Participatory Modeling in Environmental Systems

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Abstract: Participatory modeling has grown in popularity in recent years as a tool to investigate environmental systems and generate consensus among stakeholders around environmental problems. System dynamics has one of the longest track records of any modeling field of incorporating stakeholder input into model-building, and therefore has much to offer the growing field of participatory modeling. However, key challenges remain to conducting participatory modeling processes in environmental systems. These include: variation in stakeholders' goals and desired outcomes in environmental systems; feasibility of assembling relevant stakeholders; temporal and spatial scale of the problems encountered and presence of exogenous drivers; difficulty in collecting information relevant to the problem; and the need for specialized and scientific knowledge about the system being modeled. Participatory modeling efforts around the environment would benefit from the lessons contained in the system dynamics group modeling literature, while simultaneously moving the field forward by addressing the challenges mentioned above.

Introduction: Growth of Participatory Modeling

Participatory, group, or mediated modeling is a tool that has grown in popularity over the last decade in a wide variety of disciplines (Figure 1). The practice of modelers and scientists building models together with stakeholders and decision-makers has become increasingly common in processes that address environmental problems such as water use (Pahl-Wostl & Hare 2004), and wildlife and forest management (Beall & Zeoli 2008;

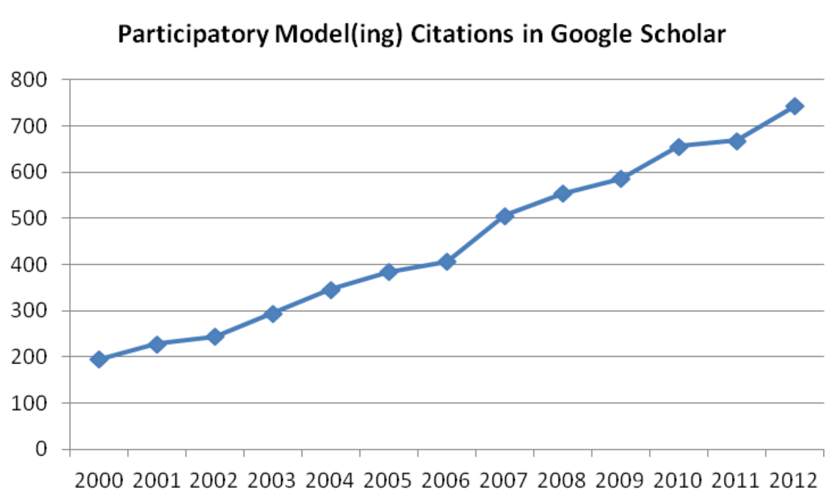

Figure 1. The number of papers with 'participatory model' or 'participatory modeling' mentioned anywhere in the article has more than tripled between 2000 and 2013, according to Google Scholar.

Mendoza & Prabhu 2004). This is logical, because environmental problems typically exemplify the characteristics that make participatory modeling a useful tool—complex dynamics and disagreement among stakeholders around the best way to address the problem and manage the system (Van den Belt 2004).

System dynamics has one of the oldest traditions of any modeling framework in using participatory modeling, with origins in organizational and business management (cf. Vennix 1996; Senge 2006; Richardson & Andersen 1995). The participatory, or group, model-building literature in system dynamics therefore has much to teach the community of scholars who wish to use participatory modeling to address environmental problems. Lessons drawn from the group model-building literature in business and management range from effective scripts for organizing workshops (Andersen & Richardson 1998) to methods for collecting qualitative data from relevant stakeholders (Vennix 1996; Kim & Andersen 2012) to dealing with power and conflict while building a model.

Environmental problems arguably present some of the most complex and contentious situations in which participatory model-building might be used today. Most participatory modeling in the system dynamics tradition has evolved from the business and management fields. Consequently, the differences between environmental and management arenas explain some of the disparities in problem definition, methodology and outcomes between the literature on participatory modeling of the environment and participatory modeling in business/management. As group model-building methods are used more and more frequently in environmental contexts, it is important to recognize some key challenges that remain in the application of system dynamics modeling methods to environmental problems. In this paper, I lay out five of these challenges and conclude with lessons for future research in participatory environmental modeling. It is important to note that these challenges will never be 'solved', because they are inherent characteristics of complex problems in environmental systems. Rather, they represent areas where participatory modeling can contribute greatly as a valuable tool, and also where participatory modelers still have much to learn.

Challenge 1: Variation in stakeholders' goals and desired outcomes.

In any organization, stakeholders will have varying goals, objectives and agendas when it comes to resolving a problem. Environmental problems typically involve stakeholders from a variety of organizations representing different interests and worldviews. Stakeholders in a given system may even have oppositional goals—for example, one group would prefer that a dam not be built; the other would like it to produce the maximum possible amount of electricity (Hall et al. 1989).

Group model-building represents an excellent tool for addressing the challenge of reconciling divergent goals (Van den Belt 2004). Through the mediation that a model-building process provides, different goals may be accommodated (although not perfectly), and tradeoffs between these goals may be described (Stave 2002). Also, by promoting a long-term view of a given problem, dynamic models may be able to demonstrate a set of goals for an environmental system on which multiple stakeholders may agree (Schmitt Olabisi et al. 2010). Modelers are typically process experts, rather than content experts, and can therefore approach an environmental controversy from a naïve and ostensibly ‘neutral’ position. This can give them added credibility in a contentious situation.

For all of these reasons, participatory modeling is a valuable tool for addressing environmental controversy. This does not diminish the challenge of reconciling various goals and outlooks for achieving consensus, which is the task of the modeler in such circumstances. In order to fill this role, a modeler must be skilled in model-building, facilitation, and interpersonal dynamics. There are few graduate programs that provide teaching or practical experience in all of these competencies, so finding someone to conduct a participatory model-building process may not be easy. Moreover, the question of scale is critical in assembling the appropriate stakeholders for a participatory modeling process dealing with a controversial environmental issue. If consensus is achieved at a local level, key decision-makers at higher scales may not buy in to the process. If modeling is conducted at a regional scale, the interests of local people may not be adequately represented. There is a need for more work on how best to achieve consensus with participatory modeling processes, while involving stakeholders with different scales of decision-making power.

Challenge 2: Logistical feasibility of assembling relevant stakeholders. Organizations differ widely in their degree of hierarchy and in the ability of key stakeholders (a boss, for example) to compel participation in a given modeling effort. However, assembling relevant stakeholders is arguably more feasible for an intra-organizational participatory modeling effort compared with a modeling effort that involves individuals with multiple affiliations, as is the case in most environmental systems. Participatory modeling in environmental systems can therefore require modelers and facilitators to work with a different group of stakeholders at each stage of the project. Retaining the commitment and interest of stakeholders over the typically long time period required to complete a modeling project is a common problem described by environmental systems modelers (Tàbara et al. 2008; Schmitt Olabisi et al. 2010).

This problem may be overcome in some cases by securing the support of a key stakeholder who can bring relevant participants to the modeling activity on the strength of his or her reputation (Hahn et al. 2006). It is also valuable for the modeling team and facilitators to be seen as neutral parties, particularly in a contentious situation. If the modelers are seen as ‘belonging to’ or ‘siding with’ a particular group of stakeholders, other stakeholders with a different view of the problem may choose not to participate, reasoning that the process of model-building will not accommodate their perspectives and goals.

Challenge 3: Temporal and spatial scale of the problem and degree of exogeneity. One strength of system dynamics modeling is its ability to demonstrate a long-term view, which makes it particularly suitable for representing environmental dynamics (the most famous example is undoubtedly the Limits to Growth model, which was run on a century time scale (Meadows et al. 2004)). Both the nature of environmental problems and the decision-making structures around environmental issues require a longer term view than may be required in other fields. For example, while problems in business and management may require planning that spans decades, environmental problems like climate change display dynamics that occur over centuries (Fiddaman et al. 2008).

Similarly, while models of business may require information about a global supply chain, environmental models may need to integrate hydrology, climate and economic production data from local to regional scales to inform decision-making (Suh et al. 2010). This may require model-builders to work with diverse stakeholder groups across different levels of governance and to integrate dynamics into the model that operate at different scales. Perhaps most importantly, it is more likely that an environmental model will contain exogenous forcing functions compared with a business or management model, simply because of the multi-scalar nature of environmental problems. For example, many dynamic models are currently being constructed to represent the effects of climate change on critical ecosystems or natural resources. It is rarely appropriate to include climate change dynamics as endogenous to the system, because these dynamics occur on a global scale, while many resource modeling efforts take place on a regional or local scale. While one of the strengths of system dynamics is its ability to shed light on endogenous dynamics (Richardson 2011), a purely endogenous point of view may have its limits in environmental systems, which are often highly impacted by exogenous forcing functions. In these situations, system dynamics modeling may be combined with participatory scenario processes, which are good at assessing the effectiveness of a given management or policy option in light of multiple plausible futures. Scenarios allow stakeholders to consider the plausible future states of exogenous variables over which they have no or limited control (Peterson et al. 2003, Johnson et al. 2012). System dynamics modeling and scenario-building are therefore highly complementary methodologies, and they should be combined more often for analyzing and deriving solutions to environmental problems (Schmitt Olabisi et al. 2010).

Challenge 4: Ability to collect information relevant to the problem. Related to Challenge 3 above, the larger temporal and spatial extent of environmental system problems compared with intra-institutional problems may necessitate a more rigorous and extensive data collection effort in order to properly parameterize and calibrate the model. This may add time and expense to the participatory modeling process in an environmental system. The need to integrate spatial information into the model through GIS data, for example, adds complexity and computational demand to a modeling process, and precludes the use of popular system dynamics platforms which are ill-equipped to handle spatial data.

Participatory agent-based modeling and scenario planning techniques have arguably dealt with the problem of displaying potential future states in space better than system dynamics (Swart et al. 2004; Guyot & Honiden 2006). However, agent-based models tend to be more 'opaque' to non-modelers compared with system dynamics models, as there are fewer agent-based platforms that represent model structure in an accessible way. One solution is to display the core decision-making processes of a representative agent in a system dynamics format, including inputs from other agents and from the environment as exogenous drivers. This 'core' structure may then be used in a group model-building exercise. Combining spatial dynamic modeling with participatory processes remains a challenge, although there are successful examples (Beall & Zeoli 2008; Zellner et al. 2012).

Challenge 5: Stakeholders' level of knowledge about the system being modeled. In institutional settings, it may be possible to conduct a participatory modeling process using only the knowledge and expertise available in the room. In environmental systems, this is rarely possible, because of the specialized knowledge and information needed to model the system adequately. Scientists in several fields often need to collect and analyze information related to the problem in order to present it in a way that stakeholders can understand, and in which it can be used in the model. For example, to build a system dynamics model of human health impacts of extreme heat events in urban centers in Michigan, epidemiological and climatic data had to be analyzed in order to use the model to accurately depict heat waves and their impacts on hospitalizations and deaths (Schmitt Olabisi et al. 2012). Stakeholders participating in the model-building process (for example, local planners and county health officials) do not typically have access to this data or the capability to analyze it. This necessitates more stages of the model-building process, in which modelers and collaborating scientists collect this data and prepare it for use in a model. Stakeholders may not be able to participate in this process, as they lack the expertise necessary for working with this data. Participatory modeling processes in environmental systems may therefore be challenged to strike a balance between being open and transparent to stakeholder input and acknowledging that stakeholders will not be able to participate in all aspects of model-building. In the case of the heat and human health model described above, this was accomplished by conducting a workshop in which local decision-makers interacted with the model and data and were able to construct their own scenarios for model runs.

Conclusion: 'Messiness' and Scope of Environmental Problems and Implications for Participatory Modeling Work

Complex human-environmental systems and institutional systems have much in common. System dynamics modelers and other scholars have described problems that arise in these systems as 'wicked' or 'messy', meaning that the cause(s) of the problem may not be clear, and the stakeholders in the system may have different worldviews and objectives related to the problem (Vennix 1999; Batie 2008). These types of problems require both a trans-disciplinary approach and a methodology for integrating different perspectives and worldviews to generate consensus through social learning. Participatory modelers in environmental systems may learn from system dynamics modelers who have used these approaches and methodologies in other arenas for decades.

The scope and complexity of environmental problems compared to problems in business and management, however, may necessitate longer participatory processes with more uncertain outcomes compared to the 'classic' participatory modeling processes represented in the system dynamics literature. In addition, environmental models may incorporate more exogenous forcing functions compared with models that represent a single institution or interactions between institutions. It is important for modelers of environmental systems to keep these challenges in mind as they plan modeling projects and participatory processes. In addition, it would be beneficial for participatory system dynamics modelers to learn from other literatures on participatory modeling and participatory processes that have been used in environmental systems; for example, participatory agent-based modeling (Guyot & Honiden 2006); participatory scenario planning (Enfors et al. 2008); and participatory action research, which has been used for decades in international development (Fals-Borda & Rahman 1991). In particular, environmental problems with significant exogenous drivers should be addressed through a combined system dynamics/scenario development approach. Systems with spatial dynamics and bottom-up drivers should be modeled using a combination of system dynamics and agent-based approaches. Participatory processes involving development issues and poor or marginalized populations could draw from the participatory action research literature, in addition to using group model-building techniques. Combinations of approaches from different traditions and fields will undoubtedly be necessary to address the pressing environmental challenges of the 21st century.

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