The cultural side of science communication

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The main proposition of this paper is that science communication necessarily involves and includes cultural orientations. There is a substantial body of work showing that cultural differences in values and epistemological frameworks are paralleled with cultural differences reflected in artifacts and public representations. One dimension of cultural difference is the psychological distance between humans and the rest of nature. Another is perspective taking and attention to context and relationships. As an example of distance, most (Western) images of ecosystems do not include human beings, and European American discourse tends to position human beings as being apart from nature. Native American discourse, in contrast, tends to describe humans beings as a part of nature. We trace the correspondences between cultural properties of media, focusing on children's books, and cultural differences in biological cognition. Finally, implications for both science communication and science education are outlined.

culture | lay epistemologies

Communication and the exchange of information have been an ongoing dimension of learning science research. Increasingly scholars, policy makers, journalists, and other stakeholders (the recent National Academy of Sciences symposia on science communication serve as evidence) are focusing on efforts to more precisely understand and study science communication—in short, the focus is on the science of science communication. Building on the broader research on cultural differences in understanding of and engagement with science, in this paper we focus on lay epistemologies, artifacts, and their roles in science communication. We argue that science communication (e.g., words, photographs, illustrations, data visualizations) necessarily makes use of artifacts, both physical and conceptual, and these artifacts commonly reflect the cultural orientations and assumptions of their creators. These cultural artifacts both reflect and reinforce ways of seeing the world (epistemologies) and are correlated with cultural differences in ways of thinking about nature. Therefore, science communication must pay attention to culture and the corresponding different ways of looking at the world. In this paper we examine representations of the natural world and human–nature relations encoded therein to exemplify this argument. In particular, we suggest that much, if not all, of science communication has implicit and explicit messages about human–nature relations embedded within it.

The term "science communication" can vary in its scope. In its most narrow sense it refers to communication from scientists to the general public, sometimes or even commonly mediated by science writers. More broadly, science communication is reflected in science education, both formal and informal (1). Here the forms of communication are likely to be influenced by educators and educational researchers. Finally one can think of science as being communicated broadly and even implicitly in media and a wide range of cultural artifacts. Our primary focus will be on these more indirect forms of communication.

To buttress our argument concerning the importance of culture, we will draw on a variety of evidence associated with a collaborative research partnership among the American Indian Center of Chicago, Northwestern University, the Menominee Indian Tribe of Wisconsin, and more recently, the University of Washington (2). This partnership has been engaged in cultural and developmental studies of biological cognition and community-based efforts to implement culturally based science education both in Chicago and on the Menominee reservation (2–4). Relevant data come from interviews, cognitive tasks, observations in informal learning contexts, and finally, from the analysis of artifacts. To begin, we review two key constructs in our work: epistemological orientations and culture. Then we will briefly offer a sampling of our findings to illustrate the close coupling between cultural practices and understandings of human–nature relationships. Next we turn to an analysis of cultural artifacts linked to these cultural comparisons. Finally we shift to an analysis of artifacts more broadly linked with science and conclude with implications for science communication.

Epistemological Orientations

Epistemological orientations, also known as lay epistemologies, can be informally defined as the different ways in which people view, conceptualize, and engage with the world. These variations implicitly and explicitly affect knowledge construction and forms of engagement with the world. More specifically, different ways of viewing the world reflect values and goals, and shape considerations of what is relevant to a task at hand. In our work on epistemological orientations we focus on the decisions, processes, and practices that determine what phenomena are relevant, worthy of attention, and in need of explanation as well as the associated practices that influence the nature of observation, the kinds of hypothesis that are likely to be considered, and notions of what constitutes a satisfactory explanation.

In short, epistemological orientations correspond to different ways of seeing the world, each of which may be useful and accurate in itself, but each also providing a different perspective. For example, consider different maps that might be used to represent downtown Chicago. A map showing Metra stations and Chicago Transit Authority train lines would be relevant for commuters, but less relevant for bird watchers looking for the best viewing areas or parents seeking outdoor spaces for their children. Hot air balloonists might be more interested in a topographic map of the landscape, along with information about likely wind currents. A demographer would prefer a map showing population density and a sociologist might be interested in how that density varied with time of day. In short, maps reflect different views or representations of reality corresponding to different notions of what will be relevant to their users. [Note also that there are constraints associated with maps (e.g., the distance from point "a" to point "b" is the same as the distance from point b to point a) that we might want to discard or alter

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based on relevance (e.g., if we wish to know travel times, distance may very well not be symmetrical).] We suggest that more generally speaking cultural practices give rise to and shape different ways of looking at the world.

Culture

Before going further we need to make two clarifications with respect to our use of notion of culture. The first involves the distinction between lay epistemologies and the epistemological orientations associated with science. For some purposes it is tempting to think of science as a culture unto itself reflecting scientific methods for establishing knowledge. Thus, to become a scientist is to adopt the culture of science. Although this perspective does identify some commitments associated with consensual scientific practices, it would be a serious error to make the inference that scientists shed their own cultures when they enter through the doors of science (4, 5).

The second clarification is that we reject a simple box model of culture, one that invites stereotyping and often uses trait-like definitions and all-or-none membership to define and study culture (6, 7). We think of culture as made up of the diverse repertoires of practices, values, and beliefs that individuals use to engage and make sense of the world to accomplish purposes valued by them and the communities in which they participate (8). Cultural practices reflect and provide support for some ideas over others, but these ideas often are variable and contested even within a cultural community.

Culture, Ways of Looking at the World, and Artifacts

There is now quite strong evidence that participation in specific cultural communities affects not only what people think but how people think (9). Studies contrasting US college students with their East Asia counterparts indicate that basic processes of attention and perception vary across cultures. For example, Masuda and Nisbett (10, 11) found that East Asians pay more attention to background information (context) and relationships than US participants who are more likely to attend to foregrounded, focal objects. In change-detection tasks, US participants perform better than East Asians in identifying foreground changes but worse in detecting background changes. East Asians are also more likely than Westerners to spontaneously adopt another person's point of view (12, 13).

There is also substantial evidence that the artifacts and forms of representation used by different cultural communities both embody and affect cultural orientations (14). There is a long history of scholarship arguing that artifacts—tools—are critical mediators of thought (for an overview, see ref. 15). Empirical studies on this topic have identified cultural differences and examined the role of cultural artifacts in maintaining them. For example, recent work reveals that popular storybooks from the United States are more likely than those from Taiwan to depict characters in excited (versus calm) states, and that across cultures, exposing preschoolers to exciting (versus calm) storybooks alters their activity preferences and perceptions of happiness (16).

As a further example, Masuda et al. (17) analyzed portrait paintings in US and East Asian (Japan, Korea, and Taiwan) museums and found that the ratio of the face to the total area of the painting was much higher in the US portraits (14%) than in the Japanese portraits (4%). When US and East Asian international college students were asked to take a photograph of another person in a laboratory setting these same differences in the ratio of face to total area were observed. Finally, aesthetic judgments conformed to these practices. Evidence like this underlines the importance of understanding both the nature of cultural differences and the role of cultural artifacts in maintaining them. Further, scholars have identified the need to consider the implicit epistemological commitments embedded in artifacts (18). With this overview in mind, we turn to our comparisons of Native American and European American epistemological orientations associated with the natural world.

The Place of Humans in Nature

An increasingly important dimension of biological thought is understanding how relations between humans and the rest of nature are constructed and how these construals affect cognition. One key component of this relation, one that varies across cultural communities, is psychological distance (see ref. 19 for one approach to distance). (We do not describe Liberman and Trope's construal-level theory in greater detail because our approach is somewhat broader in its focus on epistemological orientations as described in the next section of this paper.) This is reflected in practices, cognition, and cultural artifacts.

Bang et al. (20) collected reports of outdoor practices (e.g., hiking, playing baseball, mowing the lawn, and so on) among urban (intertribal) and rural (Menominee) Native American children and adults and rural European American children and adults. After an initial survey identified 36 distinct outdoor practices, participants were asked whether they engaged in a given practice and if so, how often. Participants could also add any practices that were not present on the survey. Then both Native American and non-Native American research assistants, blind to our hypothesis, assigned each practice as foregrounding nature (e.g., forest walks, berry picking), backgrounding nature (e.g., playing baseball), or neither (intermediate; e.g., mowing the lawn). [Note that we are not endorsing this particular notion of foregrounding and backgrounding although it appears to be widespread in American culture. (This same cultural model would see a bird's nest as a part of nature but reject the idea that a person's home is also a part of nature.) There was substantial agreement across coders and no effect of research assistant ethnicity on these judgments. The results showed that both urban and rural Native American children and adults were reliably more likely to participate in practices where nature is foregrounded and reliably less likely to engage in practices in which nature is backgrounded.

As part of this same interview we asked parents and grandparents to list five important things about the biological world that they would like their children or grandchildren to learn. Although much of the content was similar across groups, we observed large and reliable differences in distancing discourse (20). European American parents and grandparents typically described nature as an externality, saying things like, "I want my children to respect nature and know that they have a responsibility to take care of it." In contrast, both urban and rural Native American adults were more likely to say, "I want my children to realize that they are a part of nature."

Both of these observations suggest that one key aspect of models of nature is psychological distance between humans and the rest of nature. As we will see, this difference in psychological distance is correlated with a number of other important cultural differences. It will be equally clear that the construct of distance is limited in that it does not address relational orientations.

Context, Perspective Taking, and Relational Epistemologies

Perspective taking and attention to context and relationships are basic components of both observation and the determination of what is relevant. For the past decade or so, our research team has focused on the role of culture, cultural practices, and related epistemological orientations in the development of knowledge of and reasoning about the natural world (e.g., refs. 21–24). Our research framework and results are generally concordant with work in anthropology and Native American scholarship described in terms of a relational epistemology (e.g., refs. 25–31).

We first describe a subset of converging measures on context and perspective taking and then turn to implications for conceptual organization and reasoning. Given that there are more than 560 federally recognized tribes, it would be speculative and inappropriate to claim that these results will hold for all Native American communities, which represent very diverse cultural and environmental contexts. At the same time, our findings accord well with scholarly writings concerning Native American versus Western science (27, 32).

In one assessment of attention to context, we simply asked rural Menominee and European American adults to tell us about the last time or a memorable time when they went fishing (33). Our dependent variable was the number of words spoken before the informant mentioned the goal (the fish). For European American adults the median numbers of words before fish were mentioned was 27; in contrast for Menominee adults it was the 83rd word, a highly reliable difference. Indeed, the reason we had to use medians rather than means is that several Menominee adults never got around to mentioning fish at all. Instead, they tended to describe the context (weather, place, and who else and what else was present) in detail. Informally, Menominee adults have told us that their goal in telling a story is to put a picture in the listener's head, one that might allow listeners to obtain a first-person perspective on it.

In further work bearing on perspective taking and attention to relationships (34), we interviewed 5- to 7-y-old rural Menominee and European American children about species relations (both animal–animal and animal–plant relations). Each child viewed several pairs of pictures of plants and nonhuman animals and was asked how or why the species (e.g., eagle and hawk) might go together. One striking result was that a significant number of Menominee children and only Menominee children spontaneously imitated the sounds of animals. This parallels the informal observation by Unsworth (ref. 35; Northwestern University Institutional Review Board approved the experiments and informed consent was obtained from all participants) that when rural European Americans gesture in telling stories about deer they tend to place the deer in some location, but Menominee adults may become the deer. Unsworth et al. also found that both groups of children were equally likely to mention animal–animal and animal–plant food chain relations, but Menominee children were reliably more likely to mention relationships between biological kinds and natural inanimates (e.g., water, sun, soil).

We have also done parallel studies with rural European American and Menominee fish experts (36). These experts (selected from peer nominations with expertise verified by a feature listing task given later) had an average of 40 y of fishing experience, were familiar with local species, fished year round, and targeted similar species. They differed in that Menominee experts focused more on fishing as a source of food and European American experts were more likely to practice catch-and-release. In a spontaneous sorting task ("put the fish that go together by nature into groups"), European American experts tended to sort taxonomically (e.g., "bass family") or in terms of goals (e.g., "large, prestigious game fish"). Menominee fish experts, in contrast, were relatively and reliably more likely to sort ecologically (e.g., "found in fast-moving water"). [Note that the cultural differences we have been describing cannot be captured by differences in propensity for concrete versus abstract thought. Although Menominee children and adults may pay more attention to context, this attention is also recruited in the service of understanding ecological relations. One could argue that attention to relations involves abstract thought to a greater degree than attention to objects or categories (37).]

In a follow-up study (36) we reduced our sample of fish to 21 species and probed for all pairwise combinations of species (e.g., "Does the river shiner affect the largemouth bass or the largemouth bass affect the river shiner?"). Given that 420 potential relations were being probed and that this interview lasted about 1 h, the task proceeded at a rapid pace. Menominee experts saw reliably more relations than the European American experts, including reliably more positive and reciprocal relations involving the full life cycle of fish. European American experts tended to answer in terms of adult fish.

Given the extensive expertise of these informants, we hypothesized that this difference was mediated by knowledge organization rather than knowledge per se. If so, then if we reduce the number of relations probed (from 420 to 70) and slow down the pace of the task, the differences should disappear. We did so, the differences disappeared, and European American experts began to draw on the full life cycle of fish for their answers. These findings suggest that differing epistemological orientations can be associated with fundamental differences in conceptual organization that persist under expertise established over decades.

It also appears to be the case that cultural differences in epistemological orientations strongly influence conceptions of the relations between humans and other living kinds. Ross et al. (38) asked rural European American and Menominee hunters to rate the importance of a number of plant and animal species to the forest and to themselves. Generally the two groups agreed on which species were most important, but Menominee hunters gave reliably higher ratings to both plants and animals for importance to self and for importance to the forest. The fact that the two groups did not differ on rating of importance to self for game animals undermines the idea that the difference was a difference in the use of the rating scale. The majority of the Menominee hunters (and none of the European American hunters) mentioned that everything has a role to play and therefore is of value. Menominee hunters were also more likely to say that if something is important to the forest it is also important to them.

Overall, these observations suggest that psychological closeness and relational understandings of nature are associated with a cluster of behavioral and cognitive consequences, including differences in conceptual organization that are observed in children and which persist across high levels of expertise. Now we turn to evidence suggesting that cultural differences, perspective taking, distance, and attention to context are also evident in cultural artifacts, in this case, in children's books.

Children's Books

Considerable scholarly work has focused on science learning through children's literature (e.g., refs. 39–42). Recent evidence reveals that even preschool-aged children learn biological information from children's books and extend it to their reasoning about real situations involving living animals (42, 43). Young children are also able to learn science vocabulary when they engage in joint book reading (44). Words and illustrations, including those in children's books, are not only learning tools but also cultural products, reflecting epistemic commitments. They manifest the cultural orientation of the illustrator and may also have cognitive consequences for viewers. We now turn to our analyses of children's books that either were or were not authored and illustrated by Native Americans.

First, with respect to illustrations, our coding scheme focused on psychological distance, camera shots aimed at inducing viewer perspective taking, and the diversity of perspectives directly adopted in representations. There is considerable evidence that psychologically close events are associated with (*i*) greater attention to context and mitigating factors and (*ii*) a greater likelihood of interpreting social behavioral situationally rather than dispositionally (19, 45, 46). In related work, researchers have considered how different illustrations affect the viewer's tendency to adopt either a first- or third-person perspective, and the cognitive consequences of adopting these perspectives (e.g., refs. 47–49). Results from this line of research show parallels to the work on psychological distance: A third-person perspective is more abstract and focuses more on the why of action than the how. Furthermore, different pictorial representations affect perspective taking (50); closeness facilitates adopting a first-person perspective.

If our earlier-mentioned observations on distance and perspective taking are reflected in illustrations in children's books, then we should expect that books illustrated by Native Americans should be more likely to use devices that minimize the psychological distance between the characters and readers, that invite readers to take on the perspective of a character in the story, and that provide readers with a broader range of views or perspectives into the story.

The sample consisted of 86 books, 42 written and illustrated by Native Americans and 44 by non-Native Americans. The books were selected if they were (*i*) targeted for 4- to 8-y-olds, (*ii*) included narrative and illustrations, and (*iii*) included humans and/or nonhuman animals as characters. We selected no more than two books by any given author or illustrator. We also excluded books focusing on self-help, counting, naming, and holidays. The Native American books were selected from the recommended list at Oyate.com, a website of a Native American-operated literacy organization.* The non-Native American books were selected from the highest-selling books listed on Amazon.com. Our research team has focused on young children's science learning with everyday artifacts and their interactions in nonschool settings; for this reason, we did not select books that were explicitly about science. (Of note, M.B., Jasmine Alfonso, Lori Faber, Ananda Marin, Michael Marin, Sandra Waxman, Jennifer Woodring, and D.L.M. comprise our research team) Again the question is whether the illustrations and narrative in storybooks show cultural variation in orientations to nature.

In our analysis we developed a code for distance described in terms of the vocabulary of camera shots. Each illustration was rated as providing the reader with either a (*i*) "close-up", (*ii*) "medium-distance," (*iii*) "wide-view," or (*iv*) "panoramic view of the scene as a whole." We also used camera shot terms for invited perspectives. Perspectives that invite the reader into the scene as one of the characters (50) included "over-the-shoulder" (as if a camera had been placed behind a character's shoulder) and "embodied" (in which part of a character is shown, such as hands in the foreground shots). The primary alternative perspective offered the reader an outsider's view of the scene ("voyeur,", often a default perspective where the viewer is outside the scene and viewing it from some distance).

For direct rather than invited variation of perspective, we also coded the viewing angle provided in each scene. For each illustration, viewing angle was coded as either (*i*) "above" (e.g., viewing the scene from far above, as in a bird's-eye view), (*ii*) "high-angle" (looking down on the scene), (*iii*) "eye-level" (the default viewing angle in most illustrations), or (*iv*) "low-angle" (looking up to view the scene).

One Native American and one non-Native American rater applied the coding scheme at the level of books and each coded all of the books. For each book and for each coding category (distance, invited perspective, viewing angle) raters indicated whether at least one illustration in that book included a given subcode. Although this analysis seems to require that the two types of books have about the same number of illustrations, in our sample the non-Native American books had modestly more pictures, but also reliably more pictures, which, as we will see, works against our hypotheses. Intercoder reliability was good (Kappa was equal to 0.72) and any disagreements were readily resolved through discussion.

Native American books were more likely than non-Native American books to include at least one illustration that was a psychologically close (close-up) shot (93% versus 75%) [$F(1,84) = 5.21$, MSe = 0.131, $P < 0.05$]. Native American books were also more likely than non-Native American books to include at least one wide-angle shot (90% versus 68%) [$F(1,84) = 6.82$, MSe = 0.157, $P < 0.05$]. Native American books were also far more likely to use embodied/over-the-shoulder shots (67% versus 27%) [$F(1,84) = 11.71$, MSe = 0.219, $P < 0.001$]. Nonhuman animals were often the target of these shots.

Perhaps the most striking difference between the Native American and non-Native American books is in the variety of vantage points offered within a given book. Of the four distance codes (close up, medium, wide, panoramic), 79% of Native American books contained three or more different codes compared with 52% of non-Native American books [$F(1,84) = 6.917$, MSe = 0.215, $P = 0.01$]. More Native American books (90%) than non-Native American books (66%) contained more than one different camera shot [$F(1,84) = 8.066$, MSe = 0.161, $P < 0.01$]. Finally, Native American books were more likely than non-Native American books to have views from above, as well as low- and high-angle views, although the differences were only significantly different for high angle [$F(1,84) = 4.71$, MSe = 0.179, $P < 0.05$]. Overall, Native American-authored books used a greater variety of illustrative tools, encouraging viewers to approach the story from more multiple perspectives.

Ways of thinking about and engaging with the natural world may be affected by conventions used in illustrations. Consequently, the range of devices used in Native American illustrations may support taking multiple perspectives and systems level thinking, strategies important for scientific reasoning.

We have done a related analysis of the text associated with these books (51) and again we find substantial differences in epistemological orientations. For example, Native American-authored books are reliably more likely to mention natural inanimates and native animals and are more likely to give specific names to plant life and to describe seasons, cycles, and events in nature (e.g., rain). This parallels the Unsworth et al. (34) findings that Menominee children were more likely than European American children to mention natural inanimates for probes of ecological relationships. (We are not claiming that reading Native American-authored children's books caused Menominee children to be more likely to mention natural inanimate. As an alternative, it may be that both measures reflect similar epistemological orientations.) Overall, these analyses of text show that, with respect to engagement with the natural world, Native American storybooks are more intimately engaged with the rest of nature than non-Native American books.

We suggest that the epistemological orientations embedded within the text of storybooks may influence young children's scientific thinking, including the kind and quality of explanations they generate. Children's book illustrations and text may constitute one source of information that shapes young children's reasoning about and relation to the natural world. If this is the case, then differences like the ones we have described here may have important cognitive consequences. [In related work, Williams et al. (52) analyzed historical changes in depictions of environments and human–environment interactions in award-winning children's books and speculated about the increasing focus on built environments in children's books.] Although we ourselves have yet to show that exposure to different illustration conventions or epistemological orientations embedded in text has cognitive consequences (but see ref. 53), there are studies with college students showing that camera shots affect perspective taking (e.g., ref. 50) and inference making. Further, research focused on the impacts of representations has demonstrated that multiple representations can support the construction of deeper understanding by helping to scaffold inquiry,

*It seems likely that the selections by Oyate.com are not a random sample of Native American books and one should be very cautious about generalizing findings about illustrations to the entire population of Native American books. Given that Oyate.com is a Native American-operated organization, decisions on recommended books may have favored those with illustrations and illustration conventions most closely associated with Native American Nations. If so, our samples may overestimate the magnitude of any differences we observe. On the other hand, however, one could argue that it is just those illustration conventions that we should be sampling.

constrain interpretations (e.g., ref. 54), and foster developing models of phenomena (e.g., ref. 55). Researchers have suggested that constructing drawings may make the visual–spatial demands of content learning accessible and may communicate complex information in ways other forms of representation do not (56–58). However, none of these studies have considered these issues from a cultural perspective.

In summary, once again we see converging relationships among performance on cognitive tasks, spontaneous behaviors, evaluative ratings, and differences in text and illustrations with cultural artifacts (children's books). We suggest that there is a reciprocal relation between ways of viewing the world and (cultural) artifacts. Ways of seeing the world affect the construction of artifacts and notions of what is natural; in turn these culturally infused artifacts feed back to reinforce these ways of viewing the world.

So far our observations have been on one particular cultural contrast and on science communication only in the broad sense of being (indirectly) represented in children's books. We now briefly report observations on science communication having a more explicit educational focus.

Representations of Ecosystems

We have conducted analyses of science education materials for the representations of ecosystems and the human–nature relations reflected in them. In this work we found that humans are almost never included in these representations. From our perspective, this absence of humans from ecosystems provides additional evidence for a cultural model of humans' relationship with the natural world where humans are apart from or distanced from nature.

This same pattern holds for Internet representations. We invite the reader to go online and search for images of ecosystems. In our experience with this exercise, human beings are almost never present and in the rare instances where humans appear they may be represented as outside the system looking in (we found a couple of illustrations with giant-sized children towering over an ecosystem and looking at it through a magnifying glass as one ironic exception to the exclusion of humans). To provide some numerical evidence bearing on our claim that representations of ecosystems typically do not include human beings, we searched for images on www.google.com using the word "ecosystems." Next we coded the first 400 images that appeared as excluding humans, including them within the ecosystem or presenting them as outside the ecosystems and looking in. Of the 400 images, 393 (98.2%) did not include humans, 4 (1%) had humans within the ecosystem, and 3 (0.8%) had humans outside looking in.

Presumably these artifacts are not intended to represent a commitment to the view that humans have no impact on and do not participate in ecosystem functioning. However, it may nonetheless indirectly influence how we think about environmental issues (e.g., excluding urban settings as part of any ecosystem, seeing ideal ecosystems as free of any human influence, and so on).

Distancing may even be seen as intrinsic to good science. The need for objectivity in science may rely on the metaphor of distancing. However, distancing does not seem to be an effective device for engagement and identification with science and may be ineffective for communicating science as well. Indeed research in science learning has increasingly focused on dimensions of personal relevance and identification with science (1, 59, 60) as a key factor in engagement with science. Indeed, our own research, as well as other studies in science education, has demonstrated that when science learning engages students' everyday lives and epistemic orientations, both learning and transfer to other contexts is enhanced (3, 61–64).

Furthermore, it is not the case that distancing and decontextualizing is a necessary and monolithic stance for the practice of science. That stereotype is undermined by scientists themselves. For example, the disputes between E. O. Wilson and James Watson on the "real" nature of a biological explanation had Watson arguing for an abstract, molecular approach to biology and Wilson emphasizing the importance of context [nicely summarized in chapter 12 of Wilson's 1994 book, *Naturalist* (65)].

Or consider how Nobel Laureate, Barbara McClintock approached her study of the genetics of corn. She says, "No two plants are exactly alike. They're all different, and as a consequence, you have to know that difference" … "I start with the seedling, and I don't want to leave it. I don't feel I really know the story if I don't watch the plant all the way along. So I know every plant in the field. I know them intimately, and I find it a great pleasure to know them." (ref. 66, p. 198). McClintock used her knowledge of individual plants to coordinate larger-scale (individual) plant characteristics with properties of chromosomes she observed under the microscope. Thus, she integrated observations across multiple levels of analyses to understand the genetics of corn.

Of course these examples leave us to speculate on why public representations of ecosystems overwhelmingly (implicitly) endorse the view that humans are not part of ecosystems.

Discussion and Implications

Although the primary goal of our research has been to implement culturally and community-based science education (e.g., ref. 2), we think the findings also have potentially important implications for science communication. The nucleus of our claim follows a simple syllogism: If all artifacts are cultural and if science communication employs artifacts, then science communication necessarily employs cultural artifacts. That is to say, there is a cultural side to science communication. We are far from the first to point to the significance of the relationship between messages and their audience. There is evidence that the framing of science communication may vary in effectiveness depending on recipient characteristics or individual differences in values (e.g., refs. 67–70). As we have seen in our review, these sorts of differences are correlated with culture. The challenge is to identify effective ways of communicating information to culturally diverse groups in a way that avoids cultural polarization.

Our studies may serve to build on this body of research by examining cultural practices and associated cognitive processes that are linked to ways of viewing and engaging with nature that can be summarized with the term "epistemological orientations." We believe that some of the most central questions about the place of humans on Earth and in nature are at stake in different ways of looking at the world. Do we tower over the rest of nature? Are we outside the system looking in? Or are we part of this complex system and intimately linked with its other components? What ways of looking at the world are implicit in the representations associated with science communication? We believe that this last question deserves priority on the science communication research agenda.

If science communication reveals and reinforces particular cultural orientations, we need to understand which particular perspectives are being privileged. We suspect that when lay epistemologies and orientations implicit in the artifacts used to communicate about science coincide, forms of public engagement with the issues and content will shift. Perhaps more relevant, divergence between these two orientations may be a source of alienation from and disidentification with science. (Note that the term "public" is itself distancing and tends to homogenize the recipients of science communication. In our community-based research we have been impressed with the wide diversity of experience, expertise, and perspectives within our communities.) The National Academy of Sciences has called attention to the looming crisis associated with fewer students seeking to pursue science, technology, engineering, and mathematics (STEM) careers (71, 72) and we conjecture that the distancing component we have described contributes to this lack of engagement.

In the same way, if science education and communication tend to privilege one cultural orientation over others, they may also be at least partially implicated in the very marked underrepresentation of minorities and the lack of diversity in STEM disciplines (4). [One encouraging note is that the illustrations in some more-recent science textbooks use perspective-taking devices (e.g. over-the-shoulder) that invite the reader to be closer to the science.] Part of the science of science communication should include attention to its cultural side.

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