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Strategies for communicating systems models

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ABSTRACT

Sustainable environmental policies are rooted in knowledge and assumptions that decision-making authorities hold regarding specific social–ecological settings. These decision makers are increasingly informed by systems models. Diverse audiences for environmental science and sustainability policies magnify the importance of clear model communication. This essay offers a summary of best communication practices for situations in which bridging modelers' and non-modelers' conceptions of a given system—their respective mental models—is a principal challenge. Synthesizing social research from technical communication, educational psychology, and science communication disciplines, we discuss common areas of confusion in comprehending and explaining complex information, and present strategies model developers can use to ensure their model presentations are understandable and meaningful to audiences. We argue that accessible and socially adoptable explanations benefit from modelers listening to target audiences and anticipating how and why audiences may fail to understand aspects of a model.

1. Introduction: communicating models

Interdisciplinary methodologies in the sciences are a response to overwhelming evidence that human activities are a dominant force of change in natural environments (Crutzen and Stoermer, 2000; Haff, 2003; Holling et al., 1998; Hooke, 1994, 2000; Ostrom, 2007; Vitousek et al., 1997). Where environmental science and policy converge, how do interdisciplinary teams of researchers, natural resource managers, and practitioners integrate diverse kinds of expertise into meaningful representations of human–environment systems useful for decision-making? To disentangle the processes connecting research science and actionable policy—the Gordian Knot ubiquitous in post–normal sciences such as sustainability science and decentralized environmental governance—working groups are increasingly incorporating lay characterizations of resource systems into models of human–environment dynamics (Cash et al., 2006; Clark, 2007; Kates, 2011; Kates et al., 2001; Pohl, 2011; Schmolke et al., 2010; Talwar et al., 2011). Combining scientific and lay knowledge into an accessible (and politically acceptable) system representation, which then becomes a tool for deliberating about environmental problems and making decisions, both recognizes the benefits of public-engagement practices for improved governance (Innes, 1998; Manor, 1999) and heightens the importance of clear, careful, and strategic communication regarding model definition, development, and explanation.

Public participation in environmental planning brings diverse audiences in contact with policy making, science, and models, elevating the importance and consequence of modeling conversations. It is inevitable that the act of communicating the rationale, concept, results, implications, and limitations of a model influences *how* the model is used and perceived: the "variance in the *quality of model communication* between model developers and decision makers contributes to the wide variance in attitudes towards models" (Glaser and Bridges, 2007: 442, emphasis original). Where models represent integrated interdisciplinary science (Grant, 1998; Heemskerk et al., 2003; van der Leeuw, 2004), modelers are ambassadors for both the model and the underlying science as an appropriate method of representing a given system. In this Information Age where the credentialed "scientist" and "technical expert" are not granted indiscriminant public trust, communicating science well to community planners and stakeholders is paramount (Mooney and Kirshenbaum, 2009; Nisbet and Mooney, 2007; Sarewitz, 2004).

Perhaps the best-known, worst-understood models are those of climate science (CCSP, 2009; Fischhoff, 2011; Fyfe et al., 2013; Nisbet, 2009). Pidgeon and Fischhoff (2011) note that public

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understanding of climate change is impaired in part because the science of climate change relies on simulation models that have often been communicated poorly. The contentious public debate surrounding anthropogenic climate change, with entrenched adherents and opponents, illustrates how model-generated predictions can have huge and potentially divisive social, economic, and political impacts (Begley, 2007; CCSP, 2009; Fischhoff, 2011; Nisbet, 2009). Because an accepted system representation effectively denies alternative representations, model conceptions can establish—and decommission—entire paradigms of resource management practices, enacting lasting changes in economic, social, cultural, and ecological functioning; such models become perceived in terms of how they affect budget priorities, project approval, and policies (Jacobson and Berkley, 2011; Latour, 2004). Irrespective of the model developers' intentions as tools for decision making, models are political, set within a backdrop of political gains and losses (Allen et al., 2005; Barnaud et al., 2012). Such potential political ramifications of a model further complicate its communication.

Even if a given model is relatively "simple," models are an inherently complicated concept because the term 'model' itself is ambiguous, meaning different things to different people. The more diverse an audience is, the more daunting it becomes for model designers to communicate the kind of tool their model is and what it does.

Unfortunately, modeling textbooks lead students into the experience of modeling but omit practical aspects of communicating models. While advice for writing model descriptions (Aber, 1997; Peck, 2000, 2004) and participatory model building (Metcalf et al., 2010; Thompson et al., 2010; van den Belt, 2004) are helpful resources, the challenge of designing a modeling presentation for a non-technical citizen and decision-making audience is often left to experiential learning.

In this essay, we present strategies that model developers can use to ensure model presentations are accessible and meaningful to target audiences of non-modelers. Specifically, we focus on strategies for communicating models with decision-making authorities and public audiences during stages of model development, analysis, and application. If the ultimate success or failure of a human–environmental model used in decision-making stems from the degree of stakeholder involvement in the modeling process (cf. Schmolke et al., 2010), then sensitivity to users' understanding of systems and situational context is fundamental to building and communicating a model that stakeholders and decision-makers are inclined to adopt. Whether involved in participatory, descriptive, or predictive modeling, modelers can apply the strategies we offer to communicate models of all types. First, we discuss the role of models as tools in decision making and explore aspects of communicating with diverse audiences that modelers should understand. Then we present three general obstacles to communication typical of complicated topics, and suggest ways to overcome these challenges in modeling presentations.

2. As many definitions as people in the room

At a recent workshop for a U.S. National Park Service project, approximately 30 experts in natural resource management and socio-economics met to develop a conceptual model of park visitation (Swannack et al., 2009a): why do people visit parks? what does visitation reveal about visitor preferences and expectations? and how does visitation affect attributes of the park, such as its accessibility and the quality of its physical condition, over time?

The conveners explained that the objective of the workshop was to create collaboratively a description of park visitation as a system. By identifying factors and processes related to visitation, the resulting model would help decision-makers understand which park attributes and visitor preferences should be monitored to ensure the relevance of park management programs. The conveners discussed the typology of systems models (cf. Meadows, 2008), defined the kind of model they envisioned, and presented examples of representational models they considered illustrative. Despite the participants' expressed familiarity with modeling, confusion arose among the participants and between the participants and the conveners over different interpretations of the term "model". Participants familiar with predictive modeling thought the objective of the workshop was to create a data-driven, predictive model, one that would use past visitation trends to predict future visitation trends.

Consequently, much of the workshop was devoted to discussing essential differences among various model types and analytical methods known to the audience in terms of the workshop's intended model. This example highlights an important lesson about communicating models: even for an audience of technical specialists, the model type, a justification for its selection relative to other modeling approaches, and the objectives for its application to the problem at hand should be explained clearly in terms of the audience's pre-existing experience with modeling. Because different disciplines and professions construct different kinds of models, when speaking across disciplinary lines modelers tend to communicate poorly about implicit assumptions their models use (Harte, 2002; Jakeman et al., 2006; Schmolke et al., 2010). So what is a given model for? What output does it produce and from what input? How should its results be interpreted?

3. Models as tools for explanation or prediction

Fundamentally, a model is a tool for insight. Models help investigators examine and refine hypotheses, typically in combination or in coordination with other kinds of empirical methods. Although a transdisciplinary model typology is beyond the scope of this paper, summaries of technical and conceptual challenges associated with particular modeling types and techniques are available for simulation modeling (Sokolowski and Banks, 2011), stakeholder contexts (Voinov and Bousquet, 2010), social and geospatial agent-based modeling (Crooks et al., 2008; Gilbert, 2008), and systems modeling (Meadows, 2008), among other subsets. More generally, however, in terms of purpose, models tend to fall into one of two categories (cf. Haff, 2003; Murray, 2003, 2007). A model may be designed as a description, whether quantitative or qualitative, that offers an **explanation** of the dynamics of a phenomenon or system. The model may present a big-picture, simplified, or abstracted perspective that makes a system more tractable for problem formulation, hypothesis testing, or management (Allen et al., 2005; Grant and Swannack, 2008). Alternatively, a model may be a tool for **prediction**, such as a statistical model used to forecast trends or a detailed simulation model that provides investigators with specific information about what a system will do in the future under a given set of conditions (Glaser and Bridges, 2007). A model may be an interesting idea unto itself and may be a key that unlocks new answers, but a model is ultimately a means rather than an end.

The importance of clarifying a model's purpose, from its underlying research question to its analytical limitations, cannot be overstated. Returning to the National Park Service workshop example, the conveners and the participants had in mind two different purposes, which led to confusion concerning the model the workshop would yield. Participants thought the model's purpose was to predict visitation. Such a model might include demographic data, attendance records, and visitor feedback about