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Participatory Modeling: A Methodology for Engaging Stakeholder Knowledge and Participation in Social Science Research

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Abstract

Participatory modeling (PM) is an engaged research methodology for creating analog or computer-based models of complex systems, such as socio–environmental systems. Used across a range of fields, PM centers stakeholder knowledge and participation to create more internally valid models that can inform policy and increase engagement and trust between communities and research teams. The PM process also presents opportunities for knowledge co-production and eliciting cross-sectional and longitudinal data on stakeholders' worldviews and knowledge, risk assessment, decision-making, and social learning. We present an overview of the stages for PM and how it can be used for community-based, stakeholder-engaged social science research.

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Participatory modeling (PM) is a methodology that centers stakeholder knowledge and participation in models of complex systems (Sterling et al. 2019; Voinov and Gaddis 2008; Voinov et al. 2018). Systems modeling originated as a way for natural scientists to represent functions and predict outcomes of complex systems (particularly environmental systems) for policy and planning purposes (Felling 1974; Jordan et al. 2018; Voinov et al. 2016). In traditional systems modeling, researchers identify and observe key social and environmental variables, iteratively determine the relationships between those variables, and map the results into an explanatory or predictive model (Ford 2010). However, when used for socio–environmental systems, this approach has been critiqued as lacking internal validity and credibility with local stakeholders (Prell et al. 2007).

In response, participatory modeling, and related forms of collaborative and group model building (Andersen et al. 2007; Basco-Carrera et al. 2017), evolved into a broad methodology for incorporating stakeholder knowledge and participation into the modeling process. Used across a wide range of fields—including health (Lee et al. 2017; Weeks et al. 2017), development planning (Papageorgiou et al. 2020), and environmental research (Hedelin et al. 2017; Röckmann et al. 2012)—the goal of PM is to facilitate stakeholder interactions as they come to agree on shared, mutually understood models of complex systems that can better inform problem-solving and policy decisions (Voinov et al. 2018).

Participatory modeling enables stakeholder-centered knowledge co-production. Researchers may also capture dynamic data on human cognition, behavior, and interactions that may be more difficult to elicit through more conventional researcher-driven methods like interviews and surveys (Jordan et al. 2018). Such data can illuminate stakeholders' worldviews, risk perceptions, and conceptualizations of the environment (Hemmerling et al. 2019; Landström et al. 2011). Further, through PM, researchers can capture cross-sectional and longitudinal data on social learning (Gray et al. 2018; Hedelin et al. 2017), collaborative decision-making and consensus-building (de Vente et al. 2016; Falconi and Palmer 2017), and community engagement (Newell et al. 2021) during the model's development. Because PM prioritizes stakeholder–researcher collaboration, it can help democratize knowledge production like other forms of participatory research and praxis (Cornwall and Jewkes 1995).

Below, we outline the generalized stages for PM and indicate some of the different methods researchers may use during the PM process, with a focus on techniques for eliciting and analyzing social science data. In practice, PM incorporates diverse methods and should therefore be considered a methodology, or general approach to methods, rather than a specific method in itself (King 1994). PM is also highly iterative; researchers often work through multiple stages simultaneously (Voinov et al. 2018).

Stage 1: Selecting Roles and Sites

Research teams first identify who will fulfill different roles in the PM process, including the discussion facilitator (who elicits information and facilitates interactions) and the modeler (who interprets that information to build the model) (Richardson and Anderson 1995). One individual can play multiple roles, but the skills for each role are unique and it can be counterproductive to execute multiple processes simultaneously (Langsdale et al. 2013; Richardson and Anderson 1995). When the modeler facilitates, for instance, they may unintentionally gatekeep knowledge (Butler and Adamowski 2015). The meeting location, in person or virtual, should be neutral and accessible for the community (Butler and Adamowski 2015) to ensure participation from the whole group rather than only the most powerful or vociferous (Voinov et al. 2016).

Stage 2: Identifying and Recruiting Participants

Researchers purposefully select participant stakeholders based on expertise or vested interests in the research (Freeman 2010; Mitchell et al. 1997; Wood et al. 2021). Identifying knowledgeable stakeholders benefits from ethnographic knowledge and a built rapport with the community (Reed et al. 2009) or consultation with local leaders and key informants (Nyaki et al. 2014). Researchers seek balanced representation among stakeholder groups and community members' identities (e.g., racial, ethnic, gender) to capture diverse perspectives (Butler and Adamowski 2015; Krueger et al. 2012).

Stage 3: Formulating the Model

The model's purpose and scope are determined in the formulation stage. Some scholars advocate for stakeholders to be involved in the modeling process only *after* a clear modeling goal has been identified (Voinov and Gaddis 2008). Others suggest that early collaboration ensures the model reflects stakeholders' priorities for problem-solving (Hemmerling et al. 2019; Jordan et al. 2018; Langsdale et al. 2013).

During this stage, researchers may conduct individual interviews, focus groups, or surveys to determine the limitations and boundaries of modeling exercises (e.g., questions to address) and to assess baseline knowledge, expertise, opinions, and/or agendas (Evers et al. 2012; Gray et al. 2018). This allows researchers to track how such factors may change throughout the PM process (Hedelin et al. 2017). One-on-one interviews also allow participants to express views they might be hesitant to express in a group setting (Bourget 2011; d'Aquino and Bah 2013). This information can help anticipate potential conflicts that may arise in the model building stage.

Stage 4: Conceptualizing and Building the Model

Model conceptualization begins by prompting participants to select, discuss, and/or explain interactions of key phenomena in the system. This can occur through interviews, surveys, or facilitated focus groups and workshops (Kimmich et al. 2019; Prell et al. 2007). Models are then built via analog (e.g., maps and drawings) or computer-assisted processes (e.g., geographic information systems or specialized software) (Barthel et al. 2016; Basco-Carrera et al. 2017; Cleland and San Jose 2018). Analog techniques (e.g., drawings or role-playing and scenario games) can produce their own models (Amazonas et al. 2021; Bell and Morse 2013; d'Aquino and Bah 2013; Mayer et al. 2021; Voinov et al. 2018), or be used to inform computer models, as stakeholders are rarely fluent with these systems (Jordan et al. 2018). New technologies continue to innovate ways to engage and communicate with stakeholders (Newell et al. 2021).

Facilitation is key during this phase. If social norms, hierarchies, or power relations inhibit participation, facilitators can divide participants into smaller sub-groups and then reintegrate as the process matures (Amazonas et al. 2021; Basco-Carrera et al. 2017). Facilitators may also limit initial participation to a key group of stakeholders and incrementally add different stakeholder groups later (d'Aquino and Bah 2013). Inclusion at different phases affects how much power participants have in the overall process (Clavel et al. 2011; Voinov and Gaddis, 2008).

Each of these methods for engaging participation in conceptualizing and building the model provide social science data. Surveys and interviews provide data on participant views and knowledge, while in-person workshops provide the greatest opportunity to examine social dynamics, decision-making, and learning via direct observations (Jones et al. 2009) or recorded data (Landström et al. 2011). Self-administered questionnaires bring forth data on unpopular perspectives (Wutich et al. 2010). Materials created during meeting discussions (e.g., drawings and maps) and the model itself are also potential data sources.

Stage 5: Validating the Model

When stakeholders and researchers establish that the model is mostly complete, the research team tests the model's external and internal validity. To determine external validity, researchers may use measures of the model's representation of real-world processes and phenomena (e.g., regression for sensitivity analysis) (Ford 2010). To determine internal validity, the research team can use measures developed by and with stakeholders to evaluate how well the model represents their input. Researchers discuss and interpret findings with participants, either in additional workshops or through follow-up

interviews with selected participants (Falconi and Palmer 2017; Voinov and Gaddis 2008). This process also facilitates discussions of future actions and next steps (Langsdale et al. 2013).

Ongoing throughout Stages 3–5: Analyzing Data

Data analysis methods may be used throughout the modeling process to identify patterns and themes that inform the underlying research question or modeling problem, examine stakeholders' perceptions of the model inputs and the modeling process, and determine the final model's internal and external validity. Researchers may perform analysis procedures with or without stakeholders. For example, the research team can engage stakeholders in theme identification for thematic coding (Amazonas et al. 2019). These themes can then be analyzed via statistical tests or via quantitative relational models such as social networks analysis, multidimensional scaling, or cluster analysis (Evers et al. 2012; Goelz et al. 2020; Röckmann et al. 2012). Other forms of inductive textual analysis such a schema analysis (Quinn 2005) or grounded theory approaches (Charmaz 2014; Glaser 1999; Strauss and Corbin 1997) may also be appropriate to understand shared cognitive schemas during the modeling process (Moon et al. 2019; Papageorgiou et al. 2020).

Conclusion

Participatory modeling can facilitate mutual respect, trust, and cooperation between research teams and stakeholders that support validity in social science data, inform conceptualizations of environmental processes, and produce robust applied outcomes for the resulting model. Significantly, participatory modeling is a political process (Barber and Jackson 2015); it not only documents stakeholder perceptions, but has the potential to *actively* shift those perceptions by bringing various stakeholders into communication with one another (Turnhout et al. 2010). Participatory modeling can also connect scientific expertise and stakeholders' lived experience and situated knowledge, leading to higher quality data, more internally valid findings, and better resulting research impacts.

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References

Amazonas, I. T., N. C. Kawa, V. B. Zanetti, I. Linke, and P. A. Sinisgalli. 2019. Using rich pictures to model the "good life" in indigenous communities of the Tumucumaque complex in Brazilian Amazonia. *Human Ecology: An Interdisciplinary Journal* 47:341–54.

Amazonas, I. T., A. L. Schmitt Filho, V. B. Zanetti, J. Farley, and P. A. Sinisgalli. 2021. A participatory modeling experience with young farmers: Assessing the sustainability of family farmers in Brazil. *Research, Society and Development* 10: e50610111928.

Andersen, D. F., J. A. M. Vennix, G. P. Richardson, and E. A. J. A. Rouwette. 2007. Group model building: Problem structuring, policy simulation and decision support. *Journal of the Operational Research Society* 58:691–4.

Barber, M., and S. Jackson. 2015. "Knowledge making": Issues in modelling local and indigenous ecological knowledge. *Human Ecology: An Interdisciplinary Journal* 43:119–30.

Barthel, R., R. Seidl, D. Nickel, and H. Büttner. 2016. Global change impacts on the Upper Danube Catchment (Central Europe): A study of participatory modeling. *Regional Environmental Change* 16:1595–611.

Basco-Carrera, L., A. Warren, E. van Beek, A. Jonoski, and A. Giardino. 2017. Collaborative modelling or participatory modelling? A framework for water resources management. *Environmental Modelling & Software: With Environment Data News* 91:95–110.

Bell, S., and S. Morse. 2013. Rich pictures: A means to explore the "sustainable mind?" *Sustainable Development* 21:30–47.

Bourget, L., ed. 2011. *Converging waters: Integrating collaborative modeling with participatory processes to make water resources decisions*. Alexandria, VA: IWR Press.

Butler, C., and J. Adamowski. 2015. Empowering marginalized communities in water resources management: Addressing inequitable practices in participatory model building. *Journal of Environmental Management* 153:153–62.

Charmaz, K. 2014. *Constructing grounded theory: A practical guide through qualitative analysis*, 2nd ed. Thousand Oaks, CA: Sage.

Clavel, L., J. Soudais, D. Baudet, and D. Leenhardt. 2011. Integrating expert knowledge and quantitative information for mapping cropping systems. *Land Use Policy* 28:57–65.

Cleland, D., and R. O. San Jose. 2018. Rehearsing inclusive participation through fishery stakeholder workshops in the Philippines. *Conservation and Society* 16: 351–62.

Cornwall, A., and R. Jewkes. 1995. What is participatory research? *Social Science & Medicine* 41:1667–76.

d'Aquino, P., and A. Bah. 2013. A participatory modeling process to capture indigenous ways of adaptability to uncertainty: Outputs from an experiment in West African drylands. *Ecology and Society* 18:16.

de Vente, J., M. S. Reed, L. C. Stringer, S. Valente, and J. Newig. 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society* 21:24.

Evers, M., A. Jonoski, Č. Maksimovič, L. Lange, S. Ochoa Rodriguez, A. Teklesadik, J. Cortes Arevalo, A. Almoradie, N. Eduardo Simões, L. Wang, and C. Makropoulos. 2012. Collaborative modelling for active involvement of stakeholders in urban flood risk management. *Natural Hazards & Earth Systems Science* 12: 2821–42.

Falconi, S. M., and R. N. Palmer. 2017. An interdisciplinary framework for participatory modeling design and evaluation—What makes models effective participatory decision tools? *Water Resources Research* 53:1625–45.

Felling, W. E. 1974. Experiments in regional environmental planning. *Environmental Conservation* 1:271–75.

Ford, A. 2010. *Modeling the environment*, 2nd ed. Washington, DC: Island Press.

Freeman, R. E. 2010. *Strategic management: A stakeholder approach*. Cambridge: Cambridge University Press.

Glaser, B. G. 1999. The future of grounded theory. *Qualitative Health Research* 9: 836–35.

Goelz, T., T. Hartley, A. Scheld, and I. Carboni. 2020. The development of attitudes toward scientific models during a participatory modeling process—The impact of participation and social network structure. *Frontiers in Marine Science* 7:1–13.

Gray, S., A. Voinov, M. Paolisso, R. Jordan, T. BenDor, P. Bommel, P. Glynn, B. Hedelin, K. Hubacek, J. Introne, N. Kolagani, B. Laursen, C. Prell, L. Schmitt Olabisi, A. Singer, E. Sterling, and M. Zellner. 2018. Purpose, processes, partnerships, and products: Four Ps to advance participatory socio-environmental modeling. *Ecological Applications* 28:46–61.

Hedelin, B., M. Evers, J. Alkan-Olsson, and A. Jonsson. 2017. Participatory modelling for sustainable development: Key issues derived from five cases of natural resource and disaster risk management. *Environmental Science & Policy* 76: 185–96.

Hemmerling, S. A., M. Barra, H. C. Bienn, M. M. Baustian, H. Jung, E. Meselhe, Y. Wang, and E. White. 2019. Elevating local knowledge through participatory modeling: Active community engagement in restoration planning in coastal Louisiana. *Journal of Geographical Systems* 22:241–66.

Jones, N., P. Perez, T. Measham, G. Kelly, P. d'Aquino, K. Danie–ll, A. Dray, and N. Ferrand. 2009. Evaluating participatory modeling: Developing a framework for cross-case analysis. *Environmental Management* 44:1180–95.

Jordan, R., S. Gray, M. Zellner, P. D. Glynn, A. Voinov, B. Hedelin, E. J. Sterling, K. Leong, L. S. Olabisi, K. Hubacek, P. Bommel, T. K. BenDor, A. J. Jetter, B. Laursen, A. Singer, P. J. Giabbanelli, N. Kolagani, L. B. Carrera, K. Jenni, and C. Prell, National Socio-Environmental Synthesis Center Participatory Modeling Pursuit Working Group. 2018. Twelve questions for the participatory modeling community. *Earth's Future* 6:1046–57.

Kimmich, C., L. Gallagher, B. Kopainsky, M. Dubois, C. Sovann, C. Buth, and C. Bréthaut. 2019. Participatory modeling updates expectations for individuals and groups, catalyzing behavior change and collective action in water-energy-food nexus governance. *Earth's Future* 7:1337–52.

King, K. E. 1994. Method and methodology in feminist research: What is the difference? *Journal of Advanced Nursing* 20:19–22.

Krueger, T., T. Page, K. Hubacek, L. Smith, and K. Hiscock. 2012. The role of expert opinion in environmental modelling. *Environmental Modelling and Software* 36: 4–18.

Landström, C., S. J. Whatmore, S. N. Lane, N. A. Odoni, N. Ward, and S. Bradley. 2011. Coproducing flood risk knowledge: Redistributing expertise in critical "participatory modelling." *Environment and Planning A: Economy and Space* 43: 1617–33.

Langsdale, S., A. Beall, E. Bourget, E. Hagen, S. Kudlas, R. Palmer, D. Tate, and W. Werick. 2013. Collaborative modeling for decision support in water resources: Principles and best practices. *Journal of the American Water Resources Association* 49:629–38.

Lee, E., J. Dalton, D. Ngendahimana, P. Bebo, A. Davis, D. Remley, C. Smathers, and D. A. Freedman. 2017. Consensus modeling to develop the farmers' market readiness assessment and decision instrument. *Translational Behavioral Medicine* 7:506–16.

Mayer, A., J. Heyman, A. Granados-Olivas, W. Hargrove, M. Sanderson, E. Martinez, A. Vazquez-Galvez, and L. C. Alatorre-Cejudo. 2021. Investigating management of transboundary waters through cooperation: A serious games case study of the Hueco Bolson Aquifer in Chihuahua, Mexico and Texas, United States. *Water* 13: 1–17.

Mitchell, R. K., B. R. Agle, and D. J. Wood. 1997. Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review* 22:853–6.

Moon, K., A. M. Guerrero, V. M. Adams, D. Biggs, D. A. Blackman, L. Craven, H. Dickinson, and H. Ross. 2019. Mental models for conservation research and practice. *Conservation Letters* 12:e12642.

Newell, R., N. McCarthy, I. Picketts, F. Davis, G. Hovem, and S. Navarrete. 2021. Communicating complexity: Interactive model explorers and immersive visualizations as tools for local planning and community engagement. *Facets* 6: 287–316.

Nyaki, A., S. Gray, C. A. Lepczyk, J. C. Skibins, and D. Rentsch. 2014. Local-scale Dynamics and local drivers of bushmeat trade. *Conservation Biology* 28: 1403–14.

Papageorgiou, K., P. K. Singh, E. Papageorgiou, H. Chudasama, D. Bochtis, and G. Stamoulis. 2020. Fuzzy cognitive map-based sustainable socio-economic development planning for rural communities. *Sustainability (Switzerland)* 12:1–31.

Prell, C., K. Hubacek, M. Reed, C. Quinn, N. Jin, J. Holden, T. Burt, M. Kirby, and J. Sendzimir. 2007. If you have a hammer everything looks like a nail: Traditional versus participatory model building. *Interdisciplinary Science Reviews* 32:263–82.

Quinn, N. 2005. How to reconstruct schemas people share, from what they say. In *Finding culture in talk*, ed. N. Quinn, 35–81. New York: Palgrave Macmillan.

Reed, M. S., A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, H. Quinn, and L. C. Stringer. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management* 90:1933–49.

Richardson, G. P., and D. F. Andersen. 1995. Teamwork in group model building. *System Dynamics Review* 11:113–7.

Röckmann, C., C. Ulrich, M. Dreyer, E. Bell, E. Borodzicz, P. Haapasaari, K. H, Hauge, D. Howell, S. Mäntyniemi, D. Miller, G. Tserpes, and M. Pastoors. 2012. The added value of participatory modelling in fisheries management—What has been learnt? *Marine Policy* 36:1072–85.

Sterling, E. J., M. Zellner, K. Jenni, K. M. Leong, P. D. Glynn, T. K. BenDor, T. K. Bommel, K. Hubacek, A. J. Jetter, R. Jordan, L. Schmitt Olabisi, M. Paolisso, and S. Gray. 2019. Try, try again: Lessons learned from success and failure in participatory modeling. *Elementa Science of the Anthropocene* 7:9.

Strauss, A., and J. M. Corbin. 1997. *Grounded theory in practice*. Thousand Oaks, CA: Sage.

Turnhout, E., S. Van Bommel, and N. Aarts. 2010. How participation creates citizens: Governance as performative practice. *Ecology and Society* 14:26–41.

Voinov, A., and E. J. B. Gaddis. 2008. Lessons for successful participatory watershed modeling: A perspective from modeling practitioners. *Ecological Modelling* 216: 197–207.

Voinov, A., K. Jenni, S. Gray, N. Kolagani, P. D. Glynn, P. Bommel, C. Prell, M. Zellner, M. Paolisso, R. Jordan, E. Sterling, L. Schmitt Olabisi, P. J. Giabbanelli, Z. Sun, C. Le Page, S. Elsawah, T. K. BenDor, K. Hubacek, B. K. Laursen, A. Jetter, L. Basco-Carrera, A. Singer, L. Young, J. Brunacini, and A. Smajgl. 2018. Tools and methods in participatory modeling: Selecting the right tool for the job. *Environmental Modelling & Software* 109:232–55.

Voinov, A., N. Kolagani, M. Mccall, P. Glynn, M. Kragt, F. Ostermann, S. Pierce, and P. Ramu. 2016. Modelling with stakeholders—Next generation. *Environmental Modelling & Software* 77:196–220.

Weeks, M. R., J. Li, D. Lounsbury, H. D. Green, M. Abbott, M. Berman, L. Rohena, R. Gonzalez, S. Lang, and H. Mosher. 2017. Using participatory system dynamics modeling to examine the local HIV test and treatment care continuum in order to reduce community viral load. *American Journal of Community Psychology* 60: 584–98.

Wood, D. J., R. K. Mitchell, B. R. Agle, and L. M. Bryan. 2021. Stakeholder identification and salience after 20 years: Progress, problems, and prospects. *Business & Society* 60:196–245.

Wutich, A., T. Lant, D. D. White, K. L. Larson, and M. Gartin. 2010. Comparing focus group and individual responses on sensitive topics: A study of water decision makers in a desert city. *Field Methods* 22:88–110.