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Co-Design, Co-Production, and Dissemination of Social-Ecological Knowledge to Promote Sustainability and Resilience:

Urban Experiences from the U.S. Long Term Ecological Research (LTER) Network.

Abstract

To promote sustainability and resilience, the role of co-design, co-production, and dissemination of social-ecological knowledge is of growing interest and importance. Although the antecedents for this approach are decades old, the integration of science and practice to advance sustainability and resilience is different from earlier approaches in several ways. In this paper, we discuss new requirements and possibilities for co-design, co-production, and dissemination of social-ecological research to promote sustainability and resilience. While new technologies are part of the solution, traditional approaches remain important. Using our urban experiences from the U.S. long term ecological (LTER) network, we describe a dynamic framework for linking decisions and science. This framework, coupled with a user defined, theory based approach to science, can be instrumental to advance both practice and science.

Introduction

The role of co-design, co-production, and dissemination of social-ecological knowledge to promote sustainability and resilience is of growing interest and importance (Craglia et al. 2012; Cornell et al. 2013; Mauser et al. 2013; Childers et al., in review). The antecedents for this approach are decades old and can be found in participatory action research projects ranging from agriculture and forestry to industrial production (Cernea 1991; Whyte 1991). However, the integration of science and practice to advance sustainability and resilience is different from these earlier antecedents in several ways. The potential number of science disciplines required is much larger. The diversity and number of potential actors from government, business, and civil society sectors is greater. The technological infrastructures to facilitate co-design, co-production, and dissemination of social-ecological knowledge have radically changed, with the advent of and increasing access to diverse digital data, the internet, and its associated technologies. The social relationships connecting distant sectors and actors in the current era of globalization are ever more complex and dynamic. Finally, the need to address sustainability and resilience involves numerous scales—from household to global—and may be one of the defining issues for this century.

Some things have not changed since the emergence of participatory action research approaches. For the most part, and we stress here for the most part, current science is still organized in a somewhat closed system: organized and segregated by disciplines; self-regulated and autonomously-set research agendas; and substantially detached from society, politics, and the media (Cornell et al. 2013). Often, science is practiced as though scientists are the active producers of knowledge and society is the passive recipient (Mauser et al. 2013). Formidable barriers remain to practicing interdisciplinary research among the physical, biological, and social sciences and the humanities. Furthermore, applied and user-engaged research is frequently perceived by scientists and academia to be of lower value and status than basic research (Cornell et al. 2013; Pahl-Wostl et al. 2013). Thus, to a large extent, old knowledge systems and cultures are still being deployed to address new and emerging social and environmental challenges to sustainability and resilience (Cornell et al. 2013).

The rationale for and potential benefits of co-design, co-production, and dissemination of social-ecological knowledge is much broader than the advancement of applied science. The broader goal is to advance knowledge systems, where knowledge systems are made up of actors, practices, institutions, and networks to produce, share, and use knowledge. In the context of societal goals to promote sustainability and resilience, social-ecological knowledge systems are "… networks of actors connected by social relationships, formal or informal, that dynamically combine knowing, doing, and learning to bring about specific actions for sustainable development" (van Kerhoff, and Szlezak, 2010, cited in Cornell et al. 2013:62).

Scientists and practitioners are among the critical actors in knowledge systems. To promote mutual learning among scientists and practitioners, it is necessary to develop mechanisms for the sustained exchange and integration of different disciplinary and non-academic knowledges (Brandt 2013). These mechanisms are relevant to two perspectives on sustainability. One perspective suggests that sustainability and resilience are conceived of in terms of social-ecological limits, boundaries, and thresholds (Rockstrom et al., 2009). A second and complementary perspective views sustainability and resilience not as states but as open-ended processes of social learning in which a new balance is continually being sought among multiple social, economic, and environmental challenges and goals. (Cornell et al. 2013). With this emphasis on social learning, we view the distinction between basic and applied science to be a false dichotomy, ignoring the pressing need for science that is at once theory-based and user-defined (Stokes 1997, Grove et al. 2015).

In the following sections, we use three sites from the U.S. Long Term Ecological Research (LTER) network to illustrate our experiences with building knowledge systems based on co-design, co-production, and dissemination to advance sustainability and resilience. First, we provide a brief background to the LTER network and our individual LTER projects, and its implications for the co-design, co-production, and dissemination of knowledge. Second, we propose a dynamic framework linking science and practice. Third, we describe key practices that have emerged for knowledge dissemination. We conclude by discussing future needs and directions.

What are LTER projects?

The long-term ecological research (LTER) program and projects have been funded by the National Science Foundation since 1980 (Hobbie et al. 2003). The LTER network in the United States is made up of 25 sites representing a diversity of ecosystem and landscape types, climates, land uses, and degrees and histories of human influence. LTER projects are funded in six-year funding cycles and are expected to focus on fundamental ecological research questions that cannot be answered without long-term data. A key feature of LTERs is their long-term data, which are required to be accessible for anyone to use and, with the advent of the Internet and associated technologies, discoverable and downloadable through internet searches.

A considerable proportion of LTER research is conducted on public or university lands where active human presence, "imprint," or access can be limited. However, several LTER programs focus their research on places where people live, own land, and actively manage diverse land uses. Examples of LTER sites that have a dominant anthropogenic and urban component include the Baltimore Ecosystem Study (BES), Central Arizona-Phoenix (CAP), and Florida Coastal Everglades (FCE) LTERs. In essence, these LTERs are embedded in the social-ecological systems of their study regions and their research pursues social-ecological questions, data, and knowledge. BES, CAP, and FCE interact with multiple and diverse stakeholders from public, civil society, and business sectors on questions as diverse as ecological restoration; farmer, rancher and residential owners' land use, values and aspirations; municipal and other governing bodies' climate adaptation and resilience actions; greenspace management, real estate development and land use planning, and hydrological/watershed conservation.

These three LTER programs are well suited for the co-design, co-production, and dissemination of science for several reasons. We have developed durable and productive relationships in these three locations because of the stability of long-term funding and the relevance of our science to pressing societal questions and interests in our research locations. In addition, although we collect long-term data, we often need to integrate those data with additional data collected by other actors within our region to answer key social-ecological questions about sustainability and resilience (Grove et al. 2013). Our partners are involved with a variety of policy, planning, and management activities to advance local sustainability. These activities can be treated as social-ecological "experiments" for which we have skills and capacities to assist with monitoring and assessment through the identification of questions, collection and analysis of data, and collective evaluation of results (Hager 2013). Given the LTER emphasis on making data discoverable and accessible, our LTERs are oriented towards dissemination of knowledge. Finally, we recognize and continually invest in transforming our science and practices to promote co-design, co-production, and dissemination of science so that we are engaged in both the study of and the study for social-ecological systems (Childers et al. 2014; in review). In the next two sections, we share some of the key experiences and insights that have emerged through our science and practice over the past decade.

Idealized model for co-design and co-production

Our experiences at BES, CAP, and FCE suggest that there can be exchanges and partnerships between decision-makers and scientists that help practitioners address the sustainability challenges they face and to build a more general understanding of social-ecological systems (figure 1). Our generic illustration begins with separate disciplines in traditional ecology, social, behavioral, and economic sciences engaging in research relevant to a management or policy concern. A management or policy action (Action1+x) may result from this research-policy engagement. Management also entails monitoring the action-outcome to evaluate whether the desired result was achieved, or to address dynamic management goals. At the same time, LTER science has come to recognize that ecosystems and ecological processes are fundamentally enmeshed within management and policy actions, requiring a more interdisciplinary approach to ecology that includes social, behavioral and economic sciences and, increasingly, concerns and insights from the humanities. This interdisciplinary approach has been labeled social ecology (Burch and Deluca 1984; Machlis et al. 1997). The resulting interaction and partnership between decision-making and social ecology is then available to jointly evaluate subsequent decision-making concerns over time (Actions1+x). The following phases and opportunities of co-design and co-production of knowledge characterize the cycle: (1) identifying and framing questions; (2) collecting and analyzing data; (3) interpreting results; (4) disseminating and applying findings, and; (5) identifying new questions.

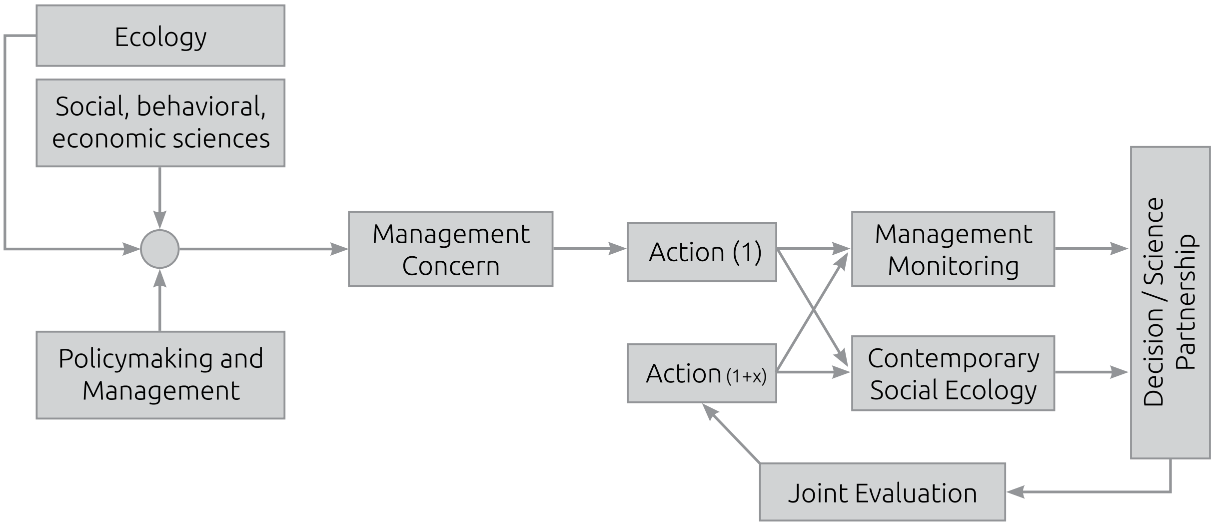

Figure 1. *Dynamic feedbacks between decision-making and science.*

A number of lessons have emerged from our application of this framework at BES, CAP, and FCE. Scientists involved in these decision/science cycles need to be aware of and concerned with both policy and management relevant products as well as basic scientific theories and methods. Knowledge integration and mutual learning are the goals of each co-production cycle. Different types of learning may be involved in a decision/science cycle (Pahl-Wostl et al. 2013). "Single-loop" learning is evident when incremental improvement in actions occurs without questioning underlying assumptions. "Double-loop learning" arises when assumptions such as cause-and-effect or trade-off relationships are evaluated within a value-normative framework. Finally, "triple-loop learning" occurs when underlying values, beliefs, and world views begin to be rethought and challenged. (Pahl-Wostl et al. 2013). This triple-loop learning is most likely to emerge over several decision/science cycles, facilitated through the development of trust and the durable, long-term relationships we noted earlier.

The "management concerns" box that we include in our diagram is associated with diverse actors, institutions, and networks from the public, business, and civic society sectors. Over time, the implementation of our decision/science framework has strengthened our networks by enhancing collaboration and coordination among a diversity of actors and researchers. Collaborations among decision-makers and scientists have enhanced flows of information and improved the legitimacy, ownership, and accountability of management concerns, actions, solutions, and science (re: Cornell et al. 2013; Mauser et al. 2013).

Co-Production, Co-Design and False Dichotomies

The dynamic feedbacks between decision-making and science in Figure 1 illustrate the potential for advancing both scientific and practitioner understanding of social-ecological systems. But what kind of science is most likely to be advanced? One perspective is to think of science as either basic or applied. Given the potential for dynamic connections between decision-makers and scientists, we suggest that this is a false dichotomy that is revealed in what Stokes (1997) calls "Pasteur's quadrant" (figure 2). Three of these quadrants are of particular interest for interdisciplinary science. The two most familiar quadrants may be the first and third. Stokes defines the first quadrant, "pure basic research," where science is performed without concern for practical ends. This quadrant is labeled "Bohr's quadrant," after the physicist Niels Bohr's "pure" scientific pursuit of a structural understanding of the atom. In this quadrant scientists work to understand physical, biological, and social theories and laws that advance our fundamental understanding of the world. For instance, social-ecological systems may be examined to understand the effects of altered climates, organismal components, substrates, and landforms, or changes in livelihoods and lifestyles on consumption, social institutions, identity, and status. The third quadrant, "pure applied research," is defined as science performed to solve a social problem without regard for advancing fundamental theory or scientific knowledge. Stokes labeled this "Edison's quadrant" after the inventor Thomas Edison who was more concerned with practical scientific questions than with the underlying theoretical implications of his discoveries and inventions. In this quadrant, scientists might work to develop solutions to specific problems, such as bio-retention systems for removing pollutants from stormwater or social marketing to increase household participation in sustainability programs. Stokes defines the second quadrant, "use-inspired basic research," as science designed to enhance fundamental knowledge while also addressing a practical concern. This quadrant is labeled "Pasteur's quadrant" because biologist Louis Pasteur's work on immunology and vaccination both advanced our fundamental understanding of biology and saved countless lives. In this quadrant, scientists work to both advance scientific theories and methods while addressing practical problems. For example, how do households' locational choices affect ecosystem services and vulnerability to climate change, or how do ecological structures and social institutions interact over the long term to affect urban resilience and sustainability? While some of our LTER work can be located in each of these three quadrants, most of our research likely resides in this second, use-inspired basic research quadrant.

Quest for fundamental understanding?	Yes	**Pure Basic Research** (Physicist Bohr)	**Use-Inspired Basic Research** (Biologist Pasteur)
	No	--	**Pure Applied Research** (Inventor Edison)
		No	Yes
		Considerations of use?	

Figure 2. *Stokes categorizes three different types of research. Most research associated with our work in BES, CAP, and FCE would be located in Pasteur's quadrant: use-inspired basic research (Adapted from Stokes (1997).*

Facilitating the dissemination of knowledge: distribution and communication

Dissemination of information and knowledge has emerged as an important facet of the decision/science collaboration. Through BES, CAP, and FCE, we have learned that there are certain requirements for dissemination. The dissemination process and knowledge both need to be credible, substantive, influential, useful, timely, inclusive, and efficient (re: Cash et al. 2003). Effective dissemination of knowledge is a two-way process. It improves the consideration and incorporation of science into decision-making, and also improves research by providing scientists with new feedbacks from diverse sectors, which can provide novel insights and access to questions, data, analysis, and interpretations that would otherwise not be available to scientists.

We have found that multiple, interdependent, and sometimes redundant pathways are often necessary to promote decision-science dissemination. To better understand the network flows of information at BES, we have inventoried and mapped the actors in the city in terms of who they work with and where they work (figure 3). This enables us to examine network members, connections and nodes, and actors and places that need to be better represented and more involved. This is particular relevant to a more socially engaged, ethical, and normative science that can meaningfully contribute to investigating the ecological implications of social marginalization and promoting environmental justice within socio-ecological systems.

Figure 3. *Network of stewardship groups in Baltimore, Md. based upon information flows (Grove et al. 2015).*

New forms of dissemination have emerged because of the growing availability of digital data, the Internet, social networking, and associated technologies. These changes are reshaping science and its relationships with society. Digital media have brought about a fundamental change in access to information. Through the Internet, new kinds of repositories of information and knowledge have become available more rapidly and to broader audiences (Cornell et al. 2013).

We have developed digital information systems and libraries with our local partners to address several goals: (1) support scientific research, (2) facilitate more open participation in science, and (3) promote increased use of science in decision-making (also see Craglia et al 2012). Our systems are designed so that data and digital media, what had been traditional "print media" such as journal articles, book chapters, maps, charts, and graphs, are replacing or are more easily available than traditional media and in forms that can be incorporated into decision makers' documents and presentations. In addition to these digital forms of traditional media, we are using new digital forums, including blogs and social media posts (Facebook, LinkedIn, and Twitter), for dissemination and sustained exchange of ideas.

Traditional forms of communication still work and remain critical. While new digital media and communications are important, they do not replace personal engagement and dialog using traditional forms and locations that are familiar and accessible to participants from diverse communities. (Cornell et al. 2013:66). Face-to-face interactions and dialog through individual and group meetings are crucial for the "give-and-take" exchange of ideas, mutual learning, reflection, epiphanies, and building trust.

Future Needs and Directions

We have provided a brief summary of our experiences with the co-design, co-production, and dissemination of social-ecological knowledge from three LTER programs. These experiences have implications for three types of needed change: scientists, technology, and science. We anticipate an increasing demand for people with "T-shaped skills" (Cornell et al. 2013). Traditionally, both scientists and decision-makers have been trained with "I-shaped" skills: persons with a high level of training in a specific discipline or profession. In contrast, persons with T-shaped skills have been formally or informally trained to have both a depth of understanding in a specific discipline coupled with a capability to understand and interact with specialists from a wide range of other fields. It is important to recognize here the need for both breadth and depth. Individual scientists and practitioners, working across disciplinary or professional boundaries, will still need to draw on some important features of established academic cultures or professions to assure their authority and standing.

With the growth of new information systems and technologies, new patterns and challenges will constantly emerge in the means of accessing knowledge, in traditional repositories of knowledge, and in the tools and forums to evaluate and reflect on socio-ecological research. This is a dynamic process that has profound implications for the production, diffusion, and use of knowledge in responding to societal problems (Cornell et al. 2013). While innovations are required, perhaps the larger challenge is how to integrate new information systems and technologies with traditional, and still socially meaningful, forms and locations of engagement and dialog.

Science is a fundamental part of sustainability and resilience processes. Science can study transitions, but it can also influence transitions (per the "knowledge to action" mantra proposed in Childers et al. 2014). Thus, we need to better understand and invest in improved roles for science that more effectively contribute to as well as incorporate socially and ecologically robust knowledge foundations, normative and ethical concerns across diverse stakeholders and decision-makers, especially those that have historically been underrepresented in decision/science cycles, and collaborative action to improve societal sustainability, equity and resilience. Recognizing that co-design, co-production, and dissemination emphasize such collaboration and coordination, it is critical that decision-makers assume a more active role in the definition of research questions and topics in collaboration with scientists.

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