RESEARCH ARTICLE

Using Simulation Games to Teach Ecosystem Service Synergies and Trade-offs

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Natural capital is of critical importance for biodiversity and people's well-being. Studies indicate that understanding the connection between environmental health and human benefit (i.e., ecosystem services) can promote conservation-friendly decisions; however, many people don't recognize the benefits they derive from nature, nor the way their decisions affect those benefits—and the consequences for our communities and economy. One method we have tested for educating people about ecosystem services and valuation is game-based learning. To help people understand their potential impact on ecosystem services, and how alternative decisions can have better or worse outcomes for people and nature, we created two social simulation games collectively called *Tradeoff!* Through an iterative design process and pilot testing in a number of locations with a variety of audiences, we have developed a set of learning principles for educational ecosystem service games.

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In a world where we are rapidly losing biodiversity and critical environmental services, there is a pressing need for new approaches to help people take natural capital into account in decisions. Since the economic marketplace does not directly capture many of the values of nature, they are often not considered in our decision making. As a consequence, we fail to make fully informed decisions about our natural resources, resulting in potentially poorer outcomes for people and nature. The problem is twofold: (a) people fail to recognize and act on the many values of nature (Millennium Ecosystem Assessment, 2005; TEEB, 2010), and (b) existing methods to incorporate nature's value into decisions are often expert-driven and thus inaccessible and difficult for decision makers to use or understand in time-sensitive decisions (Cash et al., 2003).

An important feature of ecosystem services is that it focuses not just on the ecosystem itself, but on the flow of benefits that accrue from those services. Nature supports human health, livelihoods, and economies in countless ways: ecosystems store carbon to slow climate change, purify and regulate water supplies, and provide foods, medicines, and opportunities for cultural experiences. The structure and other characteristics of an ecosystem determine how it functions and how matter and energy flowing through it are affected. Ecosystem services differ from biodiversity in that they are a product of the interaction between a functioning ecosystem and humans (often referred to as *beneficiaries*). Therefore, the same ecosystem type in two different places may have similar potential for biodiversity but different ecosystem service potential, depending on how the ecosystem interacts with other natural features, processes, and human activity (Carpenter et al., 2009; Daily et al., 2009; De Groot et al., 2010).

Many ecosystem process and assessment models require specialized expertise to apply. The Natural Capital Project (or NatCap) developed InVEST (Integrated Valuation of Environmental Services and Tradeoffs) with the hope of providing a simple, transparent tool for a diverse range of decision makers. InVEST models have been used in over a dozen significant policy applications worldwide—from the designation of ecosystem-function conservation areas in China to the establishment of water funds in Latin America and marine spatial planning in Belize. Even with a simple suite of integrated models, however, often a wealth of information and expertise is required to bring ecosystem service information successfully into decisions. Some key

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attributes of NatCap's ecosystem service approach are that it is (1) participatory, (2) specific to decision context, (3) driven by decision-making users, (4) explicitly includes people (demand), (5) spatially explicit, and (6) iterative, with built-in feedback systems for knowledge creation, modeling, analysis, synthesis, and decision-making (Ruckelshaus et al., 2013).

We found through our early training and capacity-building efforts in workshops, courses, and projects around the world that we needed an exercise to introduce concepts quickly and simply while mirroring our analytical approach. Although InVEST models are intended to be easy to use, the process of preparing spatial data, running software tools, and appropriately interpreting results can be challenging for new and advanced users alike. We sought a more effective means to convey our approach to a broader audience of potential users and decision makers, especially those who are not computer savvy or experienced scientific modelers.

One method we have tested is gamification. Creating a serious game to teach natural capital and valuation concepts held promise for several reasons. Scholars have proposed that games incorporate important learning concepts in their design and inspire intrinsic motivation in players and learners (Malone, 1981). The model of game-based learning uses accepted educational strategies, building on the process of doing, reflecting, understanding, and applying knowledge (Dieleman and Huisingh, 2006; Pivec and Dziabenko, 2004). Games promote active participation by setting a clear goal, offering frequent feedback to users, allowing player control over the process, and heightening curiosity by presenting uncertain outcomes and collaboration and competition (De Freitas, 2006; Foster, 2008; Malone and Lepper, 1987). By contextualizing basic concepts and anchoring new information to experience, games encourage assimilation of ideas and principles in learners (Cordova and Lepper, 1996; Foster, 2008). Most importantly, games are fun. They have been used to educate users and prepare them for taking real-world decisions about a variety of environmental challenges (Ulrich, 1997), including water basin and agricultural land management (Rajabu, 2007; Schulte et al., 2010), landscape planning (Lawson, 2003), habitat connectivity and loss (McIntyre, 2003), and invasive species (Hopwood et al., 2013).

Despite widespread support for the theory that games provide motivation for learning (see Wilson et al., 2009), results are mixed on the effectiveness of games for learning outcomes—for example, the transferability of game learning to novel or authentic situations (O'Neill, Wainess, and Baker, 2005; Randel et al., 1992; Vogel et al., 2006). Yet, there is some empirical evidence that games, and especially simulation games, can result in improved and sustained learning of basic concepts (Bellotti et al., 2013; Kiili, 2007; Ricci, Salas, and Cannon-Bowers, 1996; Webb et al., 2012). Meta-analysis indicates that elements of objectives, sensory stimuli, challenges, mystery, and control, among others, in games can be effective in education and training (Garris, Ahlers, and Driskell, 2002; Wilson et al., 2009). There is debate as to whether elements of fantasy or authenticity (also referred to as representation) are most important to promote learning (e.g., see Kiili, 2007; Wilson et al., 2009).

Our purpose in developing this simple game is to introduce a diverse set of audiences to concepts related to nature's benefits to people and their values. By incorporating known learning elements into a game environment, we aim to teach users about synergies and trade-offs among market and nonmarket values of ecosystem services. In particular, we introduce elements of clear objectives, sensory stimuli (especially visual and auditory), challenges, mystery, control, and both fantasy and authenticity into different game modules. Through the game, users simulate simple scenarios that have alternative ecosystem service outcomes demonstrated through points won and lost, so that users can (a) quickly learn basic concepts to recognize and act on nature's values and (b) understand a commonly used way to visualize and quantify ecosystem services, drawing on NatCap's approach used in science-policy initiatives around the world. After playing the game, players should be able to describe how considering ecosystem services in a decision can affect its outcome.

Tradeoff! made its debut in an initial edition, *Best Coast Belize*, in July 2011. It was first designed as an interactive exercise for marine conservation practitioners in the Caribbean and has since been hosted by NatCap and World Wildlife Fund (WWF), as well as a range of universities, nongovernmental organizations (NGOs), and scientific conferences. As of May 2014, it had been played by more than 1,000 people, including policy makers, students, researchers, NGO practitioners, and InVEST users.

Tradeoff!: The Game

Tradeoff! frames common natural-resource decisions, like spatial planning and land management, in a way that is fun and easy to understand. Through a 60-minute game flow, participants simulate a full-cost assessment of a decision by using spatially explicit information about nature's value to people. *Tradeoff!* provides simple, *gamified* illustrations of how complex ecosystem service models work. The value of this exercise lies in its ability to convey basic ecological economic concepts quickly, including ecosystem services, market and nonmarket valuation, and scenario comparisons. This enables players to learn by doing in a tailored, high-stakes policy or management decision.

The *Tradeoff!* series focuses on trade-offs and synergies among revenue-generating activities and the values of the services they depend on, including carbon sequestration for climate mitigation, flood protection, habitat quality, water availability for hydropower potential, and access to nontimber forest products. Game modules illustrate the environmental and economic impacts of coastal management decisions, infrastructure development, disaster risk planning, and protected area creation. Through interaction and discussion, players test different strategies to earn the most points. The exercise presents participants with the opportunity to integrate values of nature into concrete decisions with rewards and penalties, and to learn how this information can be used to identify synergies and reduce trade-offs.

Tradeoff! offers a familiar board game experience with physical playing board, game pieces, rules, and points calculator. A set of large-format maps provides clear information about ecosystem services and a subset of market and nonmarket values. The game is played in two rounds by using pieces that represent development decisions. Each team should consist of two or more players. A maximum of eight individuals per team is recommended since it can be difficult for players to access the board with larger teams. To make the game play competitive, at least two teams are required. There is no limit to the number of teams—provided that enough game boards, pieces, and scorers are made available. Players must place different pieces where they think it will maximize their points score. After round 1, an online (and downloadable) calculator scores the points each team receives from the market value of those activities. The calculator also reveals the points lost due to trade-offs from impacts on the nonmarket values of ecosystem services, which can reduce the benefits they provide. The resulting total is the round 1 score for each team, which is typically lower than players expect because of damages to ecosystem services that are not directly priced in the marketplace. In round 2, players are provided with explicit information about ecosystem service values to improve their scores. They can move their economic development activities and also protect valuable services by designating protected areas, offsets, or other conservation-friendly uses. After a timed round, the calculator computes a final score. Teams win prizes (or bragging rights) based on the highest overall score and the greatest improvement from round 1 to round 2.

Best Coast Belize

We began development of the *Tradeoff!* series with a game module simulating how nature's benefits affect the value of coastal livelihood options—specifically, fishing, tourism, and coastal property. In *Best Coast Belize* (Figure 1), ecosystem services include coastal tourism potential, fish catch and revenues, and coastal protection from storm surge and erosion. These values are extrapolated and summarized from a real ecosystem service assessment undertaken by NatCap, WWF, and the government of Belize to design a coastal management plan (Clarke, Canto, and Rosado, 2013).

In round 1, *Best Coast Belize* participants are provided with two out of four maps showing potential revenues from coastal tourism and fisheries along Belize's coast. As developers, each team must build three hotels and site five fishing camps by strategically placing them on the appropriate maps depicting potential recreation and tourism value and the potential value of coastal fisheries. Teams earn points by adding the values of the squares adjacent to where they placed each property. In between rounds, teams learn their round 1 net score, which includes points gained from development and points lost for the impact those developments have on coastal and marine ecosystem services.

The rules are designed to reveal critical information gradually, giving players an opportunity to maximize points with additional information on nature's values. Round 1 provides information only about how much teams can earn for each coastal development activity—the kind of information typically used in development decisions, whereas round 2 reveals how the benefits from nature we depend on can be lost (or gained) by choosing where to develop and where to protect. After round 1, participants are provided with two new maps showing the locations of natural habitats and nonmarket values of nature, like shoreline protection. The goal is to earn the most points by practicing smart planning to account for these values, which ultimately affect economic activities and people's welfare. Here participants must consider multiple trade-offs, including the value of healthy ecosystems as nursery habitat for economically important fisheries and as coastal protection from sea-level rise, storm surge, and flooding. These nonmarket benefits can translate to food security, additional jobs, and reductions

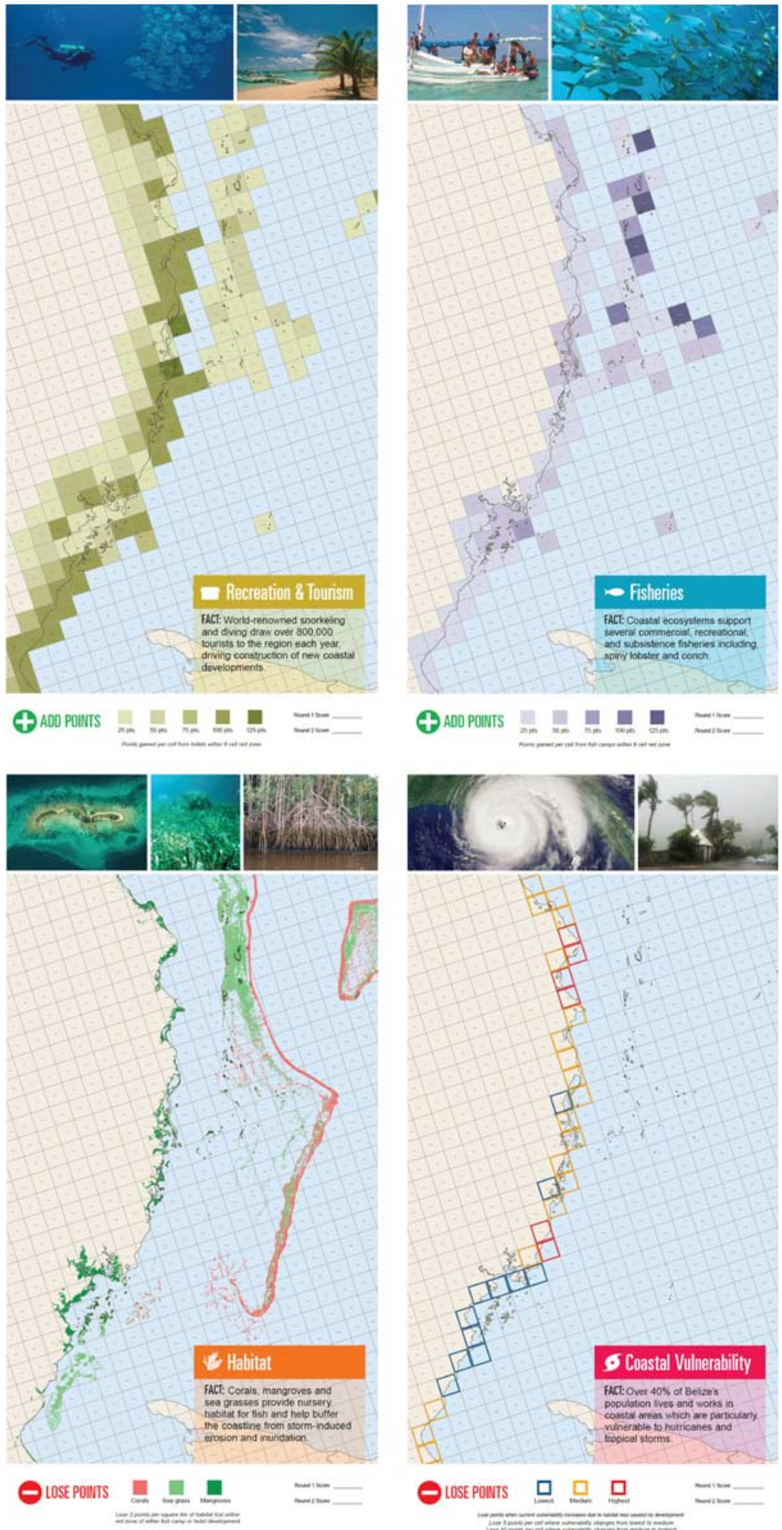

Figure 1. Full game board for *Best Coast Belize*. *Darker-colored cells* in the **top two panels** (Recreation & Tourism and Fisheries) offer more points (or revenues) for their activities. The **bottom two panels** (Habitat and Coastal Vulnerability) are revealed once participants complete round 1.

in property damage. Teams must carefully weigh these benefits against the development goals of round 1.

There are two ways to improve one's score in round 2: First, participants can designate up to five marine protected areas (MPAs), which preserve habitats from destruction and degradation and protect the services they provide.

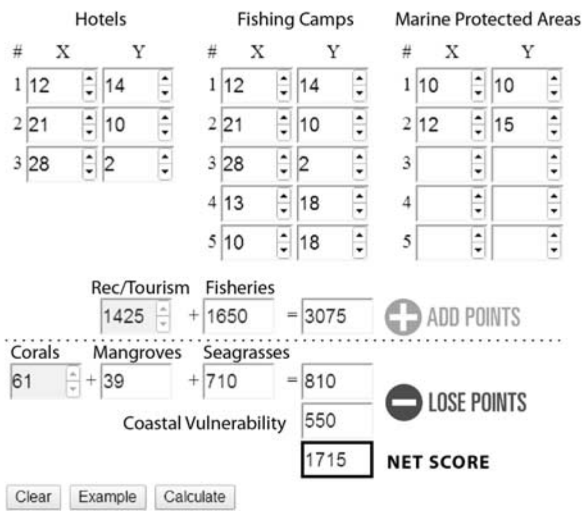

Figure 2. Downloadable, online scoring calculator.

The placement of an MPA in a particular cell forgoes the points earned from development activities, but teams are not penalized in that cell for impacting habitat from hotel or fishing-camp development. Second, teams have the option to relocate any or all of the hotels and fishing camps to new locations so as not to disturb as much habitat. They are forced to assess trade-offs between earning points for high-value areas and losing them by impacting ecosystems. Figure 2 provides an example of point tallies from round 2 of *Best Coast Belize* by using the online calculator.

We also highlight a specific example of development and protection decisions that might occur during round 2 in the *Best Coast Belize* module. Figure 3 depicts how building a hotel along the coast can create new jobs and revenue through tourist expenditures. The trade-off, however, is that removing mangroves during the construction phase can reduce the protection these ecosystems provide to people and property. Mangroves and other habitats like coral reefs and seagrass beds serve to buffer coastline by reducing the energy of waves. Without this natural defense, people and property are more susceptible to hurricanes and other major storm events. The game simulates mangrove habitat loss caused by hotel construction and subtracts points from the overall score. The calculator deducts two points for every one square kilometer of habitat within the area of

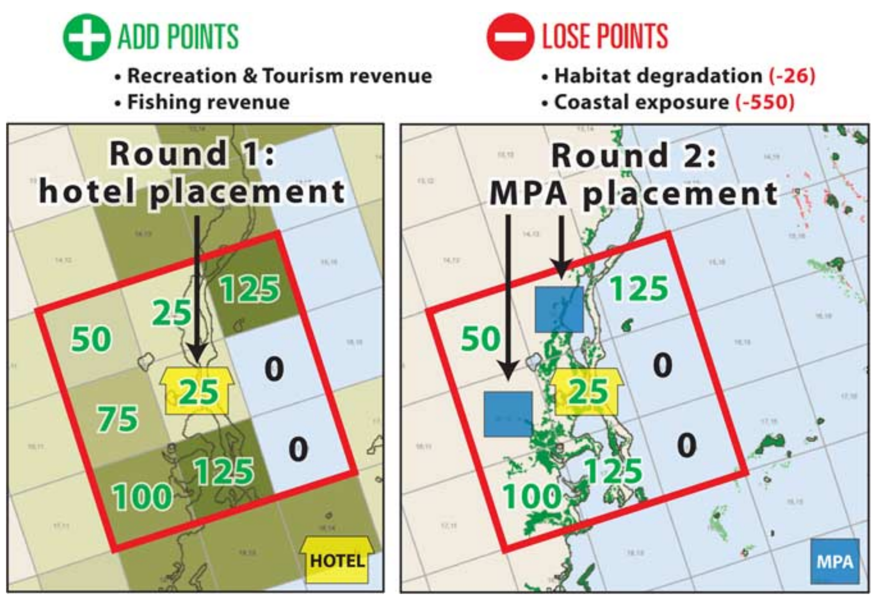

Figure 3. One concrete example of how the game works. The nine-cell impact zone (*red box*) indicates where points are gained by the placement of a hotel **(left panel)** and the points lost (26 points) from impacts on mangroves (*dark green areas*) and other coastal ecosystems **(right panel)**. Points are also lost (550 points) for increases in coastal exposure to storm-induced erosion and flooding. In round 2, placing a marine protected area (*blue square*) on the game board prevents the loss of points in that cell, but also zeros out any points to be gained where it is placed **(right panel)**.

influence, designated by the red impact zone. The degradation or loss of habitats near coastal settlements will also result in point deductions for increasing coastal vulnerability to storm surge and sea-level rise. If a team decides to build a hotel in the location shown in Figure 3, it can potentially earn 525 points from this development activity. The consequence, however, is the hotel's impact (red box) on habitats and resulting reduction in coastal protection service provided by mangroves. Designating MPAs (denoted by the blue squares) is an option in round 2. In this example, designation of the two MPAs will decrease hotel revenue by 100 points but also avoid losses from development impacts on mangroves along the coast. The strategy is to minimize loss of points from habitat degradation and increased coastal vulnerability from the hotel development while still collecting the revenue in the remaining seven cells of the red zone. The challenge is to use the maps and values to find a balance between maximizing your profits from development while minimizing harm to coastal and marine habitats.

Testing, Feedback, and Improvement

We tested *Best Coast Belize* in 15 nations with more than 1,000 participants. Playing venues included conferences, formal meetings, guest lectures, undergraduate and graduate courses, workshops, and technical trainings. As recommended by Bellotti and colleagues (2013), we collected user feedback throughout the testing phase to refine the exercise and improve the overall learning experience. Following game play, we circulated a survey (in the context of trainings), facilitated feedback discussions, and/or requested written ideas and input from game players and facilitators. We also analyzed transcripts from discussion along with video of the session to iteratively improve the game.

Early on, we conducted a focus group consisting of eight environmental scientists and communications specialists. Suggestions provide by this group led us to make major modifications to game flow along with important simplifications and visual improvements. Once the game was officially launched in October 2012, we used feedback collected from participants at actual trainings to further refine and improve the game. After we began distributing the game in early 2013, we also collected suggested improvements via e-mail from individuals who hosted *Tradeoff!* independently.

Our evaluation approach mirrored many of the techniques described in the human–computer interaction (HCI) literature. Originally called *human subjects*, HCI is a branch of cognitive science rooted in psychology, ergonomics, computer science, and operating systems. HCI aims to satisfy the needs of users by designing a product guided by how these individuals perform in their specific environment. Usability evaluation methods are essential to the successful development of a game like *Tradeoff!* because they enable developers to understand (a) user expectations, (b) usability, and (c) interaction of user and game within an environment (Haklay and Tobón, 2003; Jankowski et al., 2006).

One method for usability testing was to analyze responses from posttraining surveys administered at 18 different workshops where *Tradeoff!* was played. Although the survey did not include specific questions about the game, we were able to garner valuable feedback based on responses to the following two open-ended queries:

1. Please identify two things you found the most useful from this course.
2. What recommendations do you have for improving the course?

In short courses (less than two days long), approximately one-quarter of respondents specifically mentioned *Tradeoff!* as the most useful session of the course. This number might have been higher had the survey included a multiple-choice option of course activities. Since the survey was administered at the end of the training after multiple lectures, activities, and discussion sessions, the game was likely no longer top of mind.

Responses from a training for ecosystem service professionals indicate that the game is not well suited for participants with advanced knowledge of the science or application of ecosystem service information. Participants provided comments such as these:

> While I really enjoyed the Belize game, I think I would have preferred to use that time to talk about InVEST more in-depth.

> The game… probably took more time than it was worth to make its point.

At the midpoint of our testing phase, a collaborator who served as a game facilitator during a three-day training suggested improvements for an early version of *Best Coast Belize* that highlighted the importance of time management, clearly explaining the rules, and leaving ample time to discuss the results (Dieleman and Huisingh, 2006):

> *Best Coast Belize* could have used more structure. Participants… would have benefited from more coaching from us. After [the instructor] explained the

"We used *Best Coast Belize* ... as part of a training workshop on measuring ecosystem service values at the site scale. Participants … felt that it helped them understand some of the basic concepts being applied. They often had some suggestions for improvement, as well. It would certainly be useful to have different versions of the game available. These would provide greater relevance to some of the people we have been working with." **—Jenny Birch, ecosystem services officer, BirdLife International**	"I ran [*Best Coast Belize*] in my undergrad ecosystem services course at the end of May, and—no exaggeration—it was a smash hit! One student said, 'This activity helped me understand the concept of sustainable development better than this other course in which I got lectured at about theory for three weeks.' The students really got into the activity, and it was a great learning tool and great fun to play." **—Josh Goldstein, senior scientist at The Nature Conservancy (formerly assistant professor at Colorado State University)**	"[*Tradeoff*'s] ability to demonstrate a field-validated approach to environmental planning based on an actual ecological data set is an essential activity. While students can read about real-world examples or hear about them in lectures, actually working through the financial–ecological trade-offs in a hands-on way is critical for the way that students approach future decision making. I think the activity is an incredible example of one way to better approach conservation/development decision making." **—Christie Klimas, professor of ecology at DePaul University**

Figure 4. Reflections on *Tradeoff!* from educators and practitioners who hosted the game.

> exercise it may have been good for us to provide more guidance as coaches in individual groups. The instructions and purpose of the exercise were not overly clear…. [T]he big issue was we didn't have enough time to get the results and discussions. There should be a more sound process on getting results and interpretation…. I liked the idea of the game but it was too complex in how it was depicted to be able to make good decisions in the time we had.

We used these recommendations and other responses to improve *Best Coast Belize* and to create additional modules. We simplified our introduction to the game and clarified the rules through written instructions. We also began managing game play more effectively to allow for ample discussion time. With a more user-centered design in place, we could better anticipate the needs of future participants and focus on learning objectives rather than clarifying rules and other details.

Here we highlight some of the key lessons learned through this testing period, as well as a set of learning principles distilled from our development process. These principles are general guidelines for using game-based learning as an environmental learning tool.

Lessons Learned

Tradeoff! has been particularly effective as an educational tool for an audience new to the fields of conservation and sustainable development. These participants benefited from the game's clear illustration of core concepts, first-order principles, and directional relationships similar to those included in the InVEST ecosystem service models. A majority of players provided positive feedback about the game—focusing on its entertainment value and learning potential (see Figure 4). Since the introduction of the game, the number of InVEST software downloads and requests for training support has increased. However, we have not studied whether this increase in demand was caused by the game. Through both formal and informal testing of *Tradeoff!* among different audiences, we draw several lessons including a set of benefits and drawbacks.

Overall, *Tradeoff!* engages a diverse audience including policy makers, scientists, planners, and students—all who can build on prior knowledge through group participation. A typical team of eight participants could have experience in the fields of planning, spatial analysis, ecology, and conservation. This exercise enables teams to leverage their expertise and collaborate on a successful strategy. Team members can also learn from one another while they problem solve. In postgame conversations, players have noted that this game creates a participatory, fun learning environment during a workshop, conference, symposium, course, or technical training. Since its introduction, *Tradeoff!* has become one of NatCap's most requested teaching tools for multiple formats; for example, it has been used as an icebreaker at the start of a meeting, as a hands-on module in a university course, and in model training workshops to illustrate the fundamentals of bringing natural capital information into decision making.

In particular, we found that setting *Best Coast Belize* in an iconic, attractive location—with palm trees and beautiful beaches—engaged most audiences. A real location helped the majority of players contextualize knowledge without losing the fantasy elements that allow participants to invest in collaboration and competition because of uncertain outcomes (e.g., see Kiili, 2007; Wilson et al., 2009). One exception to this finding was scientists: researchers with deep, precise ecological or socioeconomic knowledge of the place objected to distortions in real data. Based on these findings, we suggest that a game's intended audience is the most important determinant whether to favor fantasy or authenticity in game design.

There are also some drawbacks to using a simulation game to teach real-world processes. By gamifying a set of complicated, overlapping phenomena into a 60-minute activity, certain concessions are required. To highlight basic principles, *Tradeoff!* uses simple, illustrative examples of common human–environmental interactions and complex ecological processes. For example, in reality, the revenue from and impacts on habitats from fishing and coastal development do not occur in uniform nine-cell impact zones. This kind of concession can represent a disadvantage for certain audiences, such as veteran scientists and modeling experts. Players who were deeply immersed in the ecological study of a region had difficulty overlooking certain realities, such as hydrological complexities that limit the benefit of riparian vegetation under certain conditions not clearly delineated in *Tradeoff!* In addition, we found that a single setting with a subset of ecosystem services—the coastal and marine focus of *Best Coast Belize*—was not relevant to all audiences. Without clear contextual relevance for players, the game lost some of its educational capacity—a finding consistent with the literature (e.g., see Foster, 2008; Kiili, 2007). For example, participants in landlocked countries like Nepal and Bhutan were not interested in exploring marine resource management strategies.

Based on this and other feedback, we began replicating the exercise and created additional modules that explored new ecosystem services, geographies, and decision contexts. While the rules and overall framework remained the same, we created a new version focusing on terrestrial and freshwater services and impacts from land use conversion to ranching and agricultural activities. Each new module developed will be subject to a similar testing phase to improve the game-playing experience and enhance learning.

Learning Principles

During the development and testing phases, significant modifications, based on repeated review and evaluation, were made to the games. The changes were made with two objectives in mind: (a) enhance learning by players and (b) improve the user experience. Here we offer these insights as learning principles for those seeking to develop similar exercises. To build a serious game that is both fun and educational, designers should consider an approach that incorporates the following concepts:

Simplify and Clarify

Don't try to do too much. We found in the first iterations of *Best Coast Belize* that players could not capture the nuances of an ecosystem service assessment. Our rules were too complex and our learning objectives were too onerous. Through testing, and many amendments to game design, we simplified and clarified to a few basic concepts that could be adopted by players with diverse backgrounds and knowledge. A simple, clear, and fun activity can break down barriers to interaction and learning by overcoming an individual's reluctance to participate because of a perceived lack of prior knowledge, expertise, or professional standing (e.g., see Pivec and Dziabenko, 2004; Wilson et al., 2009). A simplified version of *Tradeoff!* was less intimidating and encouraged active participation from a more diverse set of individuals. Instead of explaining the entire scientific analysis, *Tradeoff!* now teaches a few key elements that participants can build from: ecosystems provide benefits to people; these benefits are not always captured by dollars and cents in the market; our choices affect the whole suite of these benefits, or services, and their value; and, our decisions create trade-offs that we need to reconcile to have the best outcomes for people and the environment.

Optimize Game Flow

Games can deliver new information effectively and quickly, but, without good flow of activities and investment from players, they can be dull or boring. Paying keen attention to the game's flow—its pace, triggers, incentives, and outcomes—is important to create a compelling user experience (e.g., see De Freitas, 2006; Garris, Ahlers, and Driskell, 2002). We went from one long game with many rules, and all information revealed up front, to a quicker game (60 minutes or less) with two rounds, which gradually revealed germane information to influence uncertain outcomes, heightening the mystery and challenge of the game (see Wilson et al., 2009). We found that breaking up the game play allowed us to start playing quicker, providing fewer rules to remember for each round, and to enhance learning by letting players experience the outcomes of alternative strategies and decisions with different types of information. By varying the number of teams and activities, we increased the opportunities for collaboration and competition and the uncertainty of the outcomes. This made the game more fun for players and appeared to enhance learning of basic concepts.

Practice Good Design

Our earliest iterations of the game were hastily put together with maps straight from a geographic information system (GIS), paper playing pieces, and a manual approach to calculating scores. To support game flow, we found it necessary to distill and formalize the game's rules. This meant simplifying and clarifying rules and drafting an official rules sheet. Standardization made for more seamless replication of the game and comparative evaluation of the experience. We also improved the graphic design, including layout of the game boards and playing pieces. This made it easier for players to intuit and remember rules and goals of the game, providing a more compelling experience overall. We also created an automated scoring calculator, which offered quicker feedback to players eager to see the outcomes of their game strategies. Requests to use the game as a learning tool increased rapidly with these improvements, and with better design we were able to disseminate online kits for independent use. Feedback from players made it clear that these improvements made the experience more enjoyable and better targeted to our learning goals.

Build from What You Know

One of the appeals of gamification is that it helps contextualize knowledge (Foster, 2008). People learn by linking new concepts and ideas to their existing worldview and knowledge (Cordova and Lepper, 1996). Using multiple modules with alternative decision contexts and ecosystems allows people to choose the one that best fits their situation and current understanding to subsume new information and methods more readily (e.g., see Kiili, 2007). Early testing of the Belize module was relevant to those interested in coastal management, such as players in Vietnam, Mozambique, and nations in the Caribbean, but not in Bhutan and Nepal, where participants' research focus was on freshwater and mountains. It became clear that some participants did not have the existing knowledge to relate to a focus on marine-ecosystem management. By offering multiple decision contexts and geographies as part of a suite of modules, we are able to reach a broader audience. Contextualized content enables easier uptake of core principles (Cordova and Lepper, 1996). When participants are able to build from what they know about sustainable development or natural resource management, this implicit knowledge seeds greater learning of concepts introduced by the game.

Conclusion

Despite their importance, ecosystem services are not normally included in resource decisions. This is often because practical, credible information about them is lacking or inaccessible. Mapping and modeling ecosystem services can help uncover hidden costs and benefits of different natural resource management options, providing key information to improve the relationship between people and the ecosystems on which we depend. In this article, we explain how gamification of a science-based approach can serve as a valuable educational tool, especially in the field of ecological economics. The resulting set of games, *Tradeoff!*, offers a compelling and fast way to explore ecosystem service concepts, including scenarios, trade-offs, and valuation.

In particular, *Tradeoff!* has proven an effective introduction during NatCap's applied and technical workshops and for teachers in the classroom. By offering a fun, accessible group experience, we can highlight the results of complex interactions between people and the environment without the technical requirements of a typical decision-support tool. Future research by the authors will identify effective next steps to bridge the gap between the basic concepts illustrated by the game and the more technical facets of putting decision-support tools like InVEST into practice.

Building on recent improvements, we intend to expand *Tradeoff!* beyond the current modules and develop online application (app) versions of the game. For these and other versions, we seek to incorporate a role-playing component for participants to learn from multiple perspectives, simulate a stakeholder process, and work collaboratively to reach compromise. We hypothesize that these new dimensions will enable us to reach new audiences effectively and to enhance the learning opportunities for players. Challenges posed by these innovations include applying our learning principles to an online individual experience, addressing additional trade-off and synergy questions through new modules, and creating a hierarchy of complexity or levels to build intermediate to expert knowledge in ecosystem service decision making.

Game-based learning has the potential to serve as a powerful gateway to a variety of science-based approaches and tools. The learning principles distilled from the design and testing process can be used to create new, effective environmental games. Moving forward, we seek new pedagogical approaches to meet the demand for capacity building and strengthening efforts that can effectively train the next generation of scientists, policy makers, and practitioners.

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