past and current differences of outlook and approach. Updated analyses have been done on the two cultures (Nair 2005) and further quantitative data from surveys could shed additional light on the change. Some have suggested a third culture that bridges both, and when that third culture failed to be truly mutual, even a more equitable fourth culture has been suggested (Lehrer 2007).

2.2. Art and feelings create change: science alone often does not

Humans generally retain information better through visual stimulus than auditory. Why, then, are important scientific concepts so often communicated through words? The use of art, specifically visual or performing arts, can help people remember concepts and the importance of the natural environment. Art has been successfully used for years to expose social science phenomenon, political motivations, and to build community. We must begin to use it more to bring attention to physical science discoveries and as environmental discourse that is more effective than other modes of communication.

Not only do we want audiences to remember our discoveries, but we also want to inspire transformation. Environmental science has a goal: to protect natural resources and enable people to comfortably live for generations in their surroundings. Having a purpose means the communicator desires to change actions or thoughts. Change does not come easily, whether in the form of an individual reducing driving time or a politician prioritizing carbon emission policy over economic development opportunity. Personally, I act primarily on what I feel even if I also rationalize. For example, I recently started eating less meat. My "reason" was environmental. I had known for years that methane produced by cows affects the atmosphere yet took no action. Then I calculated my water footprint and related two

bites of meat to a day of painstaking reduction in water use and experiences with water shortage. I felt those impacts deeply, related that to my environmental impact as I ate a burger, and changed.

2.3. Unique opportunities of dance and live performance

If people act on how they feel, how can we facilitate experiences of *feeling*? When an audience watches dance, their mirror neurons ignite, in a way as if they themselves are performing the movement. A dance piece called Spill, choreographed by Emilie Plauché Flink, is about a bird in the Exxon Valdez oil disaster. Witnessing struggled movement, stuck and viscous, embodied by a human but portraying a bird, I imagined what such a confined and condemned existence would feel like. I also imagined how I would react differently to the news if an oil spill affected humans the way it was affecting marine life. In short, I placed the human experience inside of the bird's; this is a very different type of empathy than can most effectively be evoked by visual and performing art.

2.4. Unique application for today: environmental communication

Here I focus on physical sciences, rather than social sciences. The importance of art in the creation of societal fabrics has been well studied. Using art to increase understanding and advancement of the social sciences has also been successfully accomplished many times. For example, art in the form of sound or visuals provokes emotions, which can be studied from a psychological perspective or measured with biometrics. Using a person's art-making, such as dance or drawing, can expose their psychological states or anomalies. There are many more examples (Arends and Thakara 2003). The physical sciences, however, are much less integrated with the arts. I contend that they are especially fertile soil for dance and live performance collaborations, given the physical embodiment and movement in space. Environmental science and related fields are disciplines that constantly struggle to communicate with a broader audience. Political climate skeptics are deemed experts by many, and scientists are considered self-interested liars. There are many reasons for this. One key factor is the relatability of research results. Many questions addressed by environmental studies are at scales that are unrelatable or even unimaginable to those who are not environmental scientists. There are studies of tiny ants in Gabon and massive glaciers in Greenland. How can a human relate? When I travel for research on water, I act diligently because I can relate to stories of people observing their land changed. I think of my rural homeland I visit every summer, and my sadness over even small anthropogenic changes. Stories, feelings, and experiences of nature motivate action. Yet the global population is moving to urban centers, where it is challenging to encourage reflection and feelings regarding the environment. For creatively communicating the physical world, I propose that dance is especially apt. In part, it brings a physical embodiment to physical realities; additionally, it invites an audience to place their human experience into a story. To achieve the major cultural shift needed to save our warming planet, every human must relate to and deeply care about the changing environment.

3. Interactions between art and science

There are endless ways that art and science overlap, dialogue, and oppose. Those mentioned here are not suggested as an exhaustive classification or even a spectrum. Most individual projects or collaborations would defy categorization of any one approach. Between many of these types or approaches, there are connections and continuums. For the approaches below, I give examples from my work and that of others to instigate discussion. My intention is to highlight the complexity and wide range of opportunities to use art and science and create positive development.
Ways in which the two fields interact include: scientists hiring or using artists to effectively communicate their work to a wider audience; artists using advances in science and technology to facilitate their process and product; and the science of art-making, including studying methods, materials, and developing diagnostic and performance technology. Here I do not discuss in depth those interactions, though historical examples abound. Instead, I focus on more contentious or challenging collaborations: scientists creating artful presentations, art about scientific topics, science learning from art, and mutual art-science collaboration.

3.1. Scientists making art

Many scientists turn their research into art. Much effort goes into making their work "pretty"; being able to do good data visualizations is a valued skill. It's been argued that this is not art: "as unmediated science realism, this is abstract expressionism minus both the expressionism and the abstract, because not intentionally art, their function is the unambiguous communication of specific information" (Ede 2005). However, many decisions inform even what topic to study, how to study it, and what things are of interest and important for the world. There is human judgement in the process, all the way through how to present it. A scientist may be as proud of a final product and presentation as an artist is of their creation. Though none of my graphs about water quality I would call art, I hope that someday I master the presentation and complexity of analysis that will allow me to do so. I have been collecting references to other scientists' work that I hope to see hung in a gallery. Consider the additional curating process I am undergoing and scientists' future decisions of size, printing methods, labeling, and a gallery owner's decisions of what to hang where… all additional steps that bridge "science" and "abstract art", or more appropriately for environmental art, "realism". Thus, if a fellow scientist wants to call their work art, even if seemingly "unmediated", I shall accept it as such.

3.2. Art about science

Further proposed by Ede (2005) is that art cannot be directly about science. "Lectures, books or discussions are more successful at presenting explanations or stimulating debate. If art is 'about' anything, it is a reflection of human experience in complexity... conveyed through hints and ambiguity. Artist don't 'do' prettification, product or propaganda for the public understanding of science. But they can engage with it and create images which suggest alternative ways of seeing".
Artists can choose to take scientific information and make it more aesthetically pleasing if they are motivated to, and can also create propaganda- in fact this is a

massive genre of art. Much social action art is created to motivate a specific set of responses and reactions. The artist has something they want to communicate and a social change they want to instigate. This may be considered propaganda, but rather than being for the benefit of some higher person or institution, it is for a higher purpose which the artist values.

However, art created very literally 'about' science is less artful than when it sheds new light. I have experimented with the level of literalness communicated to the audience. I choreographed a dance piece about the gendered influences of water shortage, inspired by statistics from research I had done. Some people in the arts community gave feedback that their viewing experience was interrupted by the presence of the written statistics. The personal experience may be greater without the accompaniment of the literal scientific findings, but is that true for scientists and for people not as engaged in contemporary arts? I have since conducted other experiments to address this question. I gave different audience members different versions of the program notes; some knew the environmental phenomena, development statistics, and personal experiences that motivated the choreography in detail. Others received a one-line description, and others nothing. One such piece was inspired by infant mortality in areas with water shortage. When children are not expected to live, they are sometimes not given names until the age of two or three. Names help us remember and honor people; how can we honor those who never received a name? Reverent dance became my method, because it can be felt without words. The audience members that had none of this information enjoyed the aesthetics of the piece, and reported noticing the peaceful, reverent, innocent, and meditative qualities. Their possible interpretations and connections were far from the original inspiration. Those who had a one-line description noticed similar things, but in addition reported being "moved" by the piece. The addition of a longer description did not seem to add much, at least in the interviews immediately following the performance. Whether such information motivates longer-term memory and action is yet to be determined but is proposed in follow-up studies below. In this case, I felt that it was my role as the artist to portray my experience and interpretation of the reality through my art. Over-describing my experience in a literal way prescribed the audience's experience. Stating the reality, even a simple statistic, and being artful about its presentation seemed to be the "sweet spot". I hope that the next time those audience members hear a statistic about water scarcity or infant mortality, they react differently than they would have before, with a softer and more receptive heart. What I mean by that is that they listen more closely, are more attentive, and therefore are ready to act or react. They may not remember that my performance played a role, but that is fine; my art lived its moment and served its purpose.

3.3. Science informed by art

This type of interaction is rare, as I often notice a hierarchy in the relationship between science and art. Art can be inspired by science, but few recognize that art has something to offer science, and even fewer practice it. In one such exploration, a malaria researcher partnered and travelled with a photographer and poet. He reflected that "perhaps making connections between different realities causes us to question our assumptions, examine with fresh eyes what we take for granted and

encourage us to see things more inventively… At the end of the project I have a deeper, more holistic view of this complex subject" (Holder 2003). Because of detailed encounters with the artistic process, science "gains easier ways of understanding difficult ideas" (Arnolds 2003). They also achieve innovative thinking, done by artists. Finally, art can also remind scientist of the importance of their work, the motivation. The malaria researcher who saw the issue through the eyes of the photographer is an example of this. Remembering the intention of the work helps direct most meaningfully, which is often the most straightforward method. My short breaks when I'm researching, which often involve music or movement, are a chance to ask, "where am I going"? If they are too long, I must ask "where was I?", which is not as helpful; the same thing happens on a longer scale if I leave a topic on the backburner for days or weeks. However, a daily dance class or a weekend working on an artistic project provides a shift in perspective and environment, enough to remember to start research again with the long-term goals in mind. Keeping an eye on the objective can help scientists avoid extraneous steps.

3.4. Science and art work together

Even rarer than science informed by art is a true collaboration in which an artist and scientist are mutual learners. This is not just cross-disciplinary or interdisciplinary. Transdisciplinary work is a "means of achieving new forms of knowledge" (Arends and Thakara 2003). An example of this is the dance company Black Label Movement. Director Carl Flink's choreography interacts with subjects such as gravity, cell collision, and evolution. He regularly partners with scientists and offers a helpful explanation on the difference between collaboration and the other types of interactions mentioned previously. His work is "not so much about the science or subject as they are direct models to conduct research in the specific area of inquiry with the goal of obtaining useful information/data, subjective and objective, about the human condition and the subject itself" (personal communication, 2017).
There are instances when art and science discover similar things, with parallel but separate processes. Examples of when art's understanding came before that of science is provided by Lehrer (2007). I consider these fascinating but tragic examples of forgone opportunity. If there had been mutual learning and discovery, perhaps the arts could have understood more deeply, and the science advanced more efficiently.

4. Addressing challenges

4.1. Questions of usefulness

As a researcher, I understand the struggle of desiring to focus solely on my project without distractions. My workplace hosts many workshops that would help a researcher, but it is hard to justify going to one even as relevant as data visualization, effective communication, or statistical reporting when I'm struggling with the first step of importing raw data correctly and need to do so by the end of the week.
Yet on a long-term scale, those seemingly "unnecessary" ventures are valuable. On a national scale, it is a good sign for the economy of a country when they invest in R&D. It indicates a shift from a survival mindset to one of long-term growth. In science, we need to move from a mindset of poverty to one of plenty, and trust that

creating room for innovation will propel both the field and individual careers. Just like a company must intentionally invest in R&D, time must be set aside for artistic and creative endeavors. I hope that it becomes common, for example, to include a "creative communication" line item on research grants, like it is standard to add a certain percentage for administrative or indirect costs. Scientific researchers (or those in any other field) might also be encouraged to use a small percentage of their time towards inter-disciplinary collaborations that do not have immediate deliverables for their main projects. By intentionally releasing control over every minute's "usefulness", we see that creativity and open-minded endeavors are quite useful indeed.

4.2. Being serious

Art, to scientists, can seem frivolous. That is a good thing. Modern studies of neuroplasticity have reversed the previous convention: that we are born with all our neurons. That outdated view was determined mostly by studying animals in cages. However, once monkeys were put in a simulated natural environment with a rotating selection of toys and hidden food, they grew new neurons (Coe et al. 2003). Well before the term *neuroplasticity* was accepted in the scientific lexicon, this dynamic nature of the brain was understood by author George Elliot. Her novels exposed that "the most essential element of human nature was its malleability" (Lehrer 2007). Engaging scientists in transdisciplinary play and new types of challenges may increase neurogenesis and aid in scientific discovery.

Open-mindedness and creativity have a lot to do with innovation, which is essential for the advancement of science. "Indeed, pioneering scientists have always challenged the status quo, operating through guesswork and intuition sometimes more than through deductive logic… think of evolution which has advanced at random and without any vision or goal" (Ede 2005). Perhaps random playful moments are like mutations (Flink and Odde 2012) – many of no consequence or failing, but every once in a while resulting in (r)evolutionary breakthrough.

How can we take art seriously while appreciating its playful and exploratory nature? It is important that art's role is respected in science, policy, development, and all fields. One first step is to refrain from quickly consigning artistic creation to artists and children. It is easy to hear about exploring science through movement and imagine the potential for early education. While this is a worthy pursuit, one I am also involved with, it is a mistake to ignore art's potential to shift political views, reconcile communities, or spark discovery. Exploring new ways of thinking is not only for children; adults can learn too. It is not only age that makes us less creative, it is our environment. Recall the example of neuroplasticity in cages versus a playful and stimulating environment. Raising children who think creatively is not sufficient if the environments in which they subsequently work is stifling. We must take seriously the need to shift "working" culture: coming out of our cages so that we may playfully innovate and progress in all fields.

4.3. Differing viewpoints

There are real differences between the approaches in art and science. One difference often addressed is that scientists try to be impartial, whereas for artists, "meaning

depends on countless variables" (Ede 2005). However, absolute truth *does* depend on infinite variables, to varying levels of importance. Both disciplines search for essential components that are hidden. Can science learn from art's intuition of complexity, and can science's quest for distilled truth challenge artists to allow a momentary landing on something true, even if they must recognize its momentary nature and the subjective process of discovery or presentation?

A beautiful text about a photojournalistic exhibition of glacial change stated that "the Anthropocene may not mark the end of the world, but it marks a point of no return" (Horn 2017). What *may* mark the end of the world, however, is building walls around disciplinary fields. The field of art and the field of science must be in humble dialogue and playful co-experimentation. "For if we're not prepared always to wonder what it's like to see things from an entirely different point of view, to imagine impossible scenarios and adapt to unknown circumstances, it may spell the end of the human race. It is good to see the world from the point of view of many 'others'" (Ede 2005).

I recognize that this analysis has been ethnocentric, with few examples outside of Europe and the United States. Even discussion of the original division between art and science was located in London (the separation of the Royal Academy and Royal Society) and broadly in the western world (the Industrial Revolution). Perhaps other cultures that have not so strongly adopted culture exported from London, whether directly or indirectly via other European countries or the U.S., have maintained an integration between fields that the world can learn from. These countries and cultures can be instrumental in restoring/leading a much-needed perspective and practice. Today, most of the easily discoverable books published on the combination of art and science have still been published in London, as evidenced by the references in this paper. Future study must actively seek insight from those who may be able to more naturally lead this discussion.

5. Best practices in the interaction

In the above examples of art-science interactions, I have already introduced some collaborations that work well. I now share additional themes that emerged from my research and interviews on the topic.

5.1. Exchange of perspectives

The theoretical physicist Dirac summarized his philosophy with "physical laws should have methodical beauty" (Farmelo 2002), perhaps a surprising statement from such a methodical and unemotional person. Can the practice of art help scientists and mathematicians develop their intuition for what is beautiful? On the other hand, perhaps it is the artists who have in the past century maintained the centrality of chaos and complexity. "The artist's experience of life is uncoordinated, dislocated, contingent, incomplete" (Ede 2005). In fact, modern physics and other scientific disciplines are discovering the importance of chaos. While they previously sought governing equations, many of the most fundamental have been found. Left unknown is what governs the chaotic motion and complexity. The slow viscous flow is simple, laminar, predictable, but the turbulent waters remain troubled. Can artists

help us discover those regions? Of the two fields, art has been the one digging in the dirt to expose the unknown, while science has been trying to order it.

5.2. Partnership across disciplines

This one is perhaps obvious, but I offer two particularly effective ways of transdisciplinary partnering. The first is defining each discipline very specifically, using sub-disciplines, and requires a willingness to collaborate with seemingly unrelated sub-disciplines. An example of this is found at the Gowanus Canal, an infamously contaminated waterway in New York City. A community organizer there, Owen Foote, often partners his canoeing organization with artists. How can art affect change? He engages new groups by connecting with what they already care about. For example, creatively exploring the connection between dog-loving neighborhood walkers and city-dwelling nature lovers. If Owen's canoeing organization pursued only canoers, it would never become the neighborhood-wide advocacy force for environmental cleanup for which he aims. For art to be effective, people need to be both challenged by it and connected to it. Specificity in partnership provides the connection, and seemingly disparate partners can bring a newness or challenging perspective. I observe that this is more effective as a practice than as a one-time experiment. People who easily jump between and partner with varying disciplines seem to have a strong interdisciplinary background. As this kind of work becomes normal, the innovator focuses less on the "originality" that others perceive, and more on the outcomes.

A second effective method of collaboration across disciplines is a deep, mutual exploration: true partnership, where neither can achieve the goal without the other. Each discipline or innovator is involved throughout the process. Carl Flink, a choreographer mentioned above, has worked with a biomedical professor, Dr. David Odde, to create a process called *bodystorming,* a kinesthetic version of brainstorming (Flink and Odde 2012). "Its purpose is to create a modeling tool using bodies in space and choreographic tools to conduct substantive research in areas where it can be an effective tool for the discovery of new knowledge" (personal communication, 2017). These collaborations have resulted in published scientific work and new choreographic forms and processes.

5.3. Quantitative analysis and impact assessment

A study funded by NASA found that a program called *Beautiful Earth* increased the value which audience members ascribed to understanding the environment. The number of participants who thought it was "very important" to learn more about Earth's condition doubled after seeing the presentation. The most highly rated parts of the program incorporated live music, projected visualizations, and interactive experiences: sections that had a "wow" factor (Juffer 2003). Interestingly, discussion groups were the most poorly rated, which is a common way to address the question, "how can we get people to *engage* with this topic?". Conferences and events purporting to advance a particular field (read: change and develop) should more often include arts than endless discussion. Arts and interaction are effective, and more studies like the one on *Beautiful Earth* can guide the refinement of effective approaches.

6. Proposed study about art about science

I have personally experienced dance as an effective way to communicate, but I recognize that all people are different. How can we better understand how well dance engages with environmental science? I propose a study about a performance, with the following methodology. In it, audience members' reactions will be filmed and the audience will complete a survey right after the performance and one month later. The performance will include dance, visual art, theater, poetry, live music, video, and mixed media (projected image behind dancers with live music also playing). Each medium will be based on at least one fact related to environmental change, will draw inspiration from an aspect of the natural world that is wonderful or admirable, and each artist will identify possible actions that an audience member could take as a result of experiencing their performance. These, however, will not be communicated explicitly to the audience. The research questions addressed by the surveys and analysis of the video include:
Q1. Which artistic medium produced greatest physical or emotional feeling?
Q2. Which inspired the most personal reflection and thought?
Q3. For which medium was the knowledge or experience gained also retained over time?
Q4. Which media motivated action or lifestyle change?
Q5. Which inspired conversation related to the environment in the days following the performance?
I recognize that the quality, style, and topic of individual pieces will affect the outcome. Thus, we will look for themes that emerge so that in the future those themes can be incorporated across disciplines and add more control to follow-up experiments. The results of the study will enlighten how dance and other art mediums can not only raise awareness but also help achieve the Sustainable Development Goals. Answering the questions above will enable artists to take a more informed approach in the future as they interact with environmental topics and with scientists, policy makers, and environmental researchers. The proposed study facilitates the framework of this paper by enlightening select details of *how* to use dance and performing arts to encourage environmental respect and action. Subsequent quantitative studies could tackle best practices in other types of art-science interactions, such as those listed above. Though art can stand alone and need not always be subjected to quantitative analysis, demonstrated effects of art may make it more acceptable by those in other disciplines as an effective way of knowing, learning, and communicating. Disseminating the lessons learned in this study will enable a larger audience to transform the way they think and act about art, research, and environmental communication. In order to effectively broadcast these results, we will of course include a line item in the budget for creative post-project communication.

7. Conclusions

Achieving the Sustainable Development Goals requires scientific advancement. The arts are an essential part of sustainable development; healthy communities create art and striving communities use art to bring about change. Furthermore, science and art in dialogue can advance sustainable development more effectively than either can

alone. Scientists projecting and planning for the future can be supported by the creative processes often found in art. The chaos and complexity intuited by artists may help science understand the world more accurately. Science describes the world as is, and art in turn can help translate that knowledge into action.

To creatively communicate the physical world, dance is especially appropriate because it embodies physical realities and lets viewers connect in a personal way. The environmental sciences may especially benefit from such collaborations.

Environmental protection requires changes in the way people act, which requires altering what is prioritized and how people think. Transformative art also has this goal of: to change the way people think and act.

There are endless ways that art and science may interact. When scientists present their results artfully, the line may be blurred between science and art. Scientific topics may inspire artists, and art may inspire scientists or even help them discover. The greatest potential is realized when art and science are mutual learners. While there are obstacles stemming from differing perspectives and approaches, these differences can actually increase the benefits of collaboration.

Examples abound of fruitful collaborations, but scientific studies of their impacts are rare. Developing a theoretical framework about what makes art-science interactions work will support an integration of the concepts presented in this paper, and such a study is proposed here. Innovation in the way we imagine the future, playfully discover, and assess transformation will support holistic sustainable development.

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