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From Pictures to Numbers: Vision Mapping and Sustainability Collaboration between Native American Community Members and Mainstream Scientists

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The era of sustainability is upon us. Human patterns of production and consumption, and the values that underlie them, have led to environmentally and socially damaging behaviors.[1] A growing acceptance of our earth's limited capacity to support population growth with such patterns of consumption has led to a scientific integration of biological, physical, and social systems, sometimes referred to as *sustainability science*.[2] Research in this field is integrative and interdisciplinary and attempts to understand the complex interaction between human activity and environmental outcomes.[3] One focus in sustainability science has been to incorporate the worldviews of ethnic and cultural minorities "not only . . . for obvious equity reasons, but also to help ensure a sufficiently rich array of problem framings . . . about the

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environment, technology, justice, and sustainability."[4] This has been particularly true with regard to indigenous populations.

In the 1987 United Nations General Assembly's landmark *Report on the World Commission on Environment and Development,* we are reminded that indigenous "communities are the repositories of vast accumulations of traditional knowledge and experience that links humanity with its ancient origins. Their disappearance is a loss for the larger society, which could learn a great deal from their traditional skills in sustainably managing very complex ecological systems."[5] As humans have occupied almost every type of ecological zone (from deserts to the arctic), over time residents accumulated knowledge and evolved strategies for adapting to variability in their natural environments, enough to sustain their needs and wants.[6] Their presence significantly affected local ecologies;[7] however, some cultural responses to environmental demands, such as relational ethics directed toward nature or taboos for environmentally harmful behaviors,[8] were iteratively tuned to environmental trends.[9] Gregory Cajete, Tewa author and pioneer in the field of indigenous science, defined traditional ecological knowledge (TEK) as a body of practical environmental knowledge that is learned and transferred through generations of a people through a form of environmental and cultural education unique to them.[10] Oral traditional history is rich with accounts of how people dealt with adversity, including environmental changes due to climate variability.[11]The Intergovernmental Panel on Climate Change (IPCC) in 2007 recognized the world's indigenous communities as among those at greatest risk from climate change–driven shifts in the physical environment.[12] Environmental change has the compound effect of altering economic and cultural institutions as the availability of natural resources such as fresh water and salmon diminish with population growth.[13] In the United States, the White House Interagency Climate Change Adaptation Task Force includes indigenous communities in their formulation of sustainable solutions, saying that adaption and resilience are challenges that provide "Federal, Tribal, State, and local governments with significant opportunities for innovation."[14] In addition, "because climate impacts span political boundaries, the Federal Government must respond in partnership with communities, Tribes, and states—many of which are already beginning to implement adaptation measures."[15] This shift to include Native American perspectives in local and global development is unprecedented. It provides opportunity for Native researchers, communities, and businesses as never before.

The Problematic Collaboration

The preceding indicates, then, that indigenous traditional knowledge can help with general human adaptation to climate change. However, Native communities need inputs as well from mainstream science, technology, and engineering. For instance, Native households are ten times as likely to be without electricity and Native communities have a disproportionate number of hazardous waste facilities on or near their land to manage.[16] Native communities must collaborate with non-Native governments and organizations if they are to adapt to modern environmental pressures.

However, relations between Native communities and mainstream science have historically been, and remain, problematic. This issue has received considerable attention across several social science disciplines, both to explain underrepresentation of Native Americans/First Nations in science, technology, engineering, and math (STEM) fields, and to consider revisions of scientific paradigms and teaching methods.[17] Two primary reasons, to be discussed below, have been proposed for Native peoples' aversion to science: negative experiences with mainstream technological progress and an incompatibility between Native and scientific cultural values.

A History of Exploitation

Throughout history, groups that developed advanced technologies also gained a competitive advantage over other groups. For instance, advances in agriculture, smelting, and animal domestication provided the necessary conditions for large populations, weaponry, and immunity to disease.[18] As imperial nations grew and expanded, indigenous groups often experienced negative repercussions in the form of displacement, war, disease, discrimination, assimilationist pressures, and the dissolution of many place-based forms of livelihood.[19] Although such past experiences continue to affect Native Americans as a result of America's colonialism—such as historical trauma and impoverished communities—current issues offer new examples of scientific and technological "progress" that are negatively affecting Native communities.[20]

Historian David R. Lewis's survey of twentieth-century issues for Native peoples and the environment recounts multiple land and water disputes between tribes and surrounding cities or organizations. In his review of the effects of mining and pollution, Lewis summarizes:

> In 1990, an estimated 1,200 hazardous waste sites were located on or adjacent to reservations nationally. Cyanide heap-leach gold mining in Montana threatens sacred Sweetgrass Hills and is polluting water on the Fort Belknap Reservation. Coal strip mines surround the Northern Cheyenne Reservation, disrupting the

> ground water. Heavy metals from a nearby tailings pond are showing up in vegetables on the San Xavier Reservation. Acid rain and mercury from coal-fired power plants affects the lakes of northern Minnesota, Wisconsin, and Michigan, sources of the wild rice, fish, and waterfowl which still dominate Anishnaabeg diets. Industrial waste sites surround the St. Regis Indian Reservation and foul the St. Lawrence River. Elevated levels of PCBs are showing up in the breast milk of nursing Mohawk mothers who consume fish or use river water near the General Motors, Alcoa, and Reynolds plants.[21]

A very recent example in a different domain of action was Arizona State University's misuse of blood samples from the Havasupi tribe, which involved unapproved data sharing and analyses by other researchers. As early as 1990, researchers began taking blood samples under the auspices that genetic evidence might help curtail the high rates of diabetes in that community. Instead, samples were used for research on genetic mapping that tested theories contrary to the tribe's interests and beliefs. In 2010 the tribe won a large monetary settlement and the blood samples were retrieved, but awareness of the abuse of research data spread among Native groups and has produced a sense of skepticism to proposed medical interventions or research in general.[22]

Cultural Dissonance

Literature in ecology,[23] geography,[24] history,[25] science education,[26] the sociology of scientific knowledge,[27] and organizational psychology[28] has contrasted the values and worldviews of northern Native American cultures and the mainstream scientific community. These differences purportedly affect environmental behavior and participation in science, and as such serve to guide pro-environmental behavior as well as inform science curricula in general and for Native Americans in particular. Authors who draw distinctions between indigenous cultures and scientific culture (sometimes referred to as Western science, Euro-science, mainstream science, or colonial science) caution against reifying categorical relationships such as "indigenous peoples versus science," as neither group is homogenous and a substantial amount of middle ground exists between the two.[29] Native cultures contain scientific information and methods,[30] Native American scientists are a growing demographic,[31] and the vast scope of science includes theoretical frameworks that employ holistic perspectives similar to Native cultures (for example, developmental, systems, ecological, and environmental sciences).

Nevertheless, the proposition that Native American values and worldviews differ from those in the science community is an important heuristic to consider for intercultural collaboration for sustainability. It cannot be assumed that Native and scientific communities share a similar vision of sustainability, in terms of priorities or process. For example, in a 2007 article by Glen S. Aikenhead and Masakata Ogawa, indigenous ways of living with nature were compared with mainstream science and were found to diverge from one another in several ways.[32] Mainstream science embodied philosophical assumptions such as positivism, reductionism, dualism, anthropocentrism, and universalism in linear time, while Native cultures tended toward relationalism, holism, place-based and intergenerational knowledge, and circular time.[33] Barnhardt and Kawagley reached a similar pattern of conclusions, though they are also careful to point out some of the shared characteristics of mainstream science and traditional knowledge (for example, knowledge development based on observation).[34]

In addition to the effect on epistemic and ontological beliefs, cultural values also influence the way beliefs are communicated. Cajete argues that Native cultural values (such as collectivism, holism, pragmatism, and present time-orientation) influence social-behavioral norms (such as silence), learning styles (such as non-competitiveness), and work habits that hinder positive relationships between teachers and Native students, especially in science.[35] Conversely, Native students have been shown to do well in science classes when an indigenous cultural framework is employed;[36] further, they benefit from having tribal elder support during a nurse-scientist training program, and maintaining tribal connections and spirituality while completing medical school.[37]

Overall, the literature seems to suggest that communication between Native Americans and scientists about sustainability may be affected by differences in cultural values and beliefs about the environment and science. To incorporate indigenous voices in sustainability science, a method of collaboration that can accommodate those differences is necessary, as well as others such as language and education. This is especially true when we consider that traditional ecological knowledge is often transmitted through symbols and stories rather than as rote facts.[38]

The report on a 2008 workshop supported by the National Science Foundation titled "Science, Technology, and Sustainability (STS): Building a Research Agenda" recognized this and concluded that a "central area of . . . STS research [is] inquiries into the human and social practices . . . that provide foundations for particular ways of knowing and valuing aspects of society and the environment that are critical to sustainability problems and solutions."[39] The same report concludes that "Similarly profitable would be STS research that contributed to the fashioning of new conceptual models for understanding and analyzing knowledge and valuation systems and their implications for individual and community decision-making."[40] Our project, as reported below, addresses those two goals.

Collaborative Sustainability Planning and Action

The National Research Council's Panel on Social and Behavioral Science Research Priorities for Environmental Decision Making concluded that there is a major need for research on how to bridge the "multiple, conflicting, and uncertain values" that frequently hinder effective collaborative environmental decision making, planning, and stewardship.[41] Keith James, Margaret Hiza Redsteer, David Hall, and Robert Doppelt document how such conflicts of values, as well as identity and goals, specifically affect environmental, economic, and social sustainability in North American indigenous communities.[42] Techniques that allow for effectively bridging such conflicts have, on the other hand, been shown to promote both direct sustainability action and educational success in mainstream science among indigenous peoples.[43] Here, we document a "vision mapping" technique we designed to promote collaborative action and research between Native community members and mainstream scientists.

Verbal interaction and planning tends to encourage non-indigenous people and scientists to dominate the collaboration.[44] Therefore, it is important to facilitate other less verbally oriented approaches to group participation. The technique employed involved the development of collaborative visual depictions of the path to community sustainability, that is, "vision maps." Vision maps contained end goals and steps to sustainable living. The advantage of visually based collaborative planning is that it seems to help span the wide range of education levels, values, and communication experiences and preferences that occur when non-indigenous scientists from a variety of disciplinary backgrounds engage with indigenous community members.[45] Additionally, traditional knowledge often can be only partially held verbally in indigenous peoples' minds.[46] What follows is a review of how we developed and analyzed these vision maps to quantify important dimensions and what conclusions we can draw from them. It is hoped that this paper will serve as a model for future focus-group discussions of this kind, where sensitivity to a diverse range of mental representations is required.

Method

Participants

Two indigenous sustainability workshops were hosted in 2008 that brought Native leaders and community members together with scientists from academic institutions, US state and federal governments, and private and nonprofit organizations. Workshop attendees were recruited via emails and personal solicitations sent to environmentally focused government agencies, regional colleges and universities, and Native community governments, corporations, and organizations. Reimbursements for travel and lodging expenses were offered to those who had to come long distances to attend a workshop (such as to Alaska) and would not receive reimbursement from their home organization.

The first workshop took place in May 2008 in Portland, Oregon, with the majority of Native participants being urban-resident First Nations and Native American individuals, but with some attendees from US and Canadian (British Columbian) reservations. The second workshop took place in October 2008 in Fairbanks, Alaska, with Native attendees primarily representing one of four Alaska Native corporations with lands in the Copper River Basin (Athna, Chugach, Doyan, and Sea-Alaska [Tlingit]). Native participants ranged from those with little formal education to doctoral-level Native scientists. Non-Native scientists ranged from those with recent interest in Native community or sustainability issues to long-time environmental or Native community advocates. Vision mapping did not include the collection of demographic information so workshop composition cannot be examined empirically. However, a higher percentage of non-Native academics and scientists compared to Native American academics and community members attended Workshop 1 in Portland.

Procedure

The focal question for workshop participants was "How can mainstream science and Native communities work together to promote healthy sustainable Native communities?" Workshop attendees formed small, mixed scientist and community-member breakout groups of three to ten members. Breakout groups were asked to create vision maps using drawings on large sheets of paper, words and drawings on Post-it notes, and any other materials that they wanted to add. For example, one group taped coins to their map to indicate the key roles of funding at certain points in their model of developing a sustainable community. This was done in order to create a visual representation of a group's shared vision for indigenous community sustainability that included perspectives from both the Native and the scientific community. Each group later presented its map to the full membership of the workshop.

Workshops lasted two days and opened with prayers from local elders. The first morning was devoted to defining community sustainability and presenting information on the environmental and social challenges that are affecting Native communities which demand novel plans and strategies if those communities are to sustain themselves. Following those presentations, attendees broke into small (breakout) groups composed of scientists and Native community members. Group participants introduced themselves to each other and spoke of their personal histories and experience. Post-it notes and multicolored markers/pens were provided and participants were encouraged to use them for visual or written representations of any key elements or processes for community sustainability that occurred to them during the background presentations. Discussions, brainstorming sessions, and initial vision-map construction followed in the afternoon of the first day. On day two, breakout groups reconvened to finalize their vision maps and later presented their visions to the other groups. Vision maps were collected at the end of each workshop by the research team.

Workshop 1 (Portland) produced thirteen vision maps (one per group) and Workshop 2 (Alaska) produced twelve. Seven doctoral students were recruited to analyze the vision maps in teams consisting of one lead researcher and six raters, three male and four female. One research team member (male) was Native American. Each had taken at least two doctoral research classes and was briefed about the project's background.

Analysis: Stages One and Two—Descriptive Documentation and Thematic Sorting

To get an idea of the prevalent dimensions (themes) used in the vision maps, every word or phrase and distinct image from each vision map was separately written on an index card. Index cards containing the words, phrases, or image descriptors were then organized into groups according to emergent themes by the lead graduate researcher. For example, if index cards described pictures, words, or phrases such as "hospitals," "health," or "eating healthy traditional foods, less junk foods," these index card items provided justification of a health theme. Similarly, index cards describing pictures, words, or phrases such as "diplomas," "education," or "education opportunity for Native students to learn how to do research" justified an education theme.

Analysis: Stage Three—Frequency and Strength of Themes

Themes that emerge in stage two provide a means for comparing vision maps across and within posters. Because each group worked independently, themes of sustainability appearing consistently across vision maps would seem of particular importance. Additionally, the extent to which a theme was emphasized *within* a vision map is also an indication of a theme's importance. Thus, frequency (across maps) and strength (within maps) of themes was used to assess the importance, or priority, of each theme to Native sustainability.

Three raters evaluated each workshop's vision maps. Raters were instructed to pay attention to features that indicated emphasis to determine theme strength. Features beyond general impression included the frequency of theme-related pictures, words, and phrases; a theme's position if the map was drawn hierarchically; connections drawn to other themes with arrows or lines; and bolded or highlighted writing. The strength of inclusion of a theme in each map was rated on a 7-point Likert-type scale from 0–6, with 0 representing "totally absent," 3 representing moderate presence, and 6 representing "strongly present."

Ratings were subjected to a test of internal consistency known as Cronbach's Alpha.[47] Cronbach's Alpha looks at how well multiple raters answer consistently, as we would expect they would if they were all observing the same thing in the same way. To distinguish those vision maps that did not have clear depictions of a theme from clearer vision maps in which agreement on a theme was high, we also employed an item-level agreement index appropriate for Likert-type scale data that is based on the average deviation: rWG significance tests.[48] Themes that did not result in sufficient agreement were dropped from further analyses.

Frequency was defined as the number of vision maps in which a theme was present at all (that is, received a mean rating above 0, or "totally absent"). Frequency served as a measure of importance across breakout groups. Strength of a theme's presence was calculated by its average rating of emphasis on the 7-point scale. Average strength of a theme's presence served as a measure of a theme's emphasis when it was present within workshops.

Analysis: Stage Four—The Co-occurrence of Dimensions

Using a co-occurrence matrix, we can evaluate workshop attendees' cognitive schemas. A co-occurrence matrix is simply a table of cells showing the occurrence of pairs of themes, or when two themes show up on the same map. The number and types of pairs that co-occur across vision maps reveal the way themes are thought of in relation to other themes.

Results

Results: Stages One and Two

Descriptive documentation and thematic sorting for Workshop 1 (Portland) produced sixteen themes: (1) protection of natural resources; (2) recognition and protection of culture; (3) preservation of traditional skills; (4) collaboration between communities; (5) education; (6) health and well-being; (7) addressing community problems with community input; (8) the dangers of technology; (9) the benefits of technology; (10) scientific method contribution (objectivity and quantification); (11) scientific systematization of knowledge;

(12) scientific problem identification; (13) scientific solutions; (14) scientific process; (15) scientific implementation of planning results; and (16) funding.

Workshop 2 (Alaska) yielded twelve themes that were all identified by at least one group as potential areas for fruitful Native-science collaboration: (1) protection of natural resources; (2) recognition and protection of culture; (3) preservation of traditional skills; (4) collaboration between communities; (5) education; (6) health and well-being; (7) inclusion of elders; (8) collaboration within communities; (9) family cohesion; (10) community leadership; (11) community planning; and (12) inter-organizational collaboration.

Results: Stage Three

With internal consistency (Cronbach's Alpha) reaching α=.73 for Workshop 1 (Portland) and α=.84 for Workshop 2 (Alaska), which combine for α=.78, our measure of internal consistency met the conventional acceptable level of .70 or higher.[49] However, these agreement levels included vision maps with varying thematic clarity. We therefore used an rWG index to identify and remove instances where raters could not decipher a theme's presence on a vision map. Inability to decipher a theme was defined as an inability to reach agreement after accounting for random chance. Using this standard of exclusion, Cronbach's Alpha yielded substantially higher internal consistency for both Workshop 1 (Alaska), α=.95, and Workshop 2 (Portland), α=.93 (combined α=.94).

A theme's importance across groups did not follow the same trend as its strength of emphasis at either workshop (see table 1). A theme may have been mentioned independently across many vision maps (frequency); however, its emphasis within posters may have been quite small (mean rating of presence/emphasis strength).

For Workshop 1 (Portland), thirteen vision maps produced sixteen themes. In figure 1 themes appear in order of strength of emphasis from left to right.

Table 1: Stage 3 Results

Workshop 1 - Portland, OR	Frequency	%	Strength	SD
Scientific systematization of knowledge	9	69%	5.56	0.47
Funding	5	38%	5.53	0.3
Benefits of technology	6	46%	5.28	0.49
Between-community collaboration	10	77%	5.23	0.74
Scientific initiatives	8	62%	5.17	0.67
Scientific solutions	9	69%	4.96	0.61
Education	10	77%	4.77	0.98
Community needs w/input	12	92%	4.58	1.47
Health & well-being	10	77%	4.43	1.88
Scientific method contribution	8	62%	4.29	2.19
Scientific process	8	62%	4	1.98
Traditional skills preservation	9	69%	3.9989	2.37
Natural resource protection	8	62%	3.54	2.07
Cultural recognition & protection	9	69%	3.3	1.75
Dangers of technology	8	62%	2.33	2.6
Science problem identification	4	31%	2	1.39
Workshop 2 - Fairbanks, AK	**Frequency**	**%**	**Strength**	**SD**
Natural resource protection	8	67%	5.63	0.28
Cultural recognition & protection	10	83%	5.4	0.72
Within-community collaboration	9	75%	4.74	1.38
Traditional skills preservation	11	92%	4.58	2.16
Elders	8	67%	4.54	2.6
Organizational collaboration	8	67%	4.46	1.79
Community planning	9	75%	4	1.63
Education	8	67%	3.71	2.06
Community leadership	6	50%	3.5	1.95
Family cohesion	6	50%	3.11	2.21
Between-community collaboration	9	75%	2.89	1.88
Health & well-being	8	67%	2.46	2.35

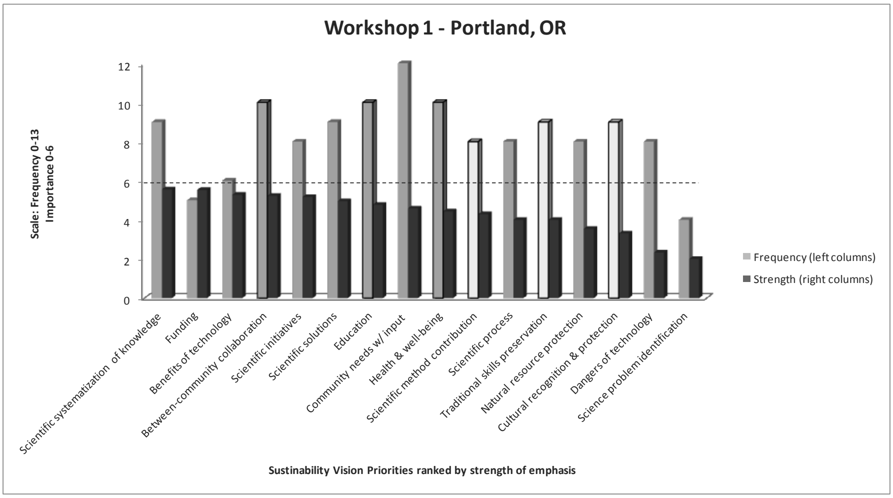

Figure 1. *Stage 3 Results: Workshop 1 – Portland, OR*

In Workshop 2 (Alaska) there were twelve vision maps with twelve themes for science-related sustainable Native community development priorities. In figure 2 the themes appear in order of strength of emphasis from left to right.

Six sustainability themes emerged in both workshops. In order of their strength across workshops, they are: 1) protect natural resources (total mean (M) = 4.59, total frequency (F) = 16); 2) recognize and protect culture (M = 4.35; F = 19); 3) preserve traditional skills (M = 4.29; F = 20); 4) promote education (M = 4.24; F = 18); 5) collaborate between-communities (M = 4.06; F = 19); and 6) improve community health and well-being (M = 3.45; F = 18). Protect natural resources, recognize and protect culture, and preserve traditional skills all rank higher than education, between-community collaboration, and health and well-being in the Alaska workshop, while the trend is reversed in the Oregon workshop (see outlined and shaded frequency bars on figs. 1 and 2).

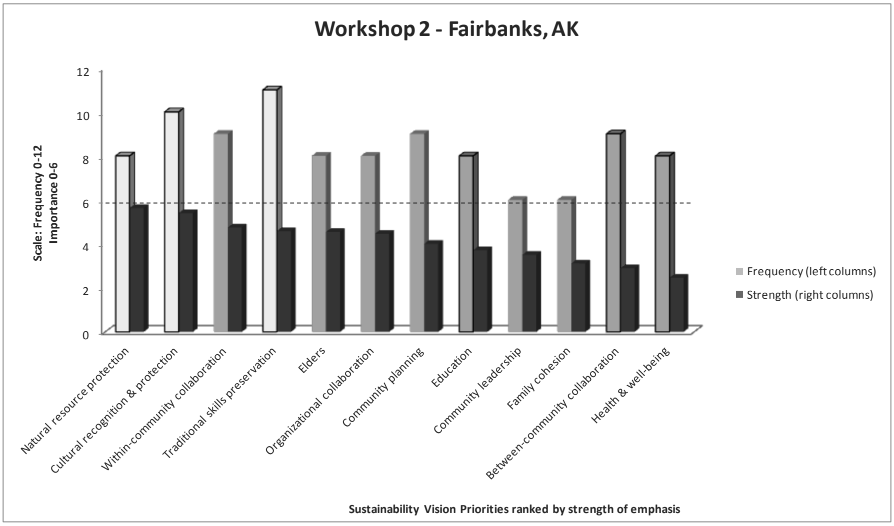

Figure 2. *Stage 3 Results: Workshop 2 – Fairbanks, AK*

Results: Stage Four

Counts of co-occurrence represent instances where two themes appeared on the same vision map. Higher numbers represent a larger number of vision maps that contained two themes at the same time. Co-occurrence matrices revealed differences between central community-sustainability themes at Workshop 1 (Portland) and Workshop 2 (Alaska). Complete matrices are reported in figures 3 and 4. Themes that co-occurred on at least half of a workshop's vision maps are below along with their rate of co-occurrence (*c* = co-occurrence, or the number of vision maps where both themes were present):

Workshop 1

Education and:	Between-community collaboration	*c* = 9
	Addressing community needs	*c* = 9
	Scientific systemization of knowledge	*c* = 8
	Science initiatives	*c* = 7
	Science solutions	*c* = 7
Addressing community needs and:	Between-community collaboration	*c* = 8
	Science initiatives	*c* = 8
	Scientific systemization of knowledge	*c* = 8
	Science solutions	*c* = 7
	Science method contribution	*c* = 6
Scientific systemization of knowledge and:	Science initiatives	*c* = 8
	Between-community collaboration	*c* = 7
	Science solutions	*c* = 7
	Preservation of traditional skills	*c* = 6
Scientific solutions and:	Science initiatives	*c* = 7
	Between-community collaboration	*c* = 6

	Traditional Skills	Collabora-tion	Natural Resource protection	Recognize & protect culture	Sci initiative	Sci Solutions	Sci Knowledge	Sci Process	Sci method	Sci Identification	Health	Funding	Ed	Tech Danger	Tech Benefit	Comm needs
Community needs	5	8	4	5	8	7	8	5	6	1	5	4	9	3	5	-
Technology Benefits	2	5	1	2	4	3	5	2	2		3	5	5	2	-	
Technology Danger	2	1	2	3	2	1	2	2			2	1	3	-		
Education	5	9	3	4	7	7	8	4	4	1	5	4	-			
Funding	1	4	1	1	4	3	5	2	2		3	-				
Health	4	5	3	3	4	4	5	3	2		-					
Sci identification	1	1			1	1	1	1	1	-						
Sci method	3	5	1	1	3	5	4	4	-							
Sci Process	4	4	3	3	5	5	5	-								
Sci Knowledge	6	7	4	4	8	7	-									
Sci Solutions	4	6	4	3	7	-										
Sci initiatives	5	5	5	4	-											
Recognize & protect culture	3	3	4	-												
Natural Resource protection	4	2	-													
Collaboration	4	-														
Traditional skills	-															

Figure 3. *Co-occurrence Matrix (Portland)*

	Natural Resource Protection	Elders	Recognize & Protect Culture	Traditional Skills	Within-Community Collaboration	Between Community Collaboration	Family Cohesion	Leadership	Community Planning	Education	Health	Organizational Involvement
Organizational Involvement	3	3	5	4	4	2	2	3	5	4	3	_
Health	3	3	3	3	3	2	2	3	3	1	_	
Education	3	3	4	3	4	3	1	2	3	_		
Community Planning	2	4	5	5	3	2	3	3	_			
Leadership	3	3	3	3	3	2	2	_				
Family Cohesion	3	4	3	3	2	1	_					
Between-Community Collaboration	3	3	3	3	3	_						
Within-Community Collaboration	6	5	8	7	_							
Traditional Skills	7	6	9	_								
Recognize & Protect Culture	8	6	_									
Elder inclusion	6	_										
Natural Resource Protection	_											

Figure 4. *Co-occurrence Matrix (Portland)*

Workshop 2

Recognition and protection of culture and:	Preservation of traditional skills	$c = 9$
	Protection of natural resources	$c = 8$
	Within-community collaboration	$c = 8$
	Inclusion of Elders	$c = 6$
Preservation of traditional skills and:	Within-community collaboration	$c = 7$
	Protection of natural resources	$c = 7$
	Inclusion of Elders	$c = 6$
Preservation of natural resources and:	Within-community collaboration	$c = 6$
	Inclusion of Elders	$c = 6$

Discussion

A major purpose of this paper is to document a technique that can assist collaboration between Native (indigenous) community members and mainstream scientists. That the mixed (Native and scientist) teams in both of our workshops were able to produce joint vision maps for community sustainability is, in itself, something of a demonstration of the potential of the technique. Verbal and written feedback from the participants also indicated that they found the vision mapping technique useful for assisting mutual understanding and collaborative planning. The comments also indicated that the participants generally found the technique compelling both for helping them to bring their own views of community sustainability to the surface, and for giving them insight into how those views needed to be elaborated, bridged to the perspectives of others, and integrated with existing circumstances for a practical sustainability plan to result.

The vision mapping technique would seem, therefore, to be potentially useful not only for other North American indigenous communities, but also for assisting indigenous communities around the world to engage in effective sustainability planning with mainstream scientists. In follow-up work, we are using the technique with indigenous groups in Canada, and have been developing the connections to extend exploration of its value to indigenous communities in Australia and New Zealand. The technique could be of potential value to non-indigenous participants from different backgrounds as well, whether professional or economic, who need to work together to develop sustainability plans and actions. We anticipate also examining those types of collaborations. In addition, the vision map technique could also be used for collaborative planning on topics other than sustainability—for instance, organizational innovation or community interventions on pressing physical health problems. We encourage others working in such areas to consider the potential utility of the vision mapping technique for them.

Much of the data analysis in this paper describes the process we used to untangle the messages locked in the largely pictorial vision maps—the scientific knowledge-development portion of this work. Of course, that aspect of this paper is preliminary, given that we had limited numbers of teams in a limited range of communities and that the coding schemes we developed emerged during our first application of the vision map technique. In follow-up studies, we are already examining, or anticipate investigating, precursors of the vision maps such as cultural values, as well as outcomes of particular visions such as participant-rated political versus educational priorities for sustainability or follow-up action. We are also working on elaborations of the approach to coding information from the vision maps (for example, direct coding of spatial relationships among map elements). Nonetheless, the steps that we used in this preliminary study are outlined in detail so that others wanting to employ or elaborate on the method will have a base from which to start.

Findings and Implications

Beyond facilitating collaboration, vision maps give us snapshots of tribal and science communities' perceptual lens for community sustainability. Our analyses reveal 1) directions for future science-related sustainability action and research with indigenous groups; and 2) insight into the differences between urban-science and rural-traditional value orientations.

Through vision mapping, Native and non-Native scientists and Native community members and leaders identified ways science and Native communities could work together for sustainable Native community development. The six priorities that appear the most (those that emerged in both workshops) are natural resource protection, recognition and protection of indigenous culture, preservation of traditional skills, education for community members, between-community collaboration, and community health and well-being. These priorities, together with the others, inform areas for potential tribal and government agency collaborations on sustainable development and research on traditional ecological knowledge. Priorities represent both valued outcomes in the interest of sustainability as well as steps to achieving those outcomes.

Analyses of the vision maps also reveal characteristics about each workshop through which we can infer perspective and emphasis. As early as stage two of our analyses, important similarities and differences emerged between the workshops' emphases. In the Oregon workshop, addressing community needs with community input, community health and well-being, education, and between-community collaboration emerged most often. The emphasis in that workshop, however, was on the potential for science to create knowledge, funding, the benefits of technology, between-community collaboration, and scientific initiatives. In the Alaska workshop, preservation of traditional skills, cultural recognition and protection, between-community collaboration, community planning, and within-community collaboration themes showed up most often. However, the emphasis was placed on natural resource protection and cultural recognition and protection. This is likely influenced by the fact that the Alaska workshop had predominantly local (Alaska) Native attendance, while the Oregon workshop had a higher percentage of academics and scientists, both Native and non-Native. Additionally, the location of the Alaska workshop attracted attendees from more rural, traditional, subsistence-based locations, while the Oregon workshop was centered at a metropolitan university.

As outlined above, six themes emerged in both workshops. By stage three, these six overlapping themes also revealed the perspectives of each workshop through their priority rankings, which indicated preference of certain goals over others depending on the workshops' traditional/rural or science/urban orientation. Whether priorities were ranked by frequency (percentage) or by strength of emphasis, the Oregon workshop prioritized education, health and well-being, and between-community collaboration *over* traditional skills preservation, recognition and protection of culture, and natural resource protection. In the Alaska workshop, the trend was reversed (see outlined bars in figs. 1 and 2). This is important as neither workshop group can be said to be "Native" or "non-Native": in both settings, workshops were collaborative efforts between Native community members and Native and non-Native scientists. Differences between groups reflect sustainable Native community needs for science-related action at different points in the Native community continuum.

The co-occurrence matrices remind us that these workshops' participants not only differed in the number and type of ideas they produced, but that their organization of ideas differed. When participants were asked how they could work together to attain Native community sustainability, themes emerged together consistently across independent groups at each workshop. The Oregon workshop produced a vision for sustainability centered on addressing community needs, collaboration, education, and the use of science to derive knowledge and initiate solutions. The Alaska vision for sustainability primarily consisted of the recognition and protection of culture, preservation of traditional skills, protection of natural resources, within-community collaboration, and the inclusion of elders.

These findings aid understanding of Native community sustainability needs in different segments of the Native community. In this way, this study echoes reminders from other authors that the Native community is not a homogenous group, but rather a diverse collection of nations and people.[50] Our study demonstrated that diversity also applies to sustainable priorities, and supports ecological literature that argues sustainability initiatives are best implemented locally.[51]

Differences between workshops showed how priorities depend on locality and lifestyle (rural or urban); however, they also revealed how orientations (traditional or scientific) affect cognitive framings of solutions. The first workshop paired addressing community needs with education, collaboration, and scientific discovery. The second workshop envisioned sustainability in which protection of the culture and the environment included involvement from the community. This suggests that whether or not collaborating groups are both Native, differences in lifestyle produce orientations that result in different problem framings for society and the environment. Regardless of the science orientation at Workshop 1, the presence and prioritization of similar themes at both workshops reiterates the importance of some priorities to all Natives. This finding advances knowledge of the type requested in national research reports for sustainable development.[52]

The technique and findings of this study are important to collaborations for sustainability, both between tribes and for Native and non-Native government, academic, private, and nonprofit organizations that work with indigenous communities. The vision map technique was demonstrated by (1) identifying specific areas for science-related sustainable Native community research and action, and (2) quantifying differences and similarities between diverse groups. Priorities can serve to inform researchers, businesses, and policy makers on research questions, marketing, and environmental policy related to Native issues. Native youth pursuing higher education in science might view these priorities as potential areas to apply their education for the benefit of their communities.

Limitations

While this project made some notable contributions, its conclusions should be interpreted within the limits of its scope and reliability. Although we took extra steps to ensure our confidence that our results were reliable, the data only represent two workshops, held in two communities, within the same twelve-month period. The sample should not be considered representative of all Native American, Alaska Native, First Nations, Hawaiian Native, or indigenous populations. Future research should continue to employ the vision map technique and observe thematic trends (or lack thereof) across time and locality. Another possibility would be to present vision map results back to the workshop attendees to see if they agree with the conclusions we came to.

A second limitation is that these groups represented individuals who responded to an invitation to participate in indigenous community sustainability workshops. As part of the workshop, participants also listened to presentations about how science can help Native communities manage new environmental challenges and how traditional ecological knowledge is a growing necessity in eco-management. It is possible that self-selection or presentation cues influenced the perspectives of workshop participants. More representative samples should be recruited in future studies.

A third and critical limitation is that breakout groups did not write their names, education, ethnic group, or any other demographic information on the vision maps, nor were they instructed to. When I joined the research team, only the recollections of team members informed the general description of those who attended. The conclusions we could draw from this data would be enhanced by quantifiable descriptors of what data pertained to which participants. Comparisons inclusive of such demographics are planned for future workshops.

Next Steps

It is the case that tribal communities must interact with outside agencies to secure their own interests. Depending on the national political climate and ethic of the era, Native communities were strategic in keeping themselves secluded as much as possible, and for some this may still be the best option. For most, however, it is necessary to become acquainted with the methods and values of societal institutions of change (for example, science).

For those who are able, the opportunity to acquire training in scientific study and begin to utilize its benefits is presenting itself as never before, together with the opportunity to change scientific study itself. Colonial ideologies of conquest and onward movement, and the technological advances that unfortunately enabled those ideologies to continue, are running their course. And now that manifest destiny has reached geographical limits, nations built on the extracted goods of subjugated territories must consider the limits to unhindered consumption, Mother Nature's equilibriums, and equitable collaboration. An advantage of this time of societal reflection is that the space is being created within the institution of science for historically marginalized groups to offer their unique insights. As our review of the literature on TEK has shown, the holistic, cyclic worldview, environmental values, and practical ecological knowledge of indigenous cultures are well positioned to contribute to the formation of an integrative, sustainably minded science.[53]

For indigenous community members who still have traditional ecological knowledge, whether in language, traditional skills, or stories and ceremonial practice, their position is even stronger should they be able to preserve it. For those indigenous groups who have lost much of their ecological knowledge through forced or voluntary assimilation, the intangible elements of their critically conscious perspective still provides a reflective process that helps to expand the limits of mainstream thought. If properly negotiated, another round of redefining indigenous identity is at hand, one where indigenous people define themselves and the environment in which we exist. Through social science studies such as this, Native scholars could continue to inform the way people think about and value the environment and uncover how those cognitive/emotional sentiments lead to individual and community decision-making for or against environmentally supportive action.[54]

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