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Essential elements for participatory modelling: Using deliberative engagement and gesture-enabled interfaces to implement energy-mineral-water solutions in the Atacama Desert, Chile

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Abstract: Sound science and adequate models of systems are necessary for environmental decisions, yet frequently it is insufficient. The ENCOMPASS and ECOGES projects aim to create science-based deliberation among diverse stakeholders about water-energy-mineral use and choices in the Atacama Desert region of Chile. The projects seek to improve levels of understanding and open possibilities for collaborative problem solving by engaging industry, academics, and indigenous communities in a long-term participatory modeling process.

Since 2009 the initiative has brought people into collaborative discussions, building technical knowledge and bridging across sectors that are often at odds over management of earth resources. Today, participants are co-designing a renewable energy plant with the goal of establishing operation by the indigenous community as a sustainable business. The proposed plant serves as a focal topic for participatory modeling and a sustained dialogue process for the multi-sector stakeholder group.

While active deliberation is underway, the project began in the shadow of marked conflict and tensions among participants. Methodologically, tensions have been reduced by combining social process with information delivery that leverages interactive touch screen applications. Models and information act as boundary objects among participants and the tenets of a conflict resolution process called sustained dialogue provide guidance for facilitating the group sessions.

Early results indicate that the gesture-enabled touch screens are useful for establishing an accessible environment for deliberation because subject matter experts and laypeople can interact with information with equal ease. Social process has been critical for bridging scales, managing group expectations and relationships, and addressing differences in epistemological and cultural perspectives.

Keywords: Participatory modelling; decision support, socio-technical systems, science-based dialogue, energy-water-mining.

1. BACKGROUND

Policies that guide management of energy and earth resources are enmeshed in complex, dynamic conditions that involve understanding from across multiple disciplines or practices. Most often the knowledge that scientists and engineers have developed through years of research, is not communicated to the communities and policymakers who need it. People involved in making decisions about natural resource management problems need information to help them understand possible implications of the possible choices. Simultaneously, a social process that enables the stakeholder groups who are affected by decisions about the use and management of resources to address tensions and differences are needed to improve the outcomes and avoid conflict once a decision has been implemented. Sustainability Science is use-inspired and oriented toward decision-making of all kinds (Matson, 2009; Miller, 2013) with the goal of informing choices about resource management. Balancing the choices requires searching for and finally building consensus about both the scientifically observed behaviors of systems and value judgments that frame the preferences of affected stakeholders. Deep sustainability science can serve to inform meta-governance and support management of transitions from one equilibrium state to another. One aspect of this is bringing together actors to strengthen their knowledge and capacity such that they can compete with dominant actors and practices (Loorbach and Rotmans, 2009). To do this sustainability scientists argue that science and technology must drastically increase contributions to sustainability (Cash et al, 2003).

This study documents the outcome of a co-design effort that was convened initially to explore the potential role that cyberinfrastructure and technology may have in supporting multi-stakeholder deliberation about sustainability transitions for a region. The research combines both a knowledge- and process-oriented approach (Miller, 2013) to convene a series of group dialogues (discourse) and create a cyberinfrastructure prototype to aid and facilitate interactions across the boundary zone between science and society as shown in Figure 1.

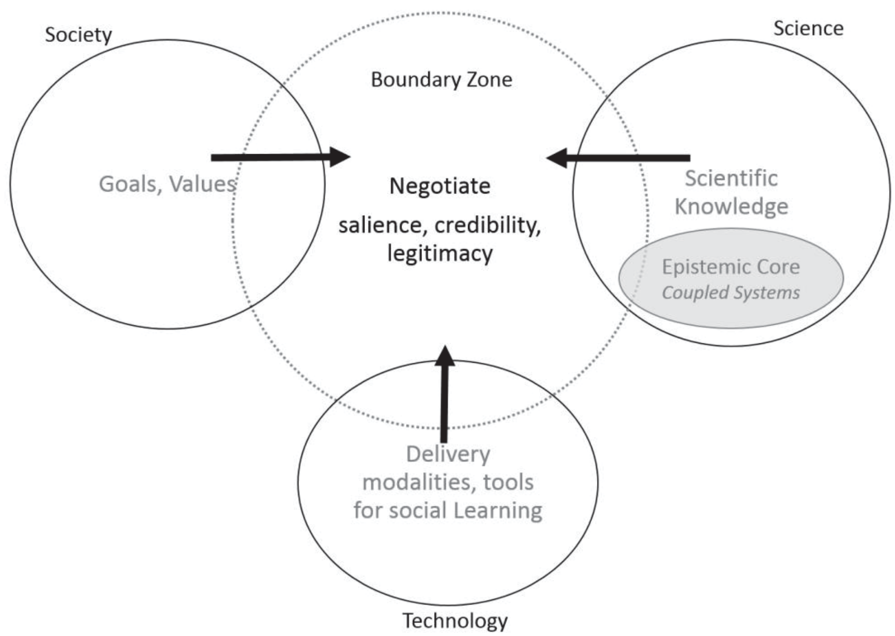

Figure 1. Knowledge-first relationship between science and society (modified from Miller, 2013).

1.1. Water-Energy-Mineral Use Case Study

This study reports inquiry into the role of technology in supporting science-based discourse for a case where conflict of the sustainable use of energy, water, and mineral resources (energy-water-mineral) are at issue. The project is located in the Atacama Desert of Chile, namely the II Region (highlighted in Figure 2), and combines data collection with interactive delivery of scientific information via a cyberinfrastructure and multi-touchscreen for participatory modeling. Engagement with key stakeholder groups from the original communities (indigenous groups) and industrial mining sector began in 2009 after an unexpected incident at a geothermal energy exploration project triggered public protests by the indigenous leaders against further environmental impacts from energy-water demands of mining (see timeline shown in Figure 2).

The field site, El Tatio, is the largest geyser field in the southern hemisphere and researchers from the The University of Texas at Austin and Universidad de Chile, primarily hydrogeologists and geomicrobiologists, have been conducting studies there since early 2002. In October 2009, an exploratory testing of an old geothermal well caused a blowout at the El Tatio geothermal complex, producing a paradigm-shifting event for the management of the site and drawing attention to the disparity and critical nature of scientific information sharing. A multidisciplinary team formed to share important antecedent data for the site and create potential mechanisms to streamline continued information sharing for the future. The initial efforts in 2009 used a knowledge-centered approach (Miller, 2013) to assess the state of coupled human-natural systems. Researchers evaluated data for both physical and social system response using antecedent data and sampling for the natural systems (Malin et al, 2011) and eliciting perceptions from stakeholder groups (Pierce et al., 2012).

While the physical system recovered relatively quickly from that well blowout incident, the human social system remained in a transition state providing an opportunity to explore perceptions and the role of information technology within the boundary zone (Figure 1). Stakeholder interviews (Pierce et al, 2012) demonstrated that a primary concern related to the perception among indigenous communities that scientific knowledge is used as a “weapon” in energy-water disputes in the Region. The indigenous stakeholders, or Allyus, hold deeply seated commitment to a sustainable future for their Region while taking an adversarial relation to mining and energy sectors. Water is a critical resource at the center of conflict due to general scarcity and the interdependencies with mineral and energy demands in the region.

After the initial energy exploration incident triggered peaceful protests by the community leaders and led to a moratorium on geothermal energy development by the Chilean Senate, the research approach transitioned to a process-oriented approach to identify trajectories for action and support social learning within the indigenous stakeholder group. The methods and events occurring within the process-centered period of the research (see Figure 2) are presented in the following sections.

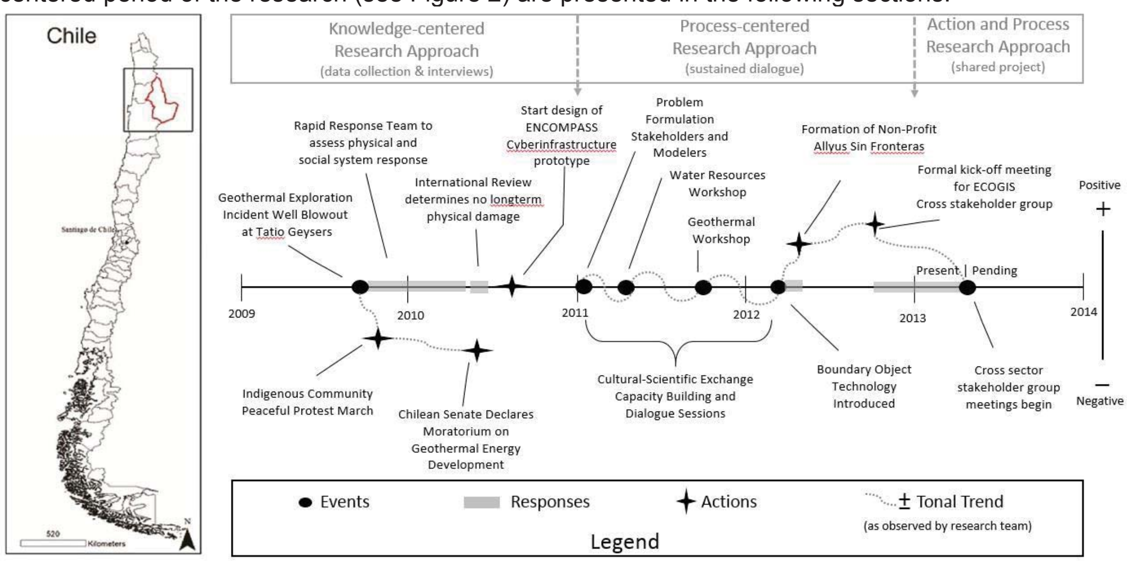

Figure 2. Case study location in the II Region of the Atacama Desert, Chile and timeline depicting important events in development of the ENCOMPASS and ECOGES projects.

2. SOCIO-TECHNICAL AND PARTICPATORY APPROACH

This research seeks to implement systems that can deliver knowledge, act as a repository, and deliver content using modalities that inspire pluralistic and substantive deliberation among groups. One goal was to provide a process that constructs a common foundation with science-based information for social action. In other words, a socio-technical environment where the descriptive data, models, and knowledge are housed, while simultaneously surfacing the disparate and shared constructs of participants with a sustained dialogue process. A key question is whether socio-technical artefacts, such as cyberinfrastructure and gesture-enabled interfaces, can support social learning and trigger transformative action.

2.1. ENCOMPASS: Cyberinfrastructure Design and Gesture-enabled Delivery

The term cyberinfrastructure (CI) refers to technological systems that enable large-scale research. CI may be comprised of numerous components including hardware, software, algorithms, computing systems, data storage systems, advanced instruments, data repositories, and visualization environments to enable large-scale research (Atkins et al, 2003). The ENCOMPASS cyberinfrastructure was designed as a prototype architecture to provide a systems view of energy, water, and mineral resource issues.

Research builds from existing data to establish the schema for dynamic data collection, real-time modeling of energy-water-mineral systems and design for citizen science engagement. The prototype CI was designed using open source platforms and populated using information for two field sites in northern Chile, the El Tatio geothermal site and Ascotan playa lake basin. Figure 3 shows a conceptual diagram of the functional elements of the ENCOMPASS CI prototype. The system includes workflows for data collection, asset storage, multi-user access, post collection analysis tools, and gesture-enabled delivery.

ENCOMPASS is designed for accessibility and, where possible uses open source or freely accessible software applications. Data collection was evaluated using handheld technologies to design electronic field notebooks with the capacity to serve multidisciplinary studies and provide a front-end data collection protocol for the larger cyberinfrastructure project. Field testing demonstrated collection of in situ datasets and enabled integrated collection of both geoscientific and social science data. These data are uploaded to the cyberinfrastructure for use by research teams for analysis or sharing for educational purposes. Storage and multi-user access to the ENCOMPASS CI is managed by an open source Liferay portal that is connected to a MySQL database and provides a flexible, secure, enterprise scale platform for the prototype CI. Additionally, the CI creates a mechanism to communicate results through analysis of data and model ouputs via post-processing and analysis tools. For this project common GIS applications were used to generate educations maps and a gesture-enabled application for group interaction was designed and implemented. This gesture-enabled tool, called Heatseeker (Malin et al, 2012), became a pivotal technology element in stakeholder interactions, as discussed in the following sections.

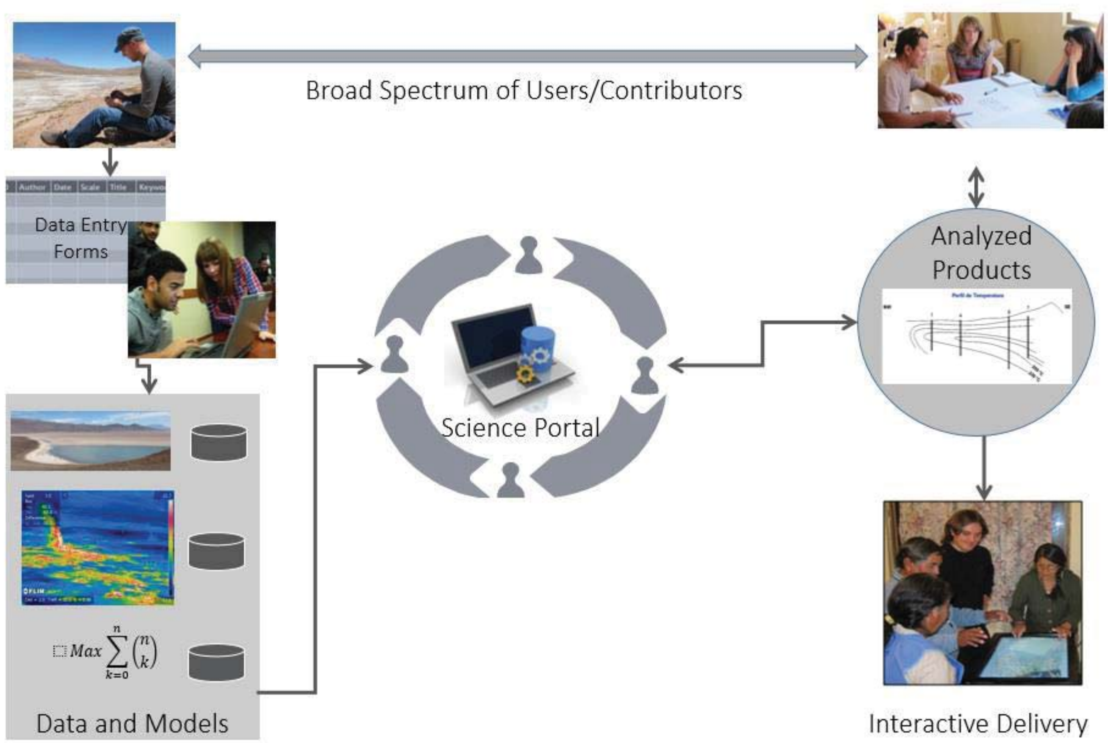

Figure 3.Conceptual depiction of the ENCOMPASS prototype cyberinfrastructure.

2.2 ECOGES: Social Process and Sustained Dialogue

Science can contribute to the topic of water and energy resource allocation by providing information about the workings of these systems and creating tools to quantify impacts or beneficial aspects of development. The ENCOMPASS CI is an example of the hardware and software solutions that improve data and information sharing among participants. Yet, tools alone cannot deliver adequate decision support for complex, ill-structured, and dynamic problems. To address the needs for application of science and planning, decision makers and community stakeholders need both computational tools and soft systems methodologies to support dialogue and deliberative processes to assist with the evaluation and presentation of resource management alternatives.

Engagement with groups of stakeholders began in January 2012 with the goal of sharing scientific information with the key indigenous community stakeholders to build the group capacity and initiate group visioning exercises. A series of five cultural-scientific exchanges were convened (see Figure 2) between January 2012 and October 2013. Approximately 19-22 participants participated in the day long workshops and dialogue sessions. Sessions included thematic presentations on technical topics, such as water resources, geothermal systems, and economic realities for Chile (Pierce et al., 2012). At the same time, each session generated group dialogue between subject matter experts (e.g. scientists and economists) and the indigenous community stakeholders regarding the shared concerns and potential paths forward that might improve relations within the Region and with other sectors, such as energy and mining sectors.

From January 2011 through March 2012 the participatory sessions followed the tenets and principles of a conflict resolution process called, sustained dialogue (Pierce et al., 2012). Results of these sessions strengthened relationships between the community and researchers and produced the identification of three preferred pathways and projects among the indigenous community members. The priority project among the pathways was the vision of improving relations with the mining sector while establishing more sustainable energy generation options for the region. Yet, the indigenous stakeholder group was reluctant to meet face-to-face with representatives from the mining industry. Over the course of 4 intense meetings in 2011 the participatory group explored information, designed the CI elements, and extended deliberation regarding realistic mechanisms for achieving the visions. Each time, participants were asked to consider meeting with mining sector representatives, opting not to throughout 2011.

As shown in Figure 2, the research team presented Heatseeker, a gesture-enabled mapping tool that accesses datasets from the ENCOMPASS CI on a large-format touchscreen for use with groups, during the first stakeholder meeting in 2012 (Malin et al, 2012). The proof-of-concept interface and application provided interactive maps, images, and simple datasets about the II Region. Primary stakeholders used the Heatseeker application for approximately 2 hours, engaging in an active discussion about key issues and using the interface to visualize the locations of conflictive water and energy projects during the dialogue session. As the session closed, the lead stakeholder stated that the group was prepared to meet with mining industry representatives and explore the renewable energy vision collaboratively. That response to the CI technology triggered several follow-on actions and transitions, including collaboration with the mining industry to co-design ECOGES, a planned renewable energy generation plant expected to be operated by the indigenous community.

3. RESULTS

3.1 Boundary Object Trigger for Action

Boundary objects are able to coordinate different groups without a consensus about their aims and interests. If they are both open to interpretation and valuable for various scientific disciplines or social groups, boundary objects can be highly useful as a communication tool in order to bridge scientific disciplines and the gap between science and policy (Cash et al. 2003).

Looking at the Atacama case study through the lens of social transition states (shown conceptually in Figure 2), the geothermal incident created a period of transition where the stakeholders were open to modified interaction patterns and set the stage for a participatory process with potential for real-world change. In this setting the concept of socio-technical processes and boundary objects for communicating with salience, credibility, and legitimacy (Figure 1) became useful. Boundary objects can serve as translational concepts, or boundary negotiating artifacts (Lee, 2005), that integrate meaning across participants as they collaborate on a shared task (Wenger, 1998). The common task in the Atacama case study began as a set of separate discussions among stakeholders representing the indigenous (or native) communities. ,

Initially, the research team and indigenous stakeholder shared the task of learning about their perspectives, values, and knowledge-base. At each meeting, the research team encouraged the inclusion of stakeholders from other sectors, such as mining, energy, or governing agencies. Yet the indigenous community resisted until the introduction of the Heatseeker gesture-enabled interface. The use of this interface that was populated by data and models from the ENCOMPASS CI triggered a transition and served as a boundary object in the ongoing dialogue process. At that moment, the indigenous stakeholders understood that they could use scientific information and appreciate that the cyberinfrastructure could contribute to their needs.

This interpretation aligns with Bechky's assertion (2003) that boundary objects can enable coordination among stakeholders with differing perspectives, allowing the group to reframe meaning within the context of a shared activity even without consensus. In this case the Heatseeker technology provided a tipping point within the larger social engagement and co-design process. To the indigenous community the interface provided access to information and confidence in in their ability to connect with concepts that might seem alien. The technology creates a bridge for the indigenous community members and research team to "speak the same language" and be in an equal, credible and trustworthy position.

The gesture-enabled interface and Heatseeker application served as the knowledge and information delivery mode for this research. The Heatseeker tool and supporting Encompass cyberinfrastructure utilizes a client/server system architecture that provides users with access to spatial and tabular data with low bandwidth requirements. A web-based GIS platform called MapBox and a variety of related, open-source software tools are used to create a web-based multi-criteria weighting utility with spatial overlays. Javascript is used to implement the calculations of a simple linear weighting multi-criteria decision analysis model and provide users with display and report functionality. Additionally, the tool is optimized for use with a gesture-enabled touchscreen device (Noll, 2013). During development the following development and functionality requirements were identified as key to creating a flexible tool:

- Support spatial overlay consistent with favorability mapping and site selection procedures
- Utilize open source software with accessible web-browser and minimal dependencies
- Maintain data in a central repository with efficient input/output procedures
- Facilitate real-time collaboration among users through scenario generation
- Optimize the application for use on a multi-touch surface device

While the technology enabled interactive engagement with data sources, it is important to note that the observed shifts in stakeholder attitudes occurred within the context of a maturing social process that was inititated after an unexpected incident. In other words, the case study offers insights into the importance of convening participatory processes when opportunities arise, such as the geothermal incident, and then to assure a consistent social process in conjunction with facilitating technologies. The technologies provided useful interfaces and decision support environments to assess management issues and questions of competing values, yet the stakeholder dialogue process was the central focus of activities.

After the introduction of Heatseeker, or the trigger event (see Figure 2), representatives from the mining sector joined the dialogue process informally in 2013 and officially through the ECOGES project kick-off in October 2013 with the explicit goal of co-designing a renewable energy plant.

3.2 Research Method Shift

Frequently the role of science and models is seen as an informative source that may reduce uncertainty and provide subject matter expertise about a problem. In this case study, the research approach has shifted twice to date as shown in Figure 2. As the project began researchers used a knowledge-centered approach to assess the perception of stakeholders, collect physical system data, and inform the design of the ENCOMPASS CI. The early phase determined that equity and accessibility to information are the more important elements for assuring that a plurality of stakeholders may participate in deliberation about sustainable futures for the region. In a second phase the research shifted to a process-centered approach that emphasized substantive dialogue, deliberation, capacity and relationship building. After the boundary object trigger event in 2012 the research methods shifted to a hybridized version of process- and action- centered approaches. The outcomes of the third phase, or ECOGES project, remain to be observed. A critical advance has come from the first two phases to enable this third phase through the expansion of the stakeholder participants to include indigenous community members, mining sector representatives, as well as physical and social scientists.

3.3 Real World Transitions

Today, ECOGES project participants are co-designing a renewable energy plant that will be operated by the indigenous community and aspires to become a sustainable business. The proposed plant serves as a focal topic for participatory modeling and shared vision for the entire stakeholder group. Initially, indigenous community stakeholders viewed dialogue or collaboration with the mining sector as infeasible. The participatory development of the ENCOMPASS CI and sustained dialogue process established trust and credibility between the indigenous community members and subject matter experts (of the research team). After the trigger event in early 2012 occurred actions to establish cross sector collaboration were completed with relative speed. The invitation to collaborate on the ECOGES project represents a significant real world transition that was inspired by the participatory modeling process. In concrete terms, the indigenous community decided to create a non-profit organization called “Allyus Sin Fronteras” to act as the primary entity for deliberations with mining sector partners. At the same time that positive shifts occurred in concrete project and organizational terms, the indigenous community group has also experienced a certain level of social fracturing. Some members of the indigenous stakeholder group have opted not to participate in the ECOGES process, yet the reasons for this are reportedly due to a combination of factors beyond the participatory modeling project. This fracturing has had some impact on the trajectory of interactions since October 2013 (shown in Figure 2), along with challenges for bridging communication between corporate and community realities.

4. SUMMARY AND DISCUSSION

The ENCOMPASS and ECOGES projects are based on the premise that sociotechnical platforms and processes aid sharing and communication between scientists, engineers, policymakers, and communities. Results of this research suggest that three elements are essential for strengthening participatory modeling and increasing the likelihood of outcomes that affect sustainability transitions for society:

1) User interfaces, or other technological artefacts, may serve as important boundary objects to instigate social transitions. Information technologies, such as the ENCOMPASS CI and Heatseeker gesture-enabled interface, are beneficial for building capacity within stakeholder groups and supporting deliberative interactions among stakeholders.
2) At the same time, pairing technologies with participatory processes to strengthen relationships and communication among stakeholders are important for assuring salience, credibility, and legitimacy of outcomes. Equal attention to both the technical and social aspects is needed with the goal of spanning boundaries: across centers of knowledge, disciplines, cultures, technologies, resource type, and global hemispheres.
3) Long-time frames and flexible research agendas to enable engagement and participation that is deep enough to observe results and transitions. ECOGES emerged after four years of research effort and several different trajectories. Real-world change and engagement in participatory processes does not occur in neat packages of time nor does it adhere to expected project timelines. Social processes that engender relational transitions and enable organizations, or projects, to emerge, grow, and stand on their own require time and commitment.

This proposed work has practical implications for resource allocation, strategic planning, and science policy. Early results indicate that the gesture-enabled touch screens are useful for establishing an accessible environment for deliberation because subject matter experts and laypeople can interact with information with equal ease. Social process has been critical for bridging scales, managing group expectations and relationships, and addressing differences in epistemological and cultural perspectives. These early indications are useful for modeling practitioners of participatory processes, because technology may serve to bridge among stakeholder groups and trigger transitions. Further research and evaluation on the role of models and accessible interfaces as a bridge to advance proactive and open dialog or deliberation regarding resource management for the future is needed. Moreover, results from this case study and pilot testing of gesture-enabled interfaces indicate that incorporating technologies (or other boundary objects) within a sustained social process may trigger sustainability transitions. Decision support and participatory modeling practice are based on the use of technologies and methods that serve to untangle wicked problems. Understanding the potential role of technology as boundary objects and explicitly designing processes to test the effectiveness of various objects in participatory settings offers a significant area for future research as the field matures

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