Title: Theoretical challenges in designing a social simulation game of balancing sustainability objectives in fisheries management

Authors: Jørn Weines[1], Melania Borit[1]*, Petter Holm[1], Rafal Hrynkiewicz[2]

Affiliation: [1] UiT (University of Tromsø) - The Arctic University of Norway, Norway
[2] T-Xchange, The Netherlands
* Corresponding author: melania.borit@uit.no

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1. Introduction

Management of socio-ecological complex adaptive systems (SECAS) such as fisheries is not an easy task. Modeling and simulation have been and remain to be among the most common tools to support decision making in fisheries management (Schnute & Richards, 2001). However, modelling fisheries as SECAS is a significant challenge due to the characteristics of these systems (e.g. coupled human-natural systems, nonlinear feedbacks, strategic interactions, complexity) (Österblom et al., 2013). While a great deal has been achieved in modelling the natural part of fisheries systems, modelling the social processes underling the human dimension of these systems is still a major challenge. Certain such processes are ordinarily implicit in humans behaviour, and thus, they are difficult to grasp by the modeller. In our research we intend to use a social simulation game to explore the social processes behind the design of fisheries management plans, as a preliminary tool in the process of building an agent-based model of these social processes. Such social simulation games are a kind of abstraction in which certain social process are explicitly mirrored in the structure and functioning of the game (Coleman, 2006). This paper focuses on the first phase of this research, i.e. designing the social simulation game, a phase in which we attempt to answer the questions of: 1. taking an Actor-network theory (ANT) (Latour, 1987) approach, what is the level of reduction, abstraction and symbolization necessary to capture the core social processes of designing fisheries management plans; and 2. how does this level shape the way in which the social simulation game allows for transportation between the different realities of the game and the real world. We describe here the theoretical challenges we experienced during this phase. As such, this research can be considered work in progress.

Even though there are many studies in the domain of social simulation (see, for example, the research published in the *Journal of Artificial Societies and Social Simulation*) and in the domain of using games for nature resource management (see, for example, volume 38 issue 2 of the journal *Simulation & Gaming*), to our knowledge there are only few description of how to design a social simulation game, i.e. a game as a simulation of social interaction (e.g. (Coleman, 2006)). Therefore, our study could contribute to the research field of social simulation and games by providing a detailed description of the theoretical challenges encountered when designing such games.

2. Context of this study

The practical context for exploring our research questions is the development process of the Green Grouper Social Simulation Game (GGSSG), a serious game about the process of creating a management plan for a sustainable seafood industry based on the harvest of the invented fish species Green Grouper in the fictitious world of Simnesia. This board game is meant for the first year students in a Norwegian Bachelor's program in Fisheries and Aquaculture Science (FHV), and in its iterative development are involved second year students of the same Bachelor's program and the game design firm T-Xchange, The Netherlands. Using GGSSG in a learning context is based on approaches to learning such as student active learning (Felder & Brent, 2009); game-based learning (Tobias, Fletcher, & Wind, 2014) and learning through role-playing games (Blanchard & Buchs, 2015)s; authentic learning environments (Herrington, Reeves, & Oliver, 2013); cognitive apprenticeship (Collins, 1991).

The intended learning outcomes (ILOs) of the learning session during which the game is played are as follows: 1. Experiment the interdisciplinary complexities in making and implementing management plans, and explain the basics about marine resource management; 2. Appreciate the interdependence between the management actions and the three sustainability pillars (Economic, Environmental and Social sustainability); 3. Experiment and explain that no perfect management plan exists, but many possibly viable solutions do.

The game scenario casts the players as independent consultants hired by the Simnesian authorities to design an environmentally, economically and socially sustainable management plan for the Green Grouper using combinations of the 14 management tools that are available to them and information about the effects of these tools on each of the three sustainability pillars.

The game is divided into four levels. Each level builds on the knowledge and experience gathered during previous level. Each level is therefore an increase in complexity and challenge. At the end of Levels 1 and 2, a draft Management Plan has to be submitted by the player, in order to be scored by the Game Master (GM). In addition to the score, the players receive stakeholder feedback on the sustainability dimensions in play. At the end of Level 3, the full version Management Plan is submitted and scored by the GM and sent on public hearing. In Level 4, the stakeholders' reactions to the plan – which focus on short-term effects in addition to long-term sustainability - are communicated to the player. The player has to decide how to change the Management Plan in order to address stakeholders' reactions. Players/teams of players move to the next level if the plan submitted achieves the score that the GM asked for. If the score is not achieved, the player/team can improve the plan within the available time. When the time is up, the GM calculates the score and the player/team moves to the next level.

The game is a combination of cooperation and competition. The cooperation part is present in the players working together as a team, making their management plan. The competition is between the teams themselves, where each team strives to have a plan that is superior to other teams'. In addition, there are some opportunities for cooperation between teams. The game can be played by 1 to 4 players per team, each team under the supervision of a GM. A number of teams can play the game simultaneously. Multiple players in a team are preferred, as it enables the "think aloud" process, explicit discussion of reasoning behind the choices and learning from peers. The GM has to be knowledgeable about the subject matter and also have a thorough understanding of the game rules. A GM facilitates gameplay and (de)briefings, and explains how this game fits into the course and in a broader sense, the reality around on which this game is based. Experienced GMs can alter the game rules and conditions on the fly, whether to address specific learning goals or to focus on a specific task or topic.

3. Theoretical challenges

3.1. Defining the reference system

In an Actor-network theory (ANT) (Latour, 1987) approach, reality is understood as heterogeneous networks, and fisheries management is such a network, where the natural system, the human system, knowledge and technology meet and mix. Following the same ANT line of thought, for a process to be social it has to allow for interaction between agents (human and/or non-humans; material and/or immaterial) and/or groups of agents; e.g. interaction between children in a classroom, between bees in a hive, between robots working on a task in a factory, between a researcher and the concepts he/she uses. As such, in our research we are interested in exploring the *social processes behind the design of fisheries management plans* (i.e. our reference system; layer A, Figure 1), understood as the interaction between: 1. planners (e.g. scientists designing the plan); 2. authorities (e.g. Ministry of Fisheries); 3. stakeholders (e.g. fishers, association of fishers, fisheries industry, non-governmental organizations, the public, the media); 4. management tools (e.g. quota, enforcement); 5. management goals (e.g. sustainability); and 6. natural and human context (e.g. a very rainy season; elections with unexpected results). Even though it might be considered controversial by some fisheries scientists (be they social scientists or biologists), such an approach seems suitable for facilitating modeling fisheries as socio-ecological complex adaptive systems.

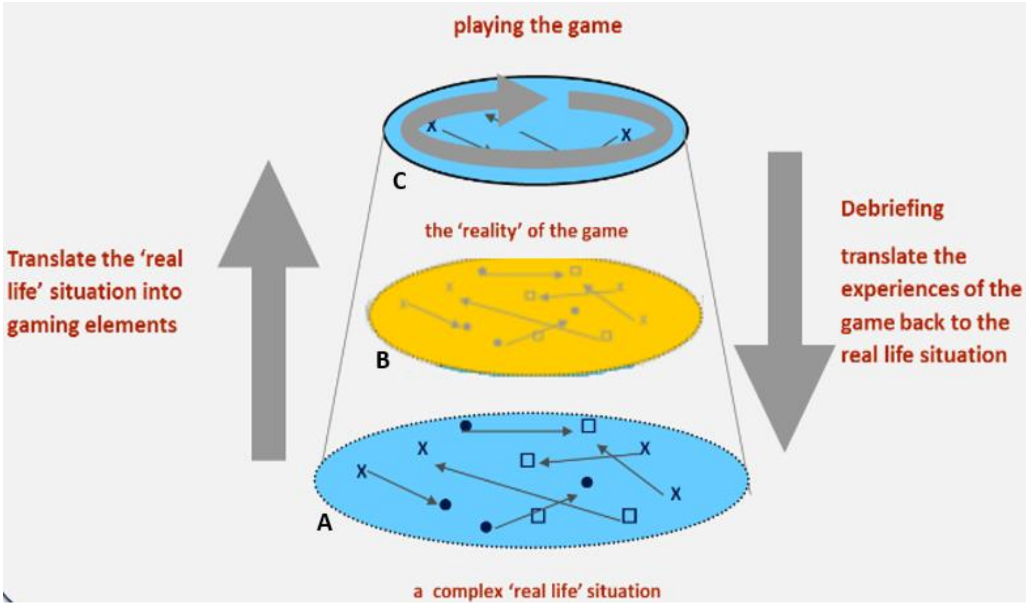

Figure 1. Layered realities. The relationship between the real life (A), its schematic (B) and the game (C) (from (Peters & Westelaken, 2014), with modifications).

3.2. *Creating the schematic*

System analysis is one of the four phases of the process of designing a simulation game (Peters & Westelaken, 2014). The purpose of this phase is the comprehensive identification of the relevant elements of the reference system and their relationships. This phase usually results in a schematic representation of the problem context, referred to as the "schematic" (layer B, Figure 1). When designing the GGSSG, besides consulting specialty literature, fisheries experts from different disciplines (e.g. biology, social sciences, food production, history) who are also teaching staff involved in FHV, together with second year FHV students, were used to identify the relevant elements of the process of designing a fisheries management plan, as well as the relationships between these, under the guidance of experts in game design.

3.3. *Mapping the schematic into the game*

One of the main tasks while designing a simulation game is to reduce the complex reality of the reference system (layer A, Figure 1) into a simpler model (i.e. the game model; layer C, Figure 1), with the use of the schematic (layer B, Figure 1). When doing so in GGSSG, we have used the three main steps described by (Peters & Westelaken, 2014): *reduction* (i.e. not all elements distinguished in the reference system will be included in the game, but only the critical ones), *abstraction* (i.e. the elements that will be represented in the game are not necessarily represented as detailed as they are in the reference system), and *symbolization* (i.e. the elements of the reference system are represented in the game in a new appearance). We consider this phase to be the most challenging in designing the game. During the reduction and abstraction steps we found it rather difficult to identify the critical elements of the reference system to include in the game and their level of detail so that we allow sufficient granularity for both achieving the ILOs and answering our overarching research question of exploring the social processes of designing fisheries management plans. During several rounds of playing the game with different students we have added and/or removed elements and details, and are now in the phase of deciding on the specific aspects and game mechanics of stakeholders feedback.

GGSSG uses the scenario mentioned in section 2 to match various challenges experienced in real-world marine resource management and seafood industries, without being a complete equivalent of the Norwegian context that the intended players are familiar with. This does not make GGSSG a management plan simulator, but represents a simplification of the planning process that takes place in the real world. The central elements of the process, the different management tools, are represented in the game through simplifications of their real-world counterparts. This is necessary not only due to the simplified game model, but also in order to make sure that, as in real life, there is no simple solution to meet the goal of the game. Likewise, the actions taken by the players are represented by different resources that correspond to different elements of a real planning process, such as accessing different management tools or more information about their estimated effects. Using the concepts of ANT, these game elements can be seen as representing the network of actors in the complex real-world management processes.

In our view, the game acts like as transportation vehicle from one type of actor-network (the game) to another (the reality). The different levels of reduction, abstraction and symbolization would allow for different directions of the movement in between these realities. For example, deduction is a way to explore the model by the version of reality it performs. This is explicit during debriefing (see Figure 1), but also an integral aspect of playing and design.

In designing the game we were inspired by the literature on the importance of debriefing for relating the game experience to the intended learning outcomes and translate it to learning, focusing on “what was done in the activity, how well the activity worked for the learner, and how the learning could be applied” (Nicholson, 2012). For GGSSG we used a brief session after the game to go through the first two points. Later the players attend a two lecture hours debrief seminar that focuses on linking the experience to the learning outcomes of the course. Here, the lecturer uses the plans made during the game as examples, and relates the Green Grouper crisis and examples from the real world.

3.4. Designing the social environment

A social simulation game always consists of a player acting in a social environment (Coleman, 2006). Usually there are two solutions for incorporating this social environment into the structure of the game. One is to allow each player in the game to act as a portion of the social environment of each other player. The rules of the game establish the obligations upon each role, and the players interact with each other while they act within the rules governing each of their roles (Coleman, 2006). A second way in which the social environment is embodied in a social simulation game is in the game rules themselves (Coleman, 2006). These rules may contain possible responses of the social environment representing the actions of human and non-human agents who are not players, but whose actions are nevertheless relevant to the player’s action. The embodiment of the social environment in the game rules requires more empirical knowledge of the responses of the system than does the alternative solution. However, this alternative solution requires greater theoretical insight, as in order to mirror the social phenomenon in question, each player’s goals and role constraints must be accurately embodied in the game rules (Coleman, 2006).

When designing the GGSSG, we chose a combination of these two solutions, with higher emphasis on the second one. Thus, a small portion of the social environment is represented by other players and the GM, and a large portion by the environmental response rules. In the GGSSG scenario, the players receive a task from the Simnesian authorities that has to be solved through interaction with players in their own player group and possibly through interaction with players of other player groups, in addition to interaction with game elements. The score of each player group in the game consists of qualitative evaluation performed by the Simnesian authorities according to the game environmental response rules.

4. Conclusions and next steps

In this study we have focused on the theoretical challenges of designing a social simulation game that we intend to use as a tool to explore the social processes behind the design of fisheries management plans. Having Actor-network theory as the main conceptual framework, we are challenged by the tasks of reducing, abstracting and symbolizing the reference system of designing management plans into the game mode. Using the ANT in GGSSG shows the agency of human (e.g. planners, authorities) and non-human agents (e.g. natural resources), material (e.g. stakeholders) and immaterial (e.g. knowledge, management objectives) agents that are involved in making a management plan, which in turn could inform the design of the agent-based model of designing fisheries management plans that we intend to build in later stages of our research.

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