Participatory Learning Games for Social-Ecological Systems

UC Davis Social-Ecological Systems Graduate Seminar, Winter 2016

Christopher Adlam, Sinéad Brien, Nina Fontana, Megan Foster, Meghan Klasic, Linda Esteli Mendez-Barrientos, Cristina Murillo-Barrick, Risa Pesapane, Claire Rapp, Jessica Rudnick, Pablo Tomas Silva, Allison Simler, Mark Lubell

How can a simple game represent a complex social-ecological system?

For the last few years, I have taught a graduate class on social-ecological systems (SES) that introduces SES concepts and frameworks along with delving into a number of related topics in environmental social science. A core activity of the class involves student groups choosing SES case studies, and applying the course topics from a particular week to the case study. Over the years, student groups have come up with creative participatory SES games as an alternative to top-down presentations. The Winter 2016 students took participatory games to the most advanced level yet—all four student groups created games representing their SES case studies. While designing an SES game was not a formal class requirement, there is obviously a strong desire for this type of learning activity. We collaboratively wrote this blog (yes...it is almost a paper....) in order to memorialize and share the lessons learned from our experiential learning class.

The overarching challenge is how to create a participatory game that adequately represents key aspects of SES, which are usually considered complex adaptive systems. Games needed to be simple enough for participants to understand and engage within a single class period, while still teaching ideas about complex social and ecological processes. The rest of this blog summarizes the outcomes of class discussions, with an eye toward generating a “design studio” for creating SES games. The current content of the blog represents brainstormed ideas and reflections, rather than in-depth research.

Why Use Participatory SES Games?

Lectures are boring. That is the first reaction of many students, and resonates with the broader movement towards more engaged and experiential learning that is happening throughout academia. A mainstay of the engaged learning movement is that participatory exercises appeal to a variety of learning styles. Some participants are capable of digesting more “top-down” presentations, while other students learn better via “bottom-up” interactions. Games build participatory space for all class members to engage (rather than selecting for extroverts) and provide memorable learning experiences.

When paired with case studies, SES games contextualize theoretical concepts in a more concrete manner. They allow players to "inhabit" complex systems. Such experiential learning engages with different parts of the brain and creates an emotional reaction and personal, albeit hypothetical, experience that may enhance long-term learning. Through “learning by doing”

(being presented with a challenge, having to make a decision, and receiving feedback on that decision) people are able to retain knowledge at a higher level.

Further, SES games serve a variety of purposes, ranging from an ice-breaker that builds trust and empathy, to stimulating discussion about core SES challenges, to providing a concrete simulation of specific SES management decisions. SES games may also identify innovative, outside-of-the box solutions to SES challenges that could not be discovered through traditional approaches. Participants can experiment with a number of different approaches, without failures leading to permanent ecological, economic, or political consequences. The game itself may be played from multiple starting points, or under various conditions, to simulate how different policies (or other SES variables) produce a range of outcomes. Hence, SES games have the potential to provide a platform for experimental testing of hypotheses.

SES games may appeal to a broad set of audiences ranging from students, to the general public, to policy stakeholders. Hence, SES games have the capacity to become a tool for community development and collaborative governance. There are already examples of development programs and scientists using games to facilitate discussions about climate change or fisheries management, and a number of research groups have developed SES games. A good example is the RESORTES game created by Speelman and colleagues.

Summaries of SES Games from Winter 2016

The table below summarizes the key elements of the student-designed SES games in Winter 2016. More detailed descriptions are available at the end of the blog. These games are in their embryonic form. As a result, some elements succeeded while others failed. There is no doubt that finalizing these games requires more design and testing. Regardless, the students put a lot of creative energy into developing the foundational concepts.

The rows of the table identify various aspects of each game that we think are important. “SES concept” refers to the core idea targeted by each game; the games did not try to tackle every single aspect of an SES. “SES Case Study” is the specific real-world context in which the game is anchored. “Key SES” outcomes are the observable aspects of SES systems that emerge from game play. “Participant Goals” are assigned by the game designer, in order to motivate the decision making of various types of game actors. “Key Social Processes” are the social processes that are most important for game play, while “Key Ecological Processes” are the ecological aspects of the system that are highlighted. Finally, “Learning Objectives” are the main pedagogical goals of the game.

Key Elements of Participatory Learning Social-Ecological System Games				
	"The Edge of Chaos"	**"Collective Action Catastrophe"**	**"COP 22"**	**"Terra Pura"**
SES Concept	Complex adaptive systems	Multi-scale cooperation	Political networks	Human decision-making with different constraints
SES Case Study	Mesopotamian Marshlands	2014 Ebola Outbreak in West Africa	COP21: 2015 UNFCCC Negotiations	Costa Rican Dry Tropical Forest
Key SES Outcomes	Interactions between social and ecological processes leading to multiple basins of attraction	Collective action, with, health or biosecurity as a public good	The structure of coalitions and the content of international environmental agreements	Patterns of land-use and benefits to multiple stakeholders
Participant Goals	Stakeholders seek to achieve water management goals	Effectively manage human disease outbreak at the global scale	Country's priorities represented in final version of text and build alliances to facilitate this goal	Optimize individual outcomes conditional on information access and resources
Key Social Processes	Power differentials, cultural change, political instability	Cooperation between global players; Investment of individual resources for common good; foreign aid	Economic and political power asymmetries influence negotiation priorities	Decision-making under uncertainty within a management regime
Key Ecological Processes	Thresholds, non-linearity, stochasticity	Zoonotic disease emergence, Increased human use of forest resources, multi-scale epidemiology	Differential exposure to climate change risks influences priorities	Wildlife-Urban interface, stochasticity, critical habitats
Learning objectives	Discuss the behavior of complex adaptive systems and the interconnectivity between resilience and vulnerability	Understand the importance of an action plan in making decisions for collective biosecurity	Compare evolution of global environmental policy between Kyoto Protocol (1992) & Paris Agreement (2015); understand network complex dynamics	Compare land use decisions that result from different management strategies based on player incentives and time period

What Makes a Good SES Game?

Throughout the social sciences, participatory games and simulations have become a regular diet of graduate/undergraduate education, and also stakeholder engagement. Hence, some of the features we nominate below are common to many policy games, such as environmental negotiation scenarios and behavioral social dilemma experiments. But SES games are differentiated by incorporating features of SES frameworks, such as those posed by Elinor Ostrom and others. This includes the fact that SES are complex adaptive systems governed by feedbacks within and between social and bio-physical processes.

Given our initial experience, SES games should include the following features:

- Be motivated by a specific case study, where the details of the social and ecological processes are relatively well-understood. Case studies provide details that anchor various abstract theoretical concepts with real-world information. Participants are able to develop more intuitive understanding of the theory. SESYNC has spent a good deal of effort developing case studies for teaching SES synthesis.
- Include some type of uncertainty and stochasticity. A major research focus is how SES respond to external shocks, and how decisions are made under risk and uncertainty. For example in "Terra Pura", fire randomly converts forest to fallow ground on land adjacent to developed areas (akin to wildland-urban interface), while in "Catastrophe" there was random long-distance dispersal events of the Ebola pathogen to other continents.
- Accurately represent the decision-making goals and strategies of different stakeholders. For example in "COP22", each country seeks to have their policy preferences represented in the final text of the international agreement. This includes their social values, and possibly different levels of political power and decision-making authority. This often means specifying the utility or payoff functions for the stakeholders, where the points they earn within the game are related to different social and ecological outcomes. The decision-makers could be confronted with different aspects of bounded rationality, for example being required to make decisions with limited time or information.
- Incorporate strategic decision-making and the emergence of conflict and cooperation. Collective-action problems like public goods and common-pool resources are commonly used in participatory games and are central to SES and environmental policy. The "Catastrophe" game created a collective-action problem because one country's investment in disease management would reduce risks for other countries, so that other countries have incentives to free ride.
- Link game outcomes to specific ecological processes. While our initial games only qualitatively considered ecological processes, a more developed game might include specific ecological theories for how diseases spread (integrated SIR models), fire ecology, population dynamics of species on landscapes, groundwater recharge rates, et

cetera. The payoffs to different strategies would then depend specifically on the ecological processes—essentially, the ecological processes are parameterizing a game theoretical decision scenario.

- Create the potential for multiple "basins of attraction". Multiple basins of attraction are an important feature of many SES. As a real-world example, the extensive water management infrastructure may have caused the California Delta to move into a different basin of attraction from the highly variable anastomosing system that existed in the 1800s, to a much simpler hydrological regime with managed flow rates and leveed flow channels. In "Edge of Chaos", the Mesopotamian marshes might exhibit a tipping point between highly saline wetlands and freshwater wetlands depending on upstream and local water management decisions.
- Play the game under different scenarios, in a way akin to experimental manipulations. SES game strategies and outcomes may be conditional on the status of theoretically interesting social and ecological variables. For example, the Terra Pura game could be played with common/public knowledge about the ecological value of particular pieces of land, versus private knowledge held by specific stakeholders. In "COP22", it would be possible to allow different network structures form depending on something like socioeconomic homophily versus freely choosing partners.

Some Common Pitfalls

Despite the prototype stage of these games, the students identified a number of potential pitfalls worth considering for future SES game development. Most of these concerns are not unique to SES games, but rather are issues that should be considered for any participatory game.

Are SES games externally valid? Can game participants truly understand the decision-making incentives of actors who have spent years in specific roles, with knowledge and preferences linked to the details of a specific SES context? Can the payoffs embodied in games really provide the same incentives for decisions that in the real world may be linked to large amounts of money or other resources, or have direct consequences for human welfare? Can the small groups that participate in games scale-up to the large groups that participate in real SES?

Because they are anchored in complex systems, SES games can be difficult to understand. There are many different types of players, each of which may have different decisions and payoffs. The ecological processes that translate decisions into outcomes could also be complex, especially when mixed with external shocks or other uncertainties. To potentially reduce this complexity, the SES games might be designed to illustrate one or a select few SES phenomena rather than trying to capture all of the different aspects of an SES into one game.

Can you make SES games a stand-alone game that could be played with on-line or other materials, or do you need some type of skilled facilitator? Ideally, an SES game could be put

together as a whole package including materials, rules, research questions for students and other pedagogical tools. In some cases a skilled facilitator may be required to instruct participants on different complex aspects of the SES game.

How can we tailor SES games to different audiences and purposes? An SES game designed for undergraduate students may not work equally well for community engagement, where the stakeholders might think the SES game is too abstract or "cartoonish" or stakeholders have a different level of technological sophistication. For example, stakeholders in some developing countries might not be comfortable working on a computer. While some SES games could be designed purely to stimulate discussion (such as the Edge of Chaos in Mesopotamia), others might have well-defined payoffs and could actually provide the basis for experimental testing of theoretical hypotheses. We expect a portfolio of different types of games is the most likely outcome.

Appendix 1: Detailed description of games

The Edge of Chaos: The Mesopotamian Marshlands as a Complex Adaptive System

This game was designed to illustrate the concepts underlying complex adaptive systems. We used the Mesopotamian Marshlands of Iraq as a case study, invoking their history of conflict, drainage, and subsequent (partial and recent) restoration efforts. In designing the game, our strategy was mainly to make tangible complex concepts such as non-linearity, heterogeneity, multiple basins of attraction, and emergence. We relied on role-playing (as the Iraqi government, Indigenous tribes, and NGOs) to discuss the way these factors explain the behavior of this social-ecological system. Our rules and point system were accordingly vague, necessitating instead active feedback between the participants and the game-makers. As the game proceeded, students accepted the free-form nature of the game, and there ensued a lively discussion of the topic, the study system, the rules, and the role of games in pedagogy.

Collective Action Catastrophe: Fighting Ebola at the Global Scale

This game simulates the outbreak and spread of the virulent Ebola virus in West African human populations. In the game, representatives of the global community must make the decision to take action to contain the Ebola outbreak, based on the recent crisis (Philips & Markham 2014). While the Ebola outbreak primarily causes mortality in West African nations, the global community's collective goal is to halt the spread of the pathogen, to halt the spread of the pathogen before it can impact other continents. The game uses a simplified spreadsheet to model the spread of Ebola in West Africa. At each time step, as disease spreads, each global player (represented by a continent beyond Africa) can make a decision to invest in treatment and prevention of the disease, but individual actors are not allowed to communicate with other global players. Investing in treatment penalizes the individual global player's health resources "budget", but in order to end the outbreak, coordinated investment is required by multiple global actors. At a certain threshold of infection, the virus will jump to another country

randomly to simulate the rapid global nature of modern travel that can lead to pandemic events. Each global actor may randomly become penalized when Ebola colonizes their respective continents, further incentivizing action, but individual threats vary widely due to stochastic mechanisms over the course of the game. Through participation in multiple rounds of decision-making around resource allocation and intervention timing and scale, players experience the benefits and frustrations involved in collective action and how individual-level penalties and losses might influence joint decisions and planning.

COP 22: Simulating Negotiation Networks in the Global Climate Policy Arena

The "mock COP" game had two objectives: (1) for players to gain a better understanding of the perspectives and priorities various key nations brought to the UNFCCC COP negotiations, and (2) to simulate the political networks or alliances that form between countries at the climate negotiations. These networks or alliances, that help each party maximize its representation, voice, and access to insider information. We assigned every student the role of a particular country and provided them information on their country's demographics and political priorities, to give them baseline information from which they were to determine how they wanted to vote on five textual issues in the climate agreement (differentiation, climate finance, adaptation, technology transfer, and transparency). Countries were assigned unequal numbers of votes in order to represent variance in political and economic power in the negotiations. These votes were they could cast on the agreement issue areas, in order to represent variance in political and economic power in the negotiations. We played three rounds, each allowing progressively more network-building (or alliance formation) than the previous. As we played, game facilitators coded live in R to plot visualizations of the networks countries were forming. This allowed players to better understand which countries were working together and how that was affecting their voting strategies. At the conclusion of the third round, we compared (1) the mapped network of the game players to theoretical political networks playing out at the actual COP (COP 21) based on negotiation meeting minutes and (2) the final version of the agreement text that was voted upon by the players in the game to the actual settled upon version of the text in the 2015 Paris Agreement.

Terra Pura: Human Decision-Making and Land Management in Dry Tropical Forests

Terra Pura aims to apply the human decision-making strategies found in the SES Social Ecological Systems framework through role-playing based on park decision processes of stakeholders involved in land management in dry tropical forests of Costa Rica. This game builds off a Settlers of Catan model with the ability to convert land parcels among three different uses: forest, fallow land, and developed agriculture. The game has two versions to coincide with different regimes during the 1970s (top-down approach) and 2000s (collaborative planning). Each piece of land is treated differently based upon its ecological value, monetary value, or distance from a town. Players take turns in the order of researchers, central government, and local communities. The goal of the researchers is to subsidize the most ecologically valuable land in order for it to be converted to forest, and in later stages of the

game subsidize access points. Researchers are also subject to a budget constraint. The central government's goal is to convert farmland to fallow and fallow land to forest (they exemplify rational objective decision-making). They have unlimited funding. The central government must always pay to convert the cheapest tile. Locals can convert forest to fallow land and fallow land to agricultural land. In later stages of the game, they build access points (exemplify bounded rationality, fast and frugal) and have a predetermined, limited amount of funding.

Appendix 2: References

The Edge of Chaos

Alwash, S. 2013. "Eden Again: Hope in the Marshes of Iraq." Tablet House Publishing.

Mahon, R., McConney, P., and Roy, R. N. 2008. "Governing fisheries as complex adaptive systems." Marine Policy, *32*(1), 104-112.

Scheffer, M., J. Bascompte, W. A. Brock, V. Brovkin, S. R. Carpenter, V. Dakos, H. Held, E. H. Van Nes, M. Rietkerk, and G. Sugihara. 2009. "Early-warning signals for critical transitions." Nature 461, 53e59."

Collective Action Catastrophe

Philips, M., & Markham, Á. (2014). Ebola: a failure of international collective action. The Lancet, 384(9949), 1181.

COP22

Bodin, Ö., & Crona, B. 2009. "The Role of Social Networks in Natural Resource Governance: What Relational Patterns Make a Difference?" Global Environmental Change, 19(3): 366-374.

United Nations Framework Convention on Climate Change. "Overview of institutions, mechanisms, and arrangements under the Convention". <http://unfccc.int/focus/overview/items/7756.php>.

Terra Pura

Gigerenzer, Gerd, and Daniel G. Goldstein. 2011. "Reasoning the Fast and Frugal Way: Models of Bounded Rationality." Heuristics: The Foundations of Adaptive Behavior 103 (4): 650–69. doi:10.1093/acprof:oso/9780199744282.003.0002.

Girot, By Pascal O, Viviane Weitzner, and Marvin Fonseca Borrás. 1977. "From Conflict to Collaboration: The Case of Cahuita National Park, Limon, Costa Rica." In Crossing Boundaries, the Seventh Biennial Conference of the International Association for the Study of Common Property, 1–21.

Janzen, Daniel H. 2000. "Costa Rica's Area de Conservación Guanacaste: A Long March to

Survival through Non-Damaging Biodevelopment.” Biodiversity 1 (February): 7–20. doi:10.1080/14888386.2000.9712501.

Schelhas, John, and Max J Pfeffer. 2005. “Forest Values of National Park Neighbors in Costa Rica.” Human Organization 64 (4): 386–98. doi:10.17730/humo.64.4.eum89efhdyvbkjlg.

Tversky, Amos, and Daniel Kahneman. 1974. “Judgment under Uncertainty: Heuristics and Biases.” Science (New York, N.Y.) 185 (4157): 1124–31. doi:10.1126/science.185.4157.1124.