

REVIEW

Opening learning spaces to create actionable knowledge for conservation

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Abstract

The limited application of science to environmental management has been termed the “science-management knowledge gap.” This gap is widely assumed to be a consequence of inefficient knowledge transfer from science to application. However, this metaphor misrepresents knowledge as a “thing” that can be readily exchanged in complex systems, rather than a “process of relating” that involves negotiation and dialogue among stakeholders. We advocate for development of a more explicit alternative model of knowledge creation founded on Nonaka’s Theory of Organizational Knowledge Creation, which emphasizes how knowledge is converted into more usable forms through socialization, externalization, combination, and internalization within “learning spaces.” Effective learning spaces require sufficient trust to enable open, honest, and receptive interactions among stakeholders. We advocate that greater emphasis on knowledge conversions within effectively designed learning spaces will accelerate development of actionable knowledge beyond that of existing models.

KEYWORDS

co-production, environmental decision-making, knowledge, learning spaces, science-management gap, social learning, theory of organizational knowledge creation, trust theory

1 | INTRODUCTION

The complexity of emerging conservation challenges often exceeds the experience and ability of those tasked with their management. These challenges span the realms of science, societal values, economic concerns, politics, and justice, and are often referred to as “wicked problems” (Rittel & Webber, 1973). The complexity, dynamics, and contested nature of these problems require that we simultaneously evaluate and prioritize all of these variables to create actionable solutions. Too often, we attempt to confront wicked problems using a

traditional, linear model of science that is not adequate to the task. In this linear model, scientists generate knowledge about the properties of the problem, then place that knowledge on a “loading dock” (Cash, Borck, & Patt, 2006) where they hope it will be picked up and used by practitioners, decision makers, and resource managers to craft actions that respond to the problem.

The linear model assumes that scientific knowledge is readily transferable and relevant to multiple environmental problems in diverse contexts. The failure of this model, as evidenced by the limited uptake of science, has been interpreted as a “science-management knowledge

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gap,” which implies that environmental managers simply fail to access or appreciate the value of science (Bertuol-Garcia, Morsello, El-Hani, & Pardini, 2018; Cook, Mascia, Schwartz, Possingham, & Fuller, 2013). However, the knowledge gap metaphor belies the complexity of knowledge theory, including how knowledge can be translated to action once it has crossed the gap (Hulme, 2014; West, van Kerkhoff, & Wagenaar, 2019).

Science is one of several knowledge sources relevant to decision making in complex socio-ecological systems (Moon & Blackman, 2014). The development of viable strategies to contend with wicked problems necessitates the convergence of scientific and management knowledge. *Management knowledge* in this realm encompasses the understanding of ecosystem structure and function gained from direct experience, as well as knowledge about how decisions can be appropriately made within managers' social, legal, organizational, and political contexts. Each can be powerfully enhanced when intertwined with local and Indigenous ecological knowledge and positive partnerships with local communities. The deliberate engagement of multiple societal stakeholders, including scientists, resource managers, community members, and policy makers, increases the potential to identify solutions to social-ecological problems that are not only scientifically sound, but also relevant, credible, and acceptable to the those involved (Cash et al., 2003; Roux, Rogers, Biggs, Ashton, & Sergeant, 2006). Unfortunately, the communities most directly affected by environmental management and conservation actions are often not included as equal partners or stakeholders in these processes (e.g., Bullard, 2000; David-Chavez & Gavin, 2018). We seek a change in this dynamic so that resource management science and practice can become places where stakeholder voices and knowledge are integral components to the generation of successful conservation and management policies and practices.

The long-acknowledged failure of the linear science model to consistently produce actionable knowledge has led to the rise of a number of alternative theories of knowledge production such as *Mode 2* science (Nowotny, Scott, & Gibbons, 2003) and co-production of knowledge (Jasanoff, 2004), as well as acceleration of research approaches intended to narrow the gap between research and action. These collaborative forms of research include action research (Greenwood & Levin, 2006), community-based and/or participatory research (Cvitanovic et al., 2019; Wallerstein & Duran, 2008), stakeholder-driven science (Dilling & Lemos, 2011), transdisciplinary research (Hadorn et al., 2006), knowledge exchange (Reed, Stringer, Fazey, Evely, & Kruijsen, 2014), translational science (Kelley, Dietl, & Visaggi, 2019), or knowledge mobilization (Nguyen, Young, & Cooke, 2017).

What these approaches all share is the understanding that knowledge becomes usable in practice when it has been generated through sufficient collaboration between diverse stakeholders (Mach et al., 2020; Norström et al., 2020). Despite the availability of these approaches, their use within traditional academic science has remained somewhat limited (Meadow et al., 2015), often due to a lack of skill on the part of researchers (Rozance et al., 2020), lack of incentives within academic institutions to produce actionable knowledge (Cvitanovic et al., 2019), and insufficient funding for the intensive work required for successful collaborative partnerships (Arnott, Kirchhoff, Meyer, Meadow, & Bednarek, 2020).

We explore how knowledge theory can be used to (a) elucidate the process of knowledge co-production so as to demonstrate the importance of engagement as part of research and (b) design systems to support meaningful collaboration between and among conservation scientists and practitioners. The production of actionable knowledge for conservation is interpreted as a fundamentally social process (Levin, 2013; Roux et al., 2006) that requires specific attention to the importance of trust. We argue for greater emphasis on opening collaborative learning spaces to catalyze more effective co-production of actionable knowledge, rather than piling more scientific information at the loading dock in hopes of its eventual access and use (Maas, Toomey, & Loyola, 2019; Toomey, Knight, & Barlow, 2017). Effective facilitation of these spaces is emphasized as a critical step toward supporting the kind of knowledge co-creation necessary to generate truly actionable knowledge for conservation. Our humble effort provides the broad contours of this approach, recognizing, but stopping short of, an extensive treatment of critical related issues of justice, power, inclusivity, and cross-cultural communication.

2 | THE SOCIAL ENTERPRISE OF PRODUCING ACTIONABLE KNOWLEDGE

Critical to the development of actionable knowledge is the realization that knowledge is not a “thing” that can be readily exchanged, but a “process of relating” that involves negotiating meaning among stakeholders (Roux et al., 2006). *Actionable knowledge* is information that has been evaluated for its truthfulness and made applicable to a specific problem or set of problems (Stern, 2018). This is why scientific evidence, in the absence of interpersonal relationships and social contexts, is insufficient to produce action (Levin, 2013). Making knowledge actionable within the realm of conservation, or any other sphere of decision making, requires several related

processes: inclusion of diverse perspectives on the problem and potential solutions to address a range of needs and interests and illuminate blindspots; agreement among those stakeholders who have the power to facilitate or block action; and ongoing evaluation of its usefulness to keep pace with environmental, social, and political changes (Gerber, Barton, Cheng, & Anderson, 2020). Developing actionable knowledge is thus undeniably a social enterprise, akin to what is often termed “social learning” (e.g., Reed et al., 2010).

This iterative collaborative process of producing actionable knowledge can be extremely challenging (Davies, Nutley, & Walter, 2008; Hulme, 2014). First, competing values, vocabularies, and cultures can lead to misunderstandings, conflicts, and distrust among those involved, inhibiting the process. Second, the actionability of knowledge can be inhibited by organizational norms, systems of accountability, and rewards; moreover, concerns about potential consequences might further limit openness to others' ways of defining and addressing problems (Coleman & Stern, 2018a; Stern, Martin, Predmore, & Morse, 2014). For example, in the United States Forest Service, predetermined and inflexible metrics for assessing the performance of employees, such as number of board feet or acres of restoration, often limit decision makers' abilities to incorporate new knowledge that might alter management plans (Hoover & Stern, 2014; Stern & Predmore, 2011). In addition to these “trained incapacities” (Merton, 1968), new information originating from outside one's own important reference group—groups (s) with whom we share common cultural or normative commitments, personal or professional—can be quickly dismissed as wrong or irrelevant (Merton, 1968; Stern, 2018). Third, the substantive social interactions that the process requires can be both time and resource intensive, and stakeholders (community members, practitioners, and scientists) are rarely adequately skilled, compensated, or recognized for their participation in these processes (Gerber et al., 2020; Young et al., 2020). Finally, the social process of developing actionable knowledge requires that participants must be willing to share and receive ideas openly. This involves taking risks and being

vulnerable—both of which are approached cautiously by most individuals. Thus, learning spaces—environments in which actionable knowledge is created—must enable the development of sufficient trust among stakeholders to support the safe exchange of ideas (Stern & Coleman, 2015).

We use Nonaka's Theory of Organizational Knowledge Creation to illuminate a possible path toward the sustained production of actionable knowledge for conservation. We provide an overview of the theory to establish the scaffolding needed to discuss the conditions that are most conducive to the development of actionable knowledge. We pay particular attention to trust development to better enable open and honest knowledge exchange within learning spaces.

3 | NONAKA'S THEORY OF ORGANIZATIONAL KNOWLEDGE CREATION

Actionable knowledge requires that scientific, local/traditional, and management knowledges meaningfully converge. Nonaka and colleagues' framework (Nonaka, 1994; Nonaka, Toyama, & Konno, 2000) helps us to see how knowledge convergence toward actionable knowledge can and does take place among participants. The theory is founded on two types of knowledge—tacit and explicit—and four knowledge conversions between them that generate new actionable knowledge (Figure 1). *Tacit knowledge* refers to knowledge developed from experience that is difficult to communicate with others. It includes our implicit assumptions, mental models, rules-of-thumb, and other beliefs about reality that might be difficult to put into words. *Explicit knowledge* involves facts, principles, or other forms of knowledge that we can articulate through language or other symbols.

The four conversions between tacit and explicit knowledge are: socialization, externalization, combination, and internalization. *Socialization* involves the sharing of tacit knowledge between individuals, typically through working together and sharing common experiences. *Externalization* is the process of converting tacit

| From | To | |
|--------------------|---|---|
| | Tacit knowledge | Explicit knowledge |
| Tacit knowledge | Socialization (S) Sharing personal experiences | Externalization (E) Drawing out explicit propositions from communicated experiences |
| Explicit knowledge | Internalization (I) Putting new knowledge to work | Combination (C) Sharing, comparing, evaluating, and improving upon explicit knowledge |

FIGURE 1 SECI (socialization, externalization, combination, internalization) knowledge conversions (based on Nonaka, 1994)

knowledge to explicit knowledge. Typically through dialogue, individuals probe and analyze each other's mental models and experiences to translate them into common concepts, terms, propositions, and principles that can then be communicated more broadly. *Combination* is the process through which newly created explicit knowledge is combined with existing explicit knowledge through conversations, reports, debates, peer review, and other means for comparing various knowledge sets. *Internalization* occurs when explicit knowledge is transformed into tacit knowledge as individuals put new knowledge into practice. The successive completion of all four knowledge conversions is referred to as a socialization-externalization-combination-internalization (SECI) cycle.

4 | LEARNING SPACES AND TRUST

Nonaka's theory stresses the importance of effective learning spaces,¹ which catalyze each knowledge conversion (Nonaka et al., 2000). As social processes, knowledge conversions require sufficient trust to enable open, honest, and receptive interactions among the stakeholders involved. We highlight three types of trust that may be particularly important to moving through a SECI cycle and generating actionable knowledge: affinitive, rational, and systems-based (Stern & Coleman, 2015) (Table 1). Research suggests that all three of these forms of trust enable longer-lasting and more effective collaborations and decision-making (Stern & Baird, 2015).

5 | SECI KNOWLEDGE CONVERSIONS

We propose that greater emphasis be placed on the development of effective multi-stakeholder learning spaces to create better opportunities for the co-production of actionable knowledge among practitioners, scientists, and other stakeholders. In the following sections, we describe how developing effective learning spaces can support Nonaka's knowledge conversions to produce actionable knowledge for conservation and other forms of environmental management.

5.1 | Socialization phase

Socialization best takes place face-to-face, in project teams, meetings, workshops, or informal gatherings where tacit knowledge is exchanged through shared experiences or story-telling in which participants describe original experiences, rather than fully processed lessons learned. While this may happen naturally among colleagues working within the same organization, there are significant barriers to socialization across organizational boundaries (Pouyat et al., 2010; Whitmer et al., 2010). Co-location, which involves physically embedding a person in the workspace of another organization (see AAAS, 2020; Stern & Mortimer, 2009), and cross-training, which involves training people in the tasks, roles, and responsibilities of others, can further enable stakeholders to better comprehend the tacit understandings of others

TABLE 1 Different forms of trust and their roles in knowledge creation

| Trust type | Sources | Role in knowledge conversions |
|--|--|--|
| <i>Affinitive trust</i> Trust based on an affinity or "liking" another party. | Shared positive social experiences, assumptions of similarity, demonstrations of understanding or caring, likeability. | <i>Socialization</i> can build affinitive trust, which can produce feelings of benevolence and grease the wheels of more open and honest sharing in subsequent stages of knowledge conversion. |
| <i>Rational trust</i> Trust based on a positive evaluation of the expected outcomes of another entity's behavior. | Perceptions of competence, consistent performance, effective and convincing arguments, values alignment. | All stages involving explicit knowledge provide opportunities for participants to demonstrate their competence. |
| <i>Systems-based trust</i> Trust in the set of rules or procedures governing interactions that minimizes the risks of open participation. | Agreed upon procedures for deliberation and decision-making, shared criteria for evaluating information and potential courses of action, transparency, equity, and fairness. | Agreed upon and transparent procedures reduce the risk of open sharing and enhance feelings of power in influencing outcomes. Attention to the collaborative creation of ground rules for interaction, whenever possible, make open participation safer. |

(Marks, Mathieu, & Zaccaro, 2001). Cross-training can include formalized training across positions within or across organizations. Alternatively, it can be approximated with external stakeholders through outreach programs designed to share managerial or scientific knowledge with others. One example includes the *Experience Your Smokies* program at Great Smoky Mountains National Park (www.experienceyoursmokies.org), in which policymakers and other stakeholders are invited to spend a day in the life of a research scientist or park manager. Extended time and interactions with local communities can yield similar benefits, as scientists or managers come to better appreciate the tacit understandings of local people. These understandings can build *affinitive trust*, or trust built upon a sense of empathy, liking, or common understanding (Stern & Coleman, 2015).

The COVID-19 pandemic has triggered a dramatic shift to more virtual professional and personal interactions. While Nonaka and colleagues (e.g., Nonaka & Konno, 1998) have stressed the importance of face-to-face interactions, other studies have revealed that socialization can also take place online. Martin-Niemi and Greatbanks (2010), for example, found that socialization can be enabled through social media tools if certain conditions are met. Their work suggests that developing a sense of shared community through engendering feelings of membership, the potential to have influence, positive reinforcement, and shared emotional connection (see also McMillan & Chavis, 1986) can enhance the sharing of intuitions and raw ideas. Thus, *systems-based trust* (Stern & Baird, 2015) may be particularly important for online interactions to promote socialization (and all subsequent knowledge conversions). The core element is to reduce perceived risks and enhance the perceived benefits of the honest sharing of personal experiences. Thoughtful facilitation can play an important role in creating this environment.

5.2 | Externalization phase

In the externalization phase, individuals engage in dialogue designed to draw explicit lessons from tacit knowledge. For example, scientists might come to understand additional important, but often unspoken, social, political, ecological, cultural, or other criteria for decision-making that managers or other stakeholders might reveal through informal storytelling or, more formally, through interviews or facilitated discussions. Making these criteria explicit may create opportunities for scientific knowledge to become actionable through the subsequent combination of these different ideas (Fernandez-Gimenez et al., 2019).

Skilled interviewers and facilitators can enhance these learning environments by establishing transparent and agreed upon guidelines for interaction between participants (*systems-based trust*) and ensuring that opportunities exist for each to demonstrate their own areas of competence (*rational trust*). For example, in a study of the Collaborative Forest Landscape Restoration Program, which involves collaborative networks of scientists, managers, and other stakeholders, Coleman and Stern (2018a) found that taking the time to establish rules for interaction enhanced systems-based trust and streamlined planning processes (see Table 2 for more detail). In another example, Meadow, Guido, Crimmins, and McLeod (2016) used social science research skills to elicit tacit knowledge from FEMA employees about their needs and interests in climate information, as well as their work processes and organizational decision frameworks. They conducted interviews with key informants and participant observation to close the gap between climate research and what could be used by FEMA in their daily processes. This process helped the project team develop tools and guidance framed to fit internal agency decision-making processes. It also helped the project team recognize the limits of climate science knowledge when making decisions during fast-moving natural disasters, when other knowledge types become far more relevant. The creation of learning spaces needed to facilitate these processes requires attention to project design, which can include ensuring adequate resources, personnel, and time to facilitate productive interviews or group discussions (Reed et al., 2014). Facilitators can also help to promote culturally appropriate interactions across disparate groups (Djenontin & Meadow, 2018).

5.3 | Combination phase

Combination is perhaps the most well-known stage of knowledge conversion, as we are accustomed to sharing and discussing scientific findings, reports, and management plans. However, combination can often occur within disparate spheres in which scientists interact with scientists (e.g., peer review), practitioners commune with practitioners (e.g., meetings, conferences), or practitioners and other stakeholders receive information from scientists or managers (e.g., commissioned reports, formal presentations, or town hall-style meetings). Integrating managers, scientists, and other stakeholders in combination may require purposive redesign of our standard operating procedures (Djenontin & Meadow, 2018; Reed et al., 2014). Preceding, or integrating, these processes with socialization and externalization with a wider array of stakeholders might expand the scope of explicit

TABLE 2 Learning spaces and trust development through the SECI cycle of an idealized case from the Collaborative Forest Landscape Restoration Program (CFLRP)**Lessons learned from the Collaborative Forest Landscape Restoration Program**

Cases within the CFLRP involve multiple stakeholders coming together to provide input on U.S. Forest Service planning and management actions. Learning spaces can be created within interdisciplinary teams within the agency in which scientists and planners debate appropriate courses of action; between external scientists and Forest Service employees; and between the Forest Service and a wide array of external stakeholders, representing industry, recreational, environmental, political, tribal, and other interests. This table depicts the basic steps taken in some of the most successful case studies observed by the lead author and colleagues (e.g., Butler & Schultz, 2019; Coleman & Stern, 2018a, 2018b). It also draws upon key concepts from principled negotiation (Fisher, Ury, & Patton, 1991).

Socialization (tacit information sharing)**Learning space facilitation**

Despite a history of conflict and mistrust, stakeholders, including scientists, managers, interest group representatives, and concerned citizens are brought together to share their personal stories and experiences and to discuss their values and concerns associated with natural resources. Oftentimes, an external facilitator leads groups through a visioning session of ideal futures, using a mixture of personal reflection, small group discussions, and large group facilitated exercises and dialogue.

Trust development

Stakeholders come to see each other as people with relatable values and different forms of relevant knowledge (e.g., experiential, economic, scientific); opportunities to build affinitive trust are based on empathy for others' stories; recognition of similarities; and opportunities for social interaction that enable the development of mutual respect and appreciation of others' views.

Externalization (converting tacit understanding into explicit knowledge)**Learning space facilitation**

The facilitator draws on the values and concerns of stakeholders revealed in the socialization phase to propose criteria for evaluating possible management options, which might include, for example, forest sustainability, economic well-being of the community, recreation access, and water quality. Rather than discussing actual management actions in this stage, participants are directed to focus on developing these criteria. As participants share values, desires, and observations, the facilitator helps to articulate more explicit (and inclusive) meanings of each. Scientific and other forms of knowledge are articulated (made explicit) that relate to how different potential actions might contribute to achievement of each criterion.

Trust development

The transparency of this process creates a space that reduces risk and facilitates dialogue that represents the interests of all stakeholders (systems-based trust). As stakeholders collaboratively develop assessment criteria, affinitive and rational trust can develop through recognition of similarities between stakeholders, social interaction, and thoughtful contributions to the exercise.

Combination (sharing, comparing, evaluating, and improving upon explicit knowledge)**Learning space facilitation**

Different approaches to assess the achievement of each goal developed in the externalization process and the contributions of potential actions to these outcomes are debated. This typically requires open communication between scientists from multiple disciplines, practitioners from multiple sectors, and other stakeholders, each asking questions of each other, to clarify and advance explicit knowledge. Monitoring plans are agreed upon to account for uncertainty in predictions. Agreements are made to alter management actions if management outcomes fail to meet expectations. Collaborative monitoring enables comparison of predicted to actual impacts and combination of different forms of data.

Trust development

The processes leading up to this point have promoted systems-based trust so that stakeholders can collaborate across multiple forms of knowledge and interests, rather than solely advocating for a win-or-lose specific action. Systems-based and rational trust is further enhanced through collaborative monitoring, which provides a mechanism to maintain accountability in the process. All collaborative engagement has the opportunity to build affinitive trust if facilitators provide clear ground rules for interaction and enforce those agreements.

Internalization (putting new knowledge to work)**Learning space facilitation**

Management-relevant knowledge has been broadened by the sharing of diverse values and perspectives. If successful, processes such as these can change the very nature of

Trust development

These processes are difficult and time-consuming, but research suggests stakeholder inclusion in problem identification and planning may enhance management outcomes, organizational

TABLE 2 (Continued)

| Internalization (putting new knowledge to work) | |
|---|--|
| Learning space facilitation | Trust development |
| stakeholder interaction, moving away from “defensive planning,” in which managers limit public involvement or focus on smaller goals to avoid conflict or uncertainty (Mortimer et al., 2011; Predmore, Stern, Mortimer, & Seesholtz, 2011). Rather, a wider array of scientific and public knowledge become part of regular decision-making, enhancing stakeholder relationships. Training programs and guidance documents can promote these basic principles. | morale, and public relations and reduce delays due to political conflict and litigation (Coleman & Stern, 2018a; Mortimer et al., 2011; Stern & Predmore, 2012). |

knowledge that can be incorporated. Structuring interactions to enable the reconciliation, through explicit discussion, of scientific, managerial, and public knowledge sources that might otherwise remain unspoken, might also require external facilitation support. In traditional forms of sharing explicit knowledge—environmental impact statements, public town halls, or commenting periods—common challenges involve distrust between groups (affinitive or rational distrust; Stern & Coleman, 2015), inadequate disclosure of decision-making criteria and processes (leading to systems-based distrust: Stern, 2008), and the privileging of certain forms of knowledge over others, which can contribute to the erosion of all three forms of trust (Predmore, Stern, & Mortimer, 2011).

Attention to earlier knowledge conversion stages, in addition to facilitated processes to establish agreed-upon decision-making criteria and ground rules for respectful deliberation, can enhance the combination stage (Fisher et al., 1991; Stern & Coleman, 2015). Collaborative efforts in transdisciplinary, indigenous, or participatory research, in which all knowledges are equally valued, reflect these characteristics (Norström et al., 2020). These learning spaces can be enhanced by ensuring that those who will use the knowledge in practice are partners in the research effort by helping to define research questions and methods, actively engaging in data collection and analysis, and sharing responsibility for data interpretation and meaning-making (David-Chavez & Gavin, 2018; Wall, Meadow, & Horganic, 2017). For example, boundary organizations have been credited with minimizing the science-management knowledge gap by facilitating meaningful interaction between managers and researchers to enhance management of an invasive tree species *Tamarix* spp. in the southwest U.S. (Clark et al., 2019).

Collaborative monitoring can extend the combination process beyond the research and planning stages and

provide another powerful means of maintaining trust and participation through implementation (Cundill & Fabricius, 2009; Fernandez-Gimenez, Ballard, & Sturtevant, 2008). Managing ecosystems inevitably involves considerable uncertainty. Collaborative monitoring, in which multiple stakeholders are involved in monitoring the outcomes of management actions, can enable more transparent sharing of the scientific process. This form of extended combination not only can enhance adaptive management and systems-based trust, but also provide additional learning spaces for further interpersonal trust development, socialization, and re-ignition of the SECI cycle as stakeholders work together to evaluate on-the-ground impacts of management decisions (Danielsen et al., 2014; Huntington, Gearheard, Mahoney, & Salomon, 2011).

5.4 | Internalization phase

The internalization phase may have both formal and informal elements. Formally, internalization can include focused training to incorporate newly developed knowledge into practice. Informally, participants in the SECI process can integrate newly gained explicit knowledge into their own work. In either case, attention to the social processes of actionable knowledge creation can produce newly shared norms, which support subsequent SECI cycles. For example, as resource managers become aware of the values and priorities of different stakeholders—through formal social science, facilitated discussions, or other collaborative processes—they may begin to approach their work quite differently. In some cases, this has contributed to new ways of approaching public involvement (e.g., Hoover & Stern, 2014) and re-imagining the role of invasive species within national parks (e.g., Fortwangler, 2009). In the latter case, years of tumultuous multi-stakeholder arguments surrounded

management decisions about non-native donkeys within Virgin Islands National Park. Park managers aimed to eradicate them as invasive species, but local residents and tourists protested. Park managers eventually developed a more collaborative stance, which involved careful assessment of both the scientific research on donkey population ecology and their ecological impacts and locally-expressed cultural heritage and economic values. This yielded a management outcome that was more satisfactory to all stakeholders; one in which donkey populations would be managed, rather than eradicated, with minimized impact to park resources.

5.5 | Trust-building

All forms of trust can play a critical role in the longevity of internalization and in the re-ignition of ongoing SECI cycles. Typically, stakeholders in environmental management and conservation settings are often beholden to multiple and varied accountabilities, including their supervisors, the stated positions of their home organizations, the norms of their professional peers, their personal convictions, and other stakeholder groups with whom they share affinities (Stern, 2018). Collaboration through all stages of the SECI cycle can enable a greater feeling of accountability to the shared process itself, as a wider array of concerns can be surfaced and trust is developed between stakeholders as a result. This can promote boundary spanning activities in which participants in the process are better able to bridge the collective decisions of the knowledge creation network with their home organizations. For example, Coleman and Stern (2018b) found that trust developed through mutually agreed upon and transparent processes within a multi-stakeholder planning process, including joint fact-finding and knowledge creation, motivated individuals to advocate for the goals of the collaborative group within their home organizations. This contributed to the consideration of scientific knowledge in tandem with social and political realities, moving environmental and conservation planning processes forward where stalemates had previously existed (see Table 2). Processes like these can also often entail scientists and managers making efforts to learn within other knowledge traditions—such as Indigenous epistemologies (see e.g., Whyte, 2018); evidence suggests that the broad principles of trust-building apply in these situations as well (Stern & Baird, 2015).

Table 2 describes how a participatory planning process can move through a SECI cycle, with specific attention to how different forms of trust can develop

throughout the process. Other applications might include multiple stakeholder engagement with invasive species management (Fortwangler, 2009; Clark et al., 2019) or on the establishment or revision of zoning or other regulations within protected areas (e.g., Sayce et al., 2013). In each case, the production of actionable knowledge benefits from attention to the processes of (a) sharing personal meanings and experiences (socialization); (b) reflective discussion about how those personal meanings can reveal what really matters and feels true to each stakeholder (externalization); (c) sharing, comparing, and evaluating those meanings to establish shared understanding (combination); and (d) using that understanding for decision-making and continued (hopefully improved) engagement (internalization). Moving through these processes with careful attention to developing and maintaining rational, affinitive, and systems-based trust can not only make the outcomes more sustainable, but also more enjoyable. This can ready the group to take on the next challenge in a new way (further internalization). Recognition that actionable knowledge is a social outcome of the SECI cycle, implemented within effective learning spaces, may contribute to the expansion of what is considered valid science in conservation and associated natural resource management disciplines (Gerber et al., 2020).

5.6 | Navigating between knowledge conversions

Navigating the SECI cycle will not always be smooth. Although each conversion is theoretically distinct, in practice the lines between each knowledge conversion are diffuse. For instance, socialization and externalization are often iterative, with people sharing and making sense of personal experiences simultaneously. Additionally, real world contexts will often involve cycling back to earlier phases of the SECI cycle, as well as repeating the process. For example, if conflict emerges or resurges late in the process (as different forms of explicit knowledge are compared in the combination phase), revisiting the socialization and externalization phases can help uncover the root causes of disagreement. Understanding the root causes can refocus interactions on stakeholder interests, enabling groups to re-visit and reset their shared criteria for how to judge the best paths for moving forward (Fisher et al., 1991). This work is challenging, and it can be time-consuming, but we argue that the prospects for producing more actionable knowledge and better decision-making may be worth the effort.

6 | CONCLUSIONS

We present an explicit alternative framework to the loading dock model to bridge the science-management divide, one founded on knowledge theory to contend with the complexity, dynamics, and contested nature of environmental challenges. The production of actionable knowledge is fundamentally a social process. Thus, trust and social learning serve as critical components in the convergence of scientific, local/traditional, and scientific knowledge (West et al., 2019). Greater attention to the creation of effective multi-stakeholder learning spaces consistent with Nonaka's SECI cycles (Nonaka, 1994) and trust theory (Stern & Baird, 2015) re-paint the science-management gap as a deficiency in the skills and dispositions necessary to blend science about the resource with the social, economic, political, and management realities encountered by environmental managers. While this paper has not delved deeply into the work of incorporating justice, power, inclusivity, and cross-cultural communication into collaborative knowledge production, we suggest that the principles we have shared may help collaborators address these crucial topics more effectively.

Implementation of these principles will require substantial reorganization of the environmental research and decision-making processes in many cases, including greater recognition of the social interactions influencing trust and distrust between parties, joint problem ownership among stakeholders, organizational commitment to development of appropriate skills, and recognition and compensation in support of this resource intensive process. Such re-organization, while not easy, may accelerate the co-production of actionable knowledge; lead to greater trust among scientific, management, and stakeholder communities; and ultimately enhance environmental sustainability and human well-being.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

David D. Briske identified the initial concept, Marc J. Stern applied Nonaka's Organizational Knowledge Theory and trust theory, and Alison M. Meadow developed knowledge exchange content. All authors contributed to writing of the text.

DATA AVAILABILITY STATEMENT

The paper is based on published literature.

ETHICS STATEMENT

No original data were collected for this paper. Institutional ethics review was not required.

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ENDNOTE

¹ Nonaka's work refers to these spaces as "ba."

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