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Science & Society

Science Communication Through Art: Objectives, Challenges, and Outcomes

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The arts are becoming a favored medium for conveying science to the public. Tracking trending approaches, such as community-engaged learning, alongside challenges and goals can help establish metrics to achieve more impactful outcomes, and to determine the effectiveness of arts-based science communication for raising awareness or shaping public policy.

Mounting concerns about anthropogenic environmental change are motivating scholars, educators, and other professional practitioners to improve the way science, and climate science in particular, is communicated to policy makers and the public [1]. The arts are emerging as a favored approach for science communication in formal and informal settings for the general public and constituencies of particular interest [2]. Despite a growing proliferation of collaborative artistic exhibits, books, performances, and installations that aim to 'activate' science [3], it remains unclear whether arts-based science communication is uniquely effective in raising awareness or shaping public policy. Thus, it is timely to consider whether, and in what ways, projects set and meet goals, as well as what steps can be taken to foster best practices. Here, we map trending approaches and register collective challenges and goals to help establish performance metrics for project assessments [4] and investments to achieve impactful outcomes.

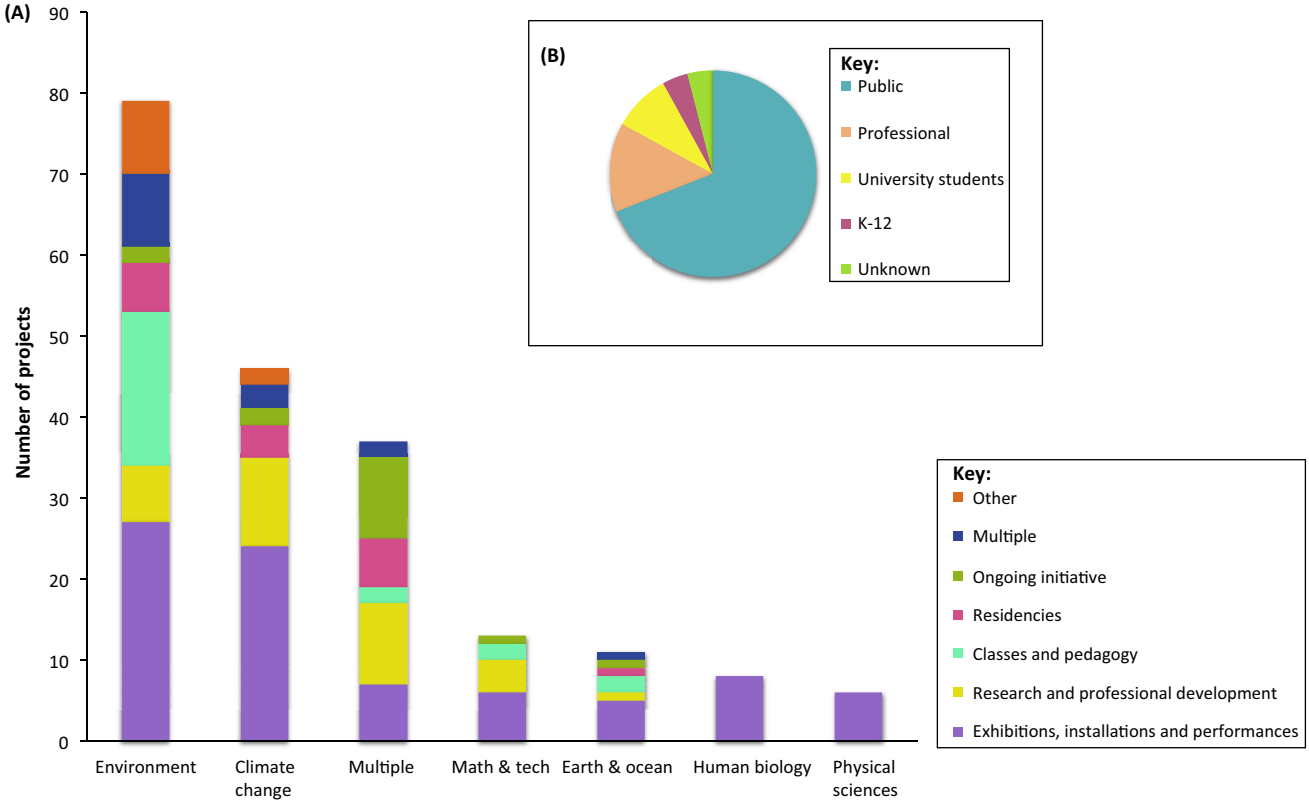
Trends in Approaches to Arts-Based Science Communication

A maturing body of work indicates that the arts can deeply engage people by focusing on the affective domain of learning (i.e., engagement, attitude, or emotion) rather than on the cognitive domain (i.e., understanding, comprehension, or application), which is often emphasized in science education [5]. Some contend that, by utilizing both domains, arts-based science communication catalyzes creativity and discovery by encouraging intuitive thinking [6]. Other work has found that a community-based participatory approach to communicating science through the arts produces meaningful change in community behavior, prompting action on environmental issues and deepening engagement [7].

A review of 200 projects in the US (see Methods in the supplemental information online) indicates that the arts have been widely adopted for science communication, although there are concentrations of projects in states with larger populations and numbers of institutions dedicated to higher learning (e.g., California, Massachusetts, and New York). Most projects are based at universities, followed by nongovernmental organizations, and then museums. Nearly 20% of projects were initiated by individual artists or independent teams of artists and scientists; all others were initiated by institutions or organizations. Most of the projects aim to increase public understanding or awareness about scientific concepts or environmental concerns, including climate change and endangered species (Figure 1). Some focus on a specific place or ecosystem such as the 'Arts in the Parks' program of the US National Park Service, as well as projects at field stations, marine laboratories, and long-term ecological research sites [8]. Although some seek to inspire action or activism, or to increase civic engagement, almost 17% of the projects aim to foster interdisciplinary work between artists and scientists to enhance learning through more creative and richer intellectual inquiry (Figure 1). For example, *Scientific Delirium Madness*, a collaborative initiative of Leonardo/The International Society for the Arts, Sciences and Technology and Djerassi Resident Artists Program, brings together six scientists and six artists for 1-month residencies that encourage creative exploration, public engagement, and academic publication (http://djerassi.org/scientific-delirium-madness.html).

A growing literature suggests that the arts are particularly well suited to climate science communication because they can foster understanding of the science and outcomes of climate change, and because they can elicit visceral, emotional responses and engage the imagination in ways that prompt action or behavior change [9]. With climate change affecting increasingly larger segments of the world's population, science communication is being reconsidered to cultivate creative and constructive approaches to raise awareness and engage vulnerable communities about the risks it poses to everyday life [10]. Climate change is a prominent focus of arts-based science communication across the US, and is being addressed through a diverse array of platforms (Figure 1). An example of a successful, ongoing arts-based climate science project is HighWaterLine (http://highwaterline.org/), in which artist Eve Mosher works with communities to delineate, with a blue line chalked first in New York City followed by several other cities, areas of flooding or the extent of sea-level rise predicted by climate models.

It is becoming clear that arts-based science communication is particularly effective when the setting is an interactive



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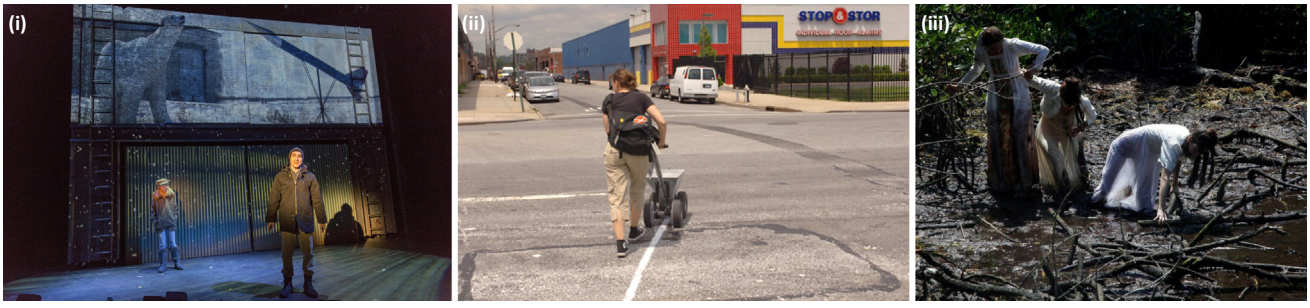

Trends in Ecology & Evolution

Figure 1. Art–Science Projects: Trends and Examples. A review of 200 arts–science projects in the US indicates that (A) by topic, projects most often focus on the environment and climate change. Comparison of project deliverables (i.e., products, type of venue, or outcome of a project, such as a dance performance, workshop, class, or exhibit) also reveals (A) that exhibitions (e.g., visual art shows in galleries, museums, or other public spaces); installations (i.e., temporary, 3D, or multimedia works of art that are sometimes interactive or site specific); and performances (e.g., dance or theater) are more common deliverables than research and professional development (i.e., projects in which data were gathered and analyzed or scholarship was produced, or a training workshop carried out for professional practitioners); classes and pedagogy (e.g., educational materials, curricula, or courses); and residencies (i.e., projects providing the opportunity for artists and/or scientists to be affiliated with, or reside at, a site, institution, or facility to engage in collaboration or produce works of art or scholarship). However, the prevalence of different deliverables varies by topic. For example, projects on climate change did not emphasize classes and pedagogy, which were among the most common deliverables of projects that focus on other environmental topics. The intended target audience (B) for most projects was the general public, illustrating that the arts are being widely adopted for science communication, outreach, and engagement. Projects also frequently engage a professional audience, reflecting an interest in professional development and fostering communities of practice. Postsecondary (i.e., university) students were a more frequent target audience than K-12 students. Settings for arts-based science communication and engagement (C) include performances, community-based projects, and installations. (i) Erin Wilhelmi and Dan Domingues in the play 'The Great Immensity', written and directed by Steve Cosson, Artistic Director of The Civilians, theater performance, 2014, New York premiere at the Public theater, New York City. (ii) 'HighWater Line', Eve Mosher, 2007, New York City. (iii) 'Lay of the Land', Naomi Fisher, 2013 video installation, Everglades National Park Artist-in-Residence. Reproduced, with permission, Richard Termine (Ci); Canary Project (ii), and Naomi Fischer (iii).

exhibit, show, or performance [11,12]. Although exhibits and shows are well represented in our survey (Figure 1), most focus on exposure to a product of art (i.e., an art work or, more often, a museum or science center exhibit) rather than the process of making art, especially in a collaborative environment. Recent work suggests that participatory, community-based approaches, where the audience becomes collaborators or makers of art, are more effective than adhering to models where knowledge is imparted by experts to a public that is posited to lack scientific understanding [7]. Participatory approaches adhere to a simple principle: having knowledge about a concept is not the same as being engaged with that topic in a constructive or useful way [7]. Despite the growing allure and popularity of 'maker movements', more rigorous conceptualization and evaluation of participatory approaches would clarify how the arts serve as a vehicle for science communication.

Collaboration: Defining Goals, Overcoming Challenges

Since 2014, we have implemented the 'Flint and Steel: Cross Disciplinary Combustion' residency program (www.astudiointhewoods.org/thematic_residencies_asitw.html) that partners artists with academic scholars, including natural scientists. The residencies serve to illustrate that interdisciplinary collaboration can be vital to engaging the arts for science communication. We have found that challenges can arise during the collaborative process and that, as in other interdisciplinary endeavors, arts–science collaborations span a continuum. On one end, artists might take inspiration from science but not work directly with scientists, and likewise there might be scientists making art without direct contact with artists. At the other end of the continuum are integral partnerships between artists and scientists (and those who practice both science and art). Although interdisciplinary collaboration is gaining in popularity as an intellectual practice (over 65% of the projects we examined involve collaboration between artists and scientists), disciplinary integration is not always intuitive or simple to resolve [13]. Expectations may differ as a consequence of disparate training, methods, values, vocabulary, funding, and income.

Collaboration can require synchronization at the outset of a project by defining a common vocabulary and by discussing goals, motivations, and desired outcomes. It is important to establish open dialogue for the consistent flow of information and ideas as well as regular reflection throughout a project [13,14]. A responsive evaluation strategy (one allowing adjustments throughout the project as evaluation and assessment are carried out) organized around cross-disciplinary goals and performance measures can also help by serving as a guiding framework (Box 1) [15]. Determining whether and how goals are being achieved can, in turn, help identify practices that yield intended and unintended outcomes.

Building Communities of Research and Practice

With interest in arts-based science communication building, it is important to foster communities of research and practice in education, the sciences, and the arts. Our review revealed that it is often difficult to glean information about project goals and that few projects disseminate performance assessments. Accordingly, we urge practitioners to clearly articulate and communicate their goals, and report evaluations of project execution and outcomes in publicly available (e.g., Internet-based) project descriptions, and project archives. A range of performance measures can be assessed and reported on the structure of a project, project execution, and project outcomes, such as

Box 1. Tools for Arts-Based Science Communication

Below is a list of recommended considerations for project development and execution, evaluation methods, and performance measures for participants and audiences reflecting the prevailing theory on interdisciplinary collaboration [13–15] and our experiences implementing interdisciplinary residencies and participating in art-science collaborations.

Project Development Considerations

- Intended overarching goals
- Project participants
- Extent and depth of collaboration
- Artist goals versus scientist goals
- Learning goals for audience
- Performance measures for overarching goals
- Assessment of goal achievement
- Assessment of intended and unintended project outcomes
- Assessment of artistic and scientific merit of the project outcomes

Evaluation Methods

- Consider professional project evaluators
- Interview artist and scientist collaborators throughout project development and execution
- Utilize multimedia formats, such as field notes, and audio and video recordings
- Track audience size
- Pre/post surveys or interviews of audience

Collaborative Team Performance Measures

- Artist and scientist collaborative capacity
- Changes in knowledge, attitudes, and perceptions of other disciplines
- Changes in understanding, knowledge, and attitudes about the project topic(s)
- Contributions of the project to collaborators' own work and discipline

Audience Performance Measures

- Awareness, interest, and appreciation of project topic(s)
- Engagement with project subject matter
- Learning and understanding of specific concepts
- Emotional and aesthetic responses

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changes in understanding, knowledge of, or engagement with the subject matter (Box 1). Guidance on performance assessment can be sought from other fields (e.g., informal science learning) that explore the role that the arts have in science learning outside of the classroom [5,14]. Some work suggests that it is helpful to engage professional evaluators who have training in education research or the social sciences and experience assessing arts-based or arts-science projects [15].

Consideration should be given to developing a common reporting platform for data and metadata on project outcomes and assessment. This process can be informed by examples of well-articulated arts-based science communication projects supported by research and evaluation. One example is the climate science-based play, *The Great Immensity*, created by the New York-based theater group *The Civilians*, which debuted in Kansas City in 2012 [11]. Scientists were engaged as collaborators as the play was developed, the theater company worked with a professional evaluator to assess the outcomes of the play, audience engagement was incorporated into the performance and assessment, and the evaluation report is publicly available through The Center for Advancement of Informal Science Education (www.informalscience.org/great-immensity-conveying-science-through-performing-arts-assessment). Although carrying out rigorous and lasting evaluation can be challenging in some circumstances (e.g., long-term projects or projects with wide-ranging goals), and although many do not have the resources necessary to carry out a project like *The Great Immensity* (which was funded by the National Science Foundation), it remains a useful case study for communities of researchers and practitioners to gauge how to frame, develop, carry out, and evaluate their endeavors. Addressing several considerations central to project development and execution (Box 1) can provide additional guidance for assessment and reporting. Having these in mind from the onset of project development can also better ensure that projects proceed according to measurable goals and that meeting project goals yields intended outcomes. Other added benefits, such as further conceptualization of arts–science collaborations, could bolster an already flourishing field.

Appendix A Supplemental Information

Supplemental Information associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tree.2016.06.004.

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Book Review

The Design of Life's Interactions: Biomechanics as a Key Tool in Ecology and Evolutionary Biology

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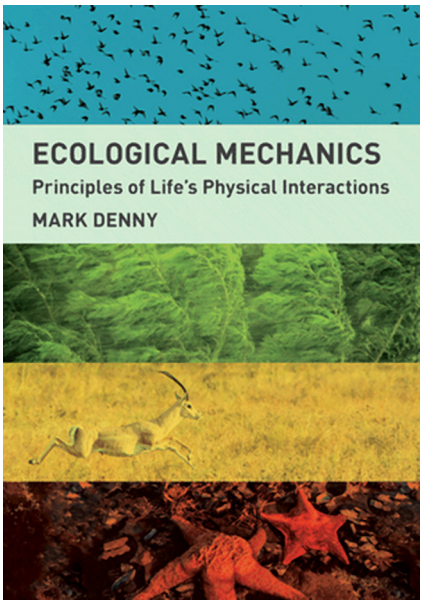

2015 and 2016 were sad years for the field of biomechanics as they saw the passing of two giants in the field, Steven Vogel and Robert McNeill Alexander. Despite their very different research programs both were exceptionally gifted in transmitting their science to the general public by rendering complex problems simple and by using everyday examples to illustrate the principles at work in nature [1–3]. Mark Denny follows in the footsteps of these exceptional scholars and with his book *Ecological Mechanics* tries to explain how biomechanics can be used to gain understanding in ecology. Although his target audience is clearly different (upper-level Masters and PhD students), he also tries to demonstrate how complex