Article

Better Game Worlds by Design: The GAS Framework for Designing and Analyzing Games Based on Socio-Ecological Systems Thinking, Demonstrated on *Nusfjord* (2017)

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Abstract

The goal of this article is to propose Game World Design and Analysis for Socio-Ecological Systems (GAS), a framework for the design and analysis of game worlds through socio-ecological systems lenses. Game World Design and Analysis for Socio-Ecological Systems invites designers to a structured reflection of their choices regarding game world correspondence with a real or fictional reference system (assessed through accuracy, comprehensiveness, and balance) and game world consistency. The framework spells out the main elements to be included in the game world for that to be a credible socio-ecological system. The GAS framework is demonstrated on *Nusfjord* (2017) as an exemplar of natural resource management–themed analog game. The framework is built using an interdisciplinary approach to game studies, history, media and literary studies, and natural resource management research. The application of the framework has the potential of making the design and analysis of game worlds more relevant to the sustainability discourse of the 21st Century.

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Introduction

Against the backdrop of the global development challenges of the 21st century, systems thinking is increasingly important for people's daily lives. Games also exhibit this trend, with scholars pleading for incorporating more complex systems concepts into commercial games as a way to offer "a public outlet for exploring the complex interdependencies of a changing world" (Kelly and Nardi, 2014, no page). While this is a timely and sensible advice, how to follow it is not straightforward, either from a design point of view or a game analysis one. This study aims to offer concrete guidance on how the concept of systems and, more specifically, socio-ecological systems (SESs), can be included in games, be they digital or analog, by proposing a framework for the design and analysis of game worlds: the GAS framework—**G**ame World Design and **A**nalysis for **S**ESs. The main research question of the study is to explore how SES thinking can be incorporated in the design and analysis of game worlds by building on knowledge and experience from the domains of game studies, history, media and literary studies, and natural resource management. The tool that we propose can be used when designing or analyzing games where SESs are a major part of the theme, type, category, or mechanism (e.g., *Agricola* (2007), *Suburbia* (2012), *Lignum* (2015), *Stardew Valley* (2016), or *Fishing: North Atlantic* (2020)).

After describing the GAS framework and its potential users (i.e., game designers and game analysts), we demonstrate its use from an analyst perspective, by examining *Nusfjord* (2017) as an exemplar of natural resource management–themed game. This is a successful and high profile board game, with a clear economic development theme and placed in a historical context. In this game, the players take the roles as the owners of a major fishing company in Nusfjord, a small fishing village in the Lofoten archipelago in Norway. Nusfjord is a real place and the Lofoten fishery is a significant part of Norwegian coastal and fisheries history. *Nusfjord* the game is designed by Rosenberg (2017) and it is published for the commercial entertainment market. The scope of the game analysis is to demonstrate the applicability of the framework in relation to the discourse on sustainable SESs management.

This study contributes to the debate on whether and how contemporary board games could become more progressive in their depiction of SESs (e.g., LaPensée (2016)). Today's game designers have certain responsibilities, and transforming players for the better is one of them (Schell, 2019). Designers have the challenge, and opportunity, to design for innovation, to produce ground-breaking player experience by trying to solve difficult problems in game design such as addressing the relationships between games and learning, or asking difficult questions about what games are, what they can be, and what their impact is on the players, both individually and

culturally (Fullerton, 2018). Responding to these demands, the GAS framework empowers designers to move players from having a simplified concept of the world they are immersing themselves in during play to reflecting on all dimensions of SESs and, as such, be more aware of the world they live in. The benefits of using GAS as a design tool range from streamlining world design practices to helping the designer in becoming an active agent of change through creating meaningful play.

Socio-Ecological Systems

Within a system, the component parts and the static relationships among them are the structure of the system, whereas the changes that occur in those components and the relationships among them over time are the processes characteristic of the system (Raser, 1972). Thus, in order to simulate any system, one must be able to describe both the structure and the processes of the system. Since SESs are a set of critical resources—natural, social (including cultural), and economic—whose flow and use are regulated by a combination of ecological and social systems (Redman, Grove, & Kuby, 2004), in their case, the structure includes component parts from both ecological and social systems. Fisheries, forestry, agriculture, water harvesting, or urban areas are examples of SESs. These are all instances when humans intervene in a natural environment that, in turn, shapes humans and their societies. A SES can be described in various ways: a coherent system of biophysical (e.g., grass and rocks) and social factors (e.g., rituals and employment) that regularly interact in a resilient, sustained manner; a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked; and a perpetually dynamic, complex system with continuous adaptation (Redman et al., 2004). As explained in Weber (2019), SES components interact in nonlinear ways that make responses and the effects of change difficult to predict. Socio-ecological systems function in a two-way feedback loop, in which a change in one subsystem can impact the other, and vice versa. Socio-ecological systems are hierarchic, for example, governmental institutions on city level, provincial level, or national level are hierarchical levels within the social subsystem, or the Antarctic Atlantic, the Weddell Sea, and the Larsen Ice Shelf depict a nested ecosystem with subsystems of different spatial scales.

As Ostrom (2009) explains, "SESs are composed of multiple subsystems and internal variables within these subsystems at multiple levels analogous to organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, etc. In a complex SES, subsystems such as a resource system (e.g., a coastal fishery), resource units (lobsters), users (fishers), and governance systems (organizations and rules that govern fishing on that coast) are relatively separable but interact to produce outcomes at the SES level, which in turn feedback to affect these subsystems and their components, as well other larger or smaller SESs." In real life, managing these systems without taking into consideration all their components and the relationship between them is considered a wicked problem, numerous examples showing how

challenging it is to develop fisheries, forestry, agricultural exploitations, mining, or urban areas in a sustainable way (Defries & Nagendra, 2017).

The SES that is included in the demonstration of the framework proposed by this study is fisheries. As explained in Syed, Borit, & Spruit (2018), the two main dimensions of a fishery are the human dimension (i.e., human agents, communities of these, and their institutions) and the natural dimension (i.e., biotic, such as predator species and prey species, and abiotic, such as water temperature and nutrients).

Worldbuilding

There are three dimensions that characterize every game (Aarseth, 2003): gameplay (the players' actions, strategies, and motives), game structure (the rules of the game, including the simulation rules), and game world (fictional content, topology/level design, textures, etc.). As such, there are many types of game design (Brathwaite & Schreiber, 2009): system design (the creation of rules and underlying mathematical patterns in a game), user interface (the design of how the players interact with the game and how the player receives information and feedback from the game through game components), and world design (the creation of the overall backstory, setting, and theme of the game; it often determines the scope of all the other design tasks related to the game).

The game world exists in the imagination of the player, and the game is a doorway to this world (Schell, 2019). The world presented by the game cues the player into making assumptions about the rules of the game (Juul, 2005). For example, if an object looks like a fishing boat, it is supposed to catch fish. At the same time, the rules of the game cue the player into imagining the world (Juul, 2005). For example, if one rule is that all the fish is sold at the end of a round, the player can imagine that there is a market for that fish, even though this market is not explicitly described. Thus, through the combination of rules, mechanics, and components, games create an imaginary world that the players experience. The actions made by players convey a sense of a connected whole: players create a story in the world of the game through the actions they make (Arnaudo, 2018). Worldbuilding is the design of this imaginary world, often beginning with space and time representations, but "potentially including complete cultural studies of inhabitants, languages, mythologies, governments, politics, economies, etc." (Fullerton, 2018) Designing game worlds bears similarities with the design of imaginary worlds for other media, for example, movies, literature, or extended reality (Zaidi, 2017). As such, methods to build worlds or analyze them can be borrowed and used across media.

According to Wolf (2014), imaginary worlds have three properties that have to be taken into consideration during the worldbuilding process: invention, completeness, and consistency. Invention can be defined as the degree to which default assumptions based on the real world (or Primary World) have been changed in the game world (or Secondary World), "regarding such things as geography, history, language, physics,

biology, zoology, culture, custom, and so on" (Wolf, 2014). Designers can decide if they want to invent a lot of the world (e.g., names, artifacts, technologies, customs, landmasses, animals, creatures, and laws of time and space), like in *Gloomhaven* (2017), which takes place in a fantasy setting. Designers can also stay as close as possible to the real world, like in *Agricola* (2007), where players are farmers in 17th century Germany. The second property, completeness, refers to the degree to which the world contains explanations and details players could expect. Besides the quantity of details included, a sense that the world has a background and history is also necessary for it to seem complete. The third property, consistency, is the degree to which world details are feasible and without contradiction (e.g., the world of *The Manhattan Project: Energy Empire* (2016)). Lacking consistency may make a game world seem sloppily constructed, or even random and disconnected. Inconsistencies may appear in the storyline, background details, world infrastructure, or world mechanics. As each of these properties grow, worldbuilding becomes more challenging because increased completeness requires more complex consistency checks, while consistency will limit what kind of invention is possible when the world grows. Thus, all three properties should be considered simultaneously as the world takes shape. The optimal combination of invention, completeness, and consistency would make a game world more or less believable, possibly having consequences on gameplay and the feeling of immersion (Wolf, 2014), although sometimes players may become less interested in the representational level of the game and more focused on the rules of the game (Juul, 2005).

When building a game world based on real places, people, or events, one also invokes history. Whether or not the game is designed as a historical game cannot be easily decoupled from the way in which it makes use of aesthetics that evoke a historical setting. Considering that games contribute to constructing players' understanding of their own past, it is critical to engage in the debates surrounding the legitimacy of games as historical representations (Begy, 2017).

In the context of a game that invokes a historical setting, an important element is that games are processes, not artifacts, and through gameplay they provide players with agency in how the representation of history is constructed and experienced (Kapell & Elliott, 2013). Furthermore, games allow players to both experience a systemic context for the actions they make as well as the consequences of these choices. The place of history in games is not only limited to illustrate actions and reactions but to foster engagement with the past. Returning to the argument made by Begy (2017), this makes questions of legitimate use of history apparent. The representations of history that players experience in games can form or shape their understanding of history. This means that game designers have the responsibility to reflect on the degree of accuracy (or the degree of invention, to use Wolf's terminology) they aim for when the game worlds they design incorporate or simulate the real world, and to make their decisions explicit, to avoid misunderstandings. For example, *Twilight Struggle* (2005), which simulates the Cold War between the United

States and the Soviet Union, uses the discredited geopolitical "domino theory" as the basis for its simulation, which makes an engaging game, but can promote misunderstanding of the complexity of the Cold War (Harrigan & Wardrip-Fruin, 2011).

GAS Framework

Description

While there are several influential publications for guiding game design (e.g, Bjork & Holopainen, 2005; Duke, 2014; Elverdam & Aarseth, 2007; Engelstein & Shalev, 2019; Järvinen, 2008; Juul, 2005; McCall, 2020; Schell, 2019), none of these includes a detailed description of how to design the game world. Facing this challenge when designing our own games, we decided to build the GAS framework as a solution that we first used ourselves and then decided to share with the wider community. Since worldbuilding is an exercise undertaken in a variety of other fields (e.g., movies, literature, or mixed reality experiences), although the terminology applied to the process may differ (Zaidi, 2017), advice on worldbuilding from these related media can be adapted for game design, and we have used this approach when building GAS. As noted by Rapoport, "[…] frameworks are neither models nor theories. Models describe how things work, whereas theories explain phenomena. Frameworks do neither; rather they help to think about phenomena, to order material, revealing patters …" (Rapoport 1985, page 256). As such, we have chosen to call our design and analysis tool a framework.

The GAS framework is visualized in Table 1. Out of space considerations, the table also includes a brief demonstration of the applicability of the framework from an analyst perspective. We chose this perspective in the demonstration and not that of a game designer because we considered that guiding the reader through reflecting over a well-known game is more effective in understanding the framework than exposing the reader to the intricacies of designing one of our own games.

The core principles of the framework are (1) games are vehicles that transport their players between different realities (Peters & Westelaken, 2014); (2) games tell stories through the combination of content and mechanics that create a consistent world where players have agency (Arnaudo, 2018); (3) like other forms of media, games are lenses through which their users experience and gain awareness of different topics (Schell, 2019). The framework is divided in three parts: decisions that are taken in the beginning of the world design phase (Part A), reflection over general elements of a SES (Part B), and considerations that have to be made in the end of the world design phase (Part C), although these considerations can be kept in mind throughout the design process.

The elements listed under Part A of the GAS framework invite to structured reflection over the *correspondence* between what is intended to be represented

Table 1. The **G**ame World Design and **A**nalysis for Socio-Ecological **S**ystems (GAS) framework. The framework can be filled in by the game designer(s) before, during, or after the design process, or by the game analyst. The framework has three parts: (A) start decisions, (B) SES reference model, and (C) final check. Explanations of how to fill in the framework are given in square parentheses. The questions in this framework focus on two main aspects: description of the design choices and reflection of why these choices. The reflection questions are made explicit. A brief demonstration of the framework on *Nusfjord* (2017) is included in italics (see *Demonstration* for more details about this game). The demonstration is made from the perspective of a game analyst.

	[If you are a game analyst, at all the reflection questions included in this framework explain what you consider the reasons of the game designer(s) were and if your answer is based on assumptions or on research.]
	[If you are a game analyst, answer the different parts of the framework in this order: A1, B, A2, C.]
Are you a game designer or a game analyst?	Analyst
A. Start decisions	
A.1. Description of the system represented in the game A.1.1. What is the system represented in the game? A.1.2. Is the system represented in the game a socio-ecological system? If yes, what system?	[Write a short description of this system.] *The fishing village Nusfjord, in Lofoten archipelago, Northern Norway, "50 years ago"* [If the game includes biophysical (natural) and social (including economic and/or cultural) variables, the answer to this question is yes.] [If the answer to this question is no, there is no need to continue using this framework.] *Yes. Exploitation of fishery and forestry*
A.1.3. Is the system represented in the game based on a previously described system, from real world or fictional? If yes, which one? If no, jump to question B.1	[If the answer to this question is yes, write a short description of this previously described system, from the real world or fictional. Include a reference to a publicly available description of this system.] [If the answer to this question is no, jump to question B.1.] *Yes, the real world village Lofoten, in Norway. The Lofoten seasonal fishery is an important part of the Norwegian past, with accounts dating back as far as there is recorded history. To give a sense of scale, the fishery is still world's largest coastal cod fishery, with up to 30.000 fishers at its height. Lofoten's importance, both as a spawning ground for the cod and the basis for small-scale fishers, makes it topical in ongoing discussions about tourism development* (Henley, 2016)*, environmental conservation, and industry development, such as potential petroleum exploration in the area. For more details, see* (Kolle, 2017c; Kolle, Nielssen, & Dossland, 2017; Johansen, 2014; Evjen, 2014)

(continued)

Table 1. (continued)

	[If you are a game analyst, at all the reflection questions included in this framework explain what you consider the reasons of the game designer(s) were and if your answer is based on assumptions or on research.]
	[If you are a game analyst, answer the different parts of the framework in this order: A1, B, A2, C.]
Are you a game designer or a game analyst?	Analyst

A. Start decisions

A.2. Correspondence of the game with the reference model (reference model = the model of the real world or fictional system described at A.1.3)

A.2.1. To what extent the game depicts correctly the reference model (i.e., the degree of accuracy)?	[If the reference model is based on a real word system, consider to what extent the game model depicts correctly historical events.] [Designer mode: Explain why you chose this degree of accuracy. Analyst mode: Explain what you find in the game.]
	[Write a short description and/or choose a number between 1 and 5, where 1 means to a low extent and 5 to a large extent.]	The mechanic of building boats does not match the historical ownership system where the vessels and equipment were owned by the fishers (Kolle, 2017a, 2017b; Solhaug, 1983), or that the Lofoten fishery was mainly seasonal, with participation from visiting fishers from the entire Norwegian coast. The framing of distribution via stock ownership does not match the historical systems, as in the period Nusfjord is set, the cooperative system and the Norwegian Fishermen's Sales-organization's monopoly was in effect. With the exception of some cards (e.g., Shipping Line and Customs Area), there are few references to export of fish, which was the main market for the historical Lofoten fishery. The laws governing the Lofoten fishery can be seen as an example of institutional sustainability, where the concerns for the many people relying on the fishery (and the fish stocks) were given more weight than industrial efficiency (Holm & Finstad, 2020). As such, intensive catch methods such as seine fishing were banned in the late 1800s. However, the game depicts modernization of the fleet. The occupations of the Elders are anachronistic (e.g., aquaculture rose to prominence several decades after the game's time frame). Moreover, nothing similar to the Elders mechanism existed in the real world
	Score 2 (low). The game creates a suitable world for players to run a major private company that harvests local natural resources to develop the area. Seen only as such, this works well. However, the stories the players experience when playing the game do not either represent the past or give insight into the interactions between historical stakeholders and their interplay with their environment	

Table 1. (continued)

		[If you are a game analyst, at all the reflection questions included in this framework explain what you consider the reasons of the game designer(s) were and if your answer is based on assumptions or on research.]
Are you a game designer or a game analyst?		[If you are a game analyst, answer the different parts of the framework in this order: A1, B, A2, C.]
		Analyst
A. Start decisions		
A.2.2. To what extent the game model encompasses all of the components of the reference model (i.e., the degree of comprehensiveness)?	[Write a short description and/or choose a number between 1 and 5, where 1 means to a low extent and 5 to a large extent.] Score 3 (moderate)	Forestry is a prominent part of the game, but commercial forestry is not possible in the archipelago due to the climatic conditions. Several artwork elements break with the historical accounts. The game boards show the archipelago and forests in sunny summer weather, which is not the season where the cod fishery takes place. The presence of various boat types (sloops, cutters, and schooners) are mostly variations of sailing ships that date from before the mid-1900s. The Sami people (i.e., Indigenous people of the northern parts of Norway, Sweden, Finland, and Russia) are highly visible in the Elders artwork. However, this representation is not representative of the Sami participation in the Lofoten fishery, as many coastal Sami fishers participated as fishers [Designer mode: Explain why you chose this degree of comprehensiveness. Analyst mode: Explain what you find in the game.] The game world encompasses many of the components of the reference system (see GAS Part B). The ecological elements are present, but as relatively unchanging, affected only by player actions. The artwork presents a stylized representation of the nature of the Lofoten archipelago, but does not manage to go beyond the clichéd landscapes described by Chang (2011), being mainly represented as a backdrop and a resource (Abraham & Jayemanne, 2017). The economic models are highly present and well developed, but do not interact with the related ecosystems. Many of the social components are present, but some categories are missing (gender) or misrepresented (Indigenous peoples). The elements of social-to-social interaction is weak. Social performance is highly visible as a result of the development done by players, but ecological performance and effects on other SESs are not touched upon

Table 1. (continued)

[If you are a game analyst, at all the reflection questions included in this framework explain what you consider the reasons of the game designer(s) were and if your answer is based on assumptions or on research.]

| Are you a game designer or a game analyst? | Analyst | | | | | |

A. Start decisions

| A.2.3. To what extent the game model is focused equally across the reference model areas of focus (i.e., the degree of balance)? | [Write a short description and/or choose a number between 1 and 5, where 1 means to a low extent and 5 to a large extent.] Score 2 (low) | [Explain why you chose this degree of balance.] Out of the five areas of focus, only the ecological one is well represented (see GAS Part B). Social components and interactions are somewhat represented. External forces and outcomes have little focus | | | | |

[If you are a game analyst, answer the different parts of the framework in this order: A1, B, A2, C.]

B. Socio-ecological systems reference model—Which of these elements are represented in the game and why?

Level 1	Level 2	Level 3	Level 4	Presence: Yes/No	Reflection: Designer mode —Why this choice? Analyst mode—What do you find in the game?
B.1. External forces	1.1 Settings	1.1.1 Economic development		Yes	Main objective
		1.1.2 Demographic trends		No	Might be implied
		1.1.3 Political stability		Yes	Players interact with leadership through recruiting elders
		1.1.4 Government resource policies		No	Not explicit, but the game rules can be considered implied policies
		1.1.5 Market incentives		Yes	Stock markets and supplies of game elements to acquire
		1.1.6 Media organization		No	
	1.2 Related ecosystems	1.2.1 Climate patterns		No	
		1.2.2 Pollution patterns (e.g. air, water, and land)		No	
		1.2.3 Flows into and out of focal SES		No	

(continued)

Table 1. (continued)

B. Socio-ecological systems reference model—Which of these elements are represented in the game and why?

Level 1	Level 2	Level 3	Level 4	Presence: Yes/No	Reflection: Designer mode —Why this choice? Analyst mode—What do you find in the game?
B.2. Ecological	2.1 Resource system	2.1.1 Sector (e.g. water, forests, pasture, and fish)		Yes	Forestry and fishery
		2.1.2 Clarity of system boundaries		Yes	Sectors are separate
		2.1.3 Size of resource system		Yes	Limited by game components
		2.1.4 Human-constructed facilities		Yes	Both implied and explicit on game boards and cards
		2.1.5 Productivity of system		Yes	Main focus of the game
		2.1.6 Equilibrium properties		Maybe	Might be implied
		2.1.7 Predictability of system dynamics		Yes	Production of systems and costs are open information
		2.1.8 Storage characteristics		No	Regulated by game rules and components
		2.1.9 Location		Yes	Between game supply and player boards
	2.2 Resource units	2.2.1 Resource unit mobility		Yes, but	No connection with real world. Controlled by player actions
		2.2.2 Growth or replacement rate		Yes	Conversion through game actions
		2.2.3 Interaction among resource units		Yes	Abstracted, based on costs of cards
		2.2.4 Economic value		Yes	Abstract tokens representing resources
		2.2.5 Number of units		Yes	Fish, branch, and coin shaped tokens
		2.2.6 Distinctive markings		Yes and no	Forests placed on player boards, but temporality is weak as production is controlled by player actions
		2.2.7 Spatial and temporal distribution		No	Not explicitly stated
B.3. Social	3.1 Governance systems	3.1.1 Government organizations			
		3.1.2 Nongovernment organizations		Yes	Player companies
		3.1.3 Network structure		Yes	Companies have their own networks, connected to Elders and community banquet table

Table 1. (continued)

B. Socio-ecological systems reference model—Which of these elements are represented in the game and why?

Level 1	Level 2	Level 3	Level 4	Presence: Yes/No	Reflection: Designer mode —Why this choice? Analyst mode—What do you find in the game?
		3.1.4 Property-rights systems		Yes	Player owned game elements can only be manipulated willingly
		3.1.5 Operational rules		Yes	Game rules structure
		3.1.6 Collective-choice rules		No	
		3.1.7 Constitutional rules		No	
		3.1.8 Monitoring and sanctioning processes		No	
		3.1.9 Markets	3.1.9.1 Harvest	Yes	Central in mechanics
			3.1.9.2 Processing	Yes	Central in mechanics
			3.1.9.3 Distribution	Yes	Central in mechanics
			3.1.9.4 Wholesale/retail	Yes	Use of resources to build and use buildings
			3.1.9.5 Consumers	Yes	Community banquet table
	3.2 Users	3.2.1 Individual attributes	3.2.1.1 Values, culture, beliefs, and worldviews	Yes	Building cards
			3.2.1.2 Knowledge	Yes	Elders, building cards
			3.2.1.3 Ethics	No	
			3.2.1.4 Perception, preferences	Yes	Elders have skills, building cards
			3.2.1.5 Importance of resource to user	Yes	Building cards
		3.2.2 Socio-economic attributes	3.2.2.1 Number of users	Yes	Player companies, workers
			3.2.2.2 Age	No	Only elders, although, historically, people of all ages participated in the fishery
			3.2.2.3 Gender	No	Only males, although, historically, women played a central role in preparing the fishing season, processing the catch, and farming. This makes the game an example of the lack of gender diversity in game art (Pobuda, 2018)
			3.2.2.1 Indigenous peoples	Yes, but	Elder cards show Sami people, but misrepresented
		3.2.3 Norms/social capital		Yes	Elders have skills
		3.2.4 History of use		Yes	Game art, building cards
		3.2.5 Technology used		Yes	Game components
		3.2.6 Location		Yes	Game art, game description
		3.2.7 Leadership/entrepreneurship		Yes	Elder cards, player companies
		3.2.8 Welfare		Yes	Building cards

(continued)

Table 1. (continued)

B. Socio-ecological systems reference model—Which of these elements are represented in the game and why?

Level 1	Level 2	Level 3	Level 4	Presence: Yes/No	Reflection: Designer mode —Why this choice? Analyst mode—What do you find in the game?
B.4. Interactions	4.1 Social to ecological	4.1.1 Harvesting levels of diverse users		Yes, but	The fish stocks are passive and reliable, but unrealistically provides the maximum possible yield. Several options for cutting down, thinning out, or planting new forests
	4.2 Social to social	4.2.1 Information sharing among users		Yes	Most information is open, small amount of private information
		4.2.2 Deliberation processes		Maybe	Except "table talk," bribe elders with fish
		4.2.3 Conflicts among users		Yes	Limited actions and buildings in supply
		4.2.4 Investment activities		Yes	Core mechanic
		4.2.5 Lobbying activities		Yes	Recruiting elders
		4.2.6 Self-organizing activities		No	Not explicitly in rules
		4.2.7 Networking activities		Yes	Player companies are networks of game assets
B.5. Outcomes	5.1 Ecological performance			No	Player actions have no consequences on resource systems
	5.2 Social performance			Yes	Developments show increase in industrial capacities and amenities
	5.3 Externalities to other SES			No	No implicit effect on other SES

C. Final Check

| C.1. To what extent do the game elements have a systematic or logical connection, fit together well, and do not contradict each other (i.e., degree of consistency of the world or consistency among game elements)? | [Write a short description and/or choose a number between 1 and 5, where 1 means to a low extent and 5 to a large extent.] Score 3 (moderate) | [Designer mode: Explain why you chose this degree of consistency. Analyst mode: Explain what you find in the game.] Fishing and forestry exhibit an internal logic, but the buildings do not fit together well. Besides buildings that match the expressed theme, there are castles and tourist attractions. The artwork contributes to lack of consistency by suggesting a confusing sense of what time-period the game takes place in, placing sailing ships and vehicles from different eras in the same environment |

through the game world (or the Secondary World) and a previously described system, either fictional or real world (or the Primary World). We call this previously described system a reference system. Building on Wolf's concepts of invention and completeness presented in the section *Worldbuilding* and on (Smythe & Thompson, 2015) practical approach to capturing internal cognitive representations of a real world, the GAS framework includes three reflection points: (1) The degree of *accuracy*, understood as the extent the game world correctly depicts the reference system. (2) The degree of *comprehensiveness*, understood as the extent to which the game world encompasses all of the components of the reference system. (3) The degree of *balance*, understood as the extent to which the game world is focused equally across the reference system's areas of focus.

The elements listed under Part B of the GAS framework build on a fusion of two of the most relevant SES frameworks used in natural resource management (Charles, 2000; Ostrom, 2007, 2009). Ostrom's multitier framework for analyzing a SES provided our GAS framework the conceptual tiers and linkages among the elements that constitute a SES. Because SESs are decomposable systems, each of the highest-tier conceptual elements can be unpacked and related to other unpacked elements. Thus, Part B of the GAS framework is organized in levels. Charles' depiction of the fishery system provided some additional elements related to the natural, human, and management systems that interact in an SES where humans rely on the harvesting, processing, and distribution of goods. The framework can be used with any (game)world that is intended to be a representation of a SES (e.g., fisheries, forestry, aquaculture, farming, mining, or city development).

Part C of the GAS framework brings attention to the extent in which game elements have a systematic or logical connection, fit together well, and do not contradict each other, that is, degree of *consistency* of the world or consistency among game elements. Although the GAS framework includes this reflection point as a final check, the degree of consistency should be kept in mind throughout the design phase, especially when building complex worlds where various elements build on each other.

The framework accommodates both qualitative and quantitative minds, as the reflection over the degree of each specific measure (e.g., balance and accuracy) can be made by writing a short description and/or by using a partly anchored 5-point numerical rating scale, which is generally considered to provide the respondent sufficient enough graded choices (Burke Johnson & Christensen, 2014). When used by designers, reflection on this degree happens in the beginning of the process (i.e., one decides how historically correct the game should be and then designs game elements), while when used by analysts, this reflection is made in the form of an evaluation performed after analyzing the game.

Users

As mentioned above, we envisage two types of users of the GAS framework: world designers and researchers/analysts. Thus, the framework can be used in a designer mode or an analyst mode. These users can be cross-media world designers and researchers/analysts (e.g., board games, video games, comics, film, literature, extended reality, etc.), although the wording of the framework focuses on *game* designers/analysts. Practitioners with a specific interest in generating worlds, or in creating meaningful play by helping the players make sense of the complex interdependencies of a changing world, can use the GAS framework as a complementary tool to any other tools that are out there on game design, for example (Raphael, Bachen, Lynn, Baldwin-Philippi, & McKee, 2010; Schell, 2019), or on worldbuilding, for example (Wrede, 2009; Zaidi, 2017). An important aspect of using the GAS framework, regardless the mode, is that, while other similar frameworks or worldbuilding processes focus mainly on separate elements of a world (Zaidi, 2017), GAS provides a method to depict the interconnections of these elements within a system. By being straightforward and providing a worked example, the framework can be easily embedded in everyday practices of designers and analysts.

Worlds designers, be they worldbuilding practitioners across media, graphic designers, or designers of bits for games (e.g., character meeples and shaped re-sources), can use the framework as a checklist or a fill in matrix. However, the elements of the GAS framework are not exhaustive, and items can be added as needed. The framework does not list items in order of importance because their importance varies in different contexts. However, it must be made clear that these items are not isolated silos and the SES is not the sum of the elements, but emerges from their integration within a game and through the meaning created by the player from the game manual, title, box, rules, and other elements before, during, or after playing the game. As also explained by Wrede (2009), while many of these elements may be helpful or crucial to certain game worlds, they will not all apply to every world. It is not necessary for a designer to include all, or even any, of the elements in order to start or finish designing. The idea is simply to provoke designers into thinking about the ways their settings and backgrounds hang together or not from a SES perspective. The GAS framework should not be considered an exhaustive and final list, but as a starting point from which each individual designer can compile a personal list. The number of elements may lead to confusion about what is essential to the game world and what is not, and render the process of building a coherent world challenging, especially if designers are picking and choosing elements from different categories. If coherence is relevant for the game, then we advise game designers to have this property in mind when reflecting over the framework elements. Moreover, as Flanagan (2009, p. 261)

noted, "most players are not attracted to overly didactic communication," thus designers have to reflect over what is the right balance of elements for their game world in order to create a safe place where players feel comfortable to play, even in a critical way.

As in the case of designers, the GAS framework can be used as a complementary tool to any other tools that are out there on game analysis, for example (González & Adelantado, 2016; Lindley, 2003). By operationalizing elements of a SES, it is possible for researchers/analysts to assess the SES representation in the game and reflect over what critical theories can be used for analyzing some elements of the game or the game as SES (e.g., eco-criticism or indigenous criticism).

Demonstration

Proposing guidelines seems easier than applying them. Thus, in order to show the applicability of the GAS framework and to encourage the reader to use it, we provide a demonstration of the tool from an analyst perspective in Table 1. In order to help the reader follow the comments included in the demonstration, we provide here a general description of this game. For the purpose of this study, the Nusfjord coastal area in Norway is considered our focal SES. In Part B of the demonstration, the game elements in *Nusfjord* the game are mapped to the SES elements of the framework.

Nusfjord (2017) is a competitive strategy Eurogame in the Worker Placement style. The theme is economic development, with the players acting as the owners of a major fishing company in Nusfjord, in the Lofoten archipelago in Norway, during its "heyday." Development is performed by exploiting natural resources and using basic market mechanisms, in addition to considering the advice from the local community (i.e., "the village elders"). To our knowledge, *Nusfjord* is one of the very few board games with commercial fisheries as its main topic. Following the format from Borit, Borit, & Olsen (2018), an overview of the game is presented in Table 2.

Here, we use the terminology from Engelstein and Shalev's *Building Blocks of Tabletop Game Design* (2019) to reference the game mechanics. *Nusfjord* is a competitive game (STR-01). The goal of the players is to develop and expand their harbor and the surrounding area. Each player has their own harbor area board, with dedicated space for buildings, forest tiles, and ships. The game comes with the different decks of buildings that emphasize different elements of the game: "herring," "codfish," and "mackerel." There is a small element of Hidden Information (UNC-08), as each player gets a private hand of buildings in the mid-stages, which they can build before these enter the common pool. The worker mechanic reinforces the economic development theme, as the actions in general

Table 2. Summary of the main aspects of the game *Nusfjord* (2017). Classifications with asterisk are reported from www.boardgamegeek.com, June 5, 2021.

	Nusfjord (2017)
Release year	2017
Number of players	1–5
Playing time (minutes)	20–100
Age	12+
Score*	7.6 out 10
Rank overall*	347
Strategy rank*	195
Ratings*	4398
Game type*	Strategy
Game category*	Economic
Mechanisms*	Worker placement
Game focus	Development, resource management, and optimization
Historical time	Unclear. Gamebox states "50 years ago"
Geographical space	Lofoten archipelago, Northern Norway
Player perspective	Owner of major fishing company
Player goal	Develop and expand the harbor and the surrounding landscape
Player gender	Not explicitly stated
Player main actions	Build buildings and ships
	Buy and issue shares
	Cut, thin out, or replant forests
	Take and use "village elders"
	Serve fish and get gold
	Transfer resources from personal reserve
Main non-player characters (NPCs)	Village elders (all men), affiliated to different domains: constructions (contractor, builder, carpenter, and architect), forestry (forest manager, silviculturist, forester, and ranger), shipyard (constructor and engineer), governance/management (sponsor, steward, and harbor master), aquaculture (pond builder, and pisciculturist), and fishing (shipowner, sailor, and fish deliverer)
Other NPCs	None
Resources	Workers
	Gold
	Wood
	Fish
Markets	Stock market
	Player built buildings
	Supply of elders
Constructions	Each game uses three decks of different building cards. Each building has various functions

do not involve fishing. Players can reserve special actions by recruiting special Elder cards.

Conclusions

Based on SES theory and worldbuilding design principles, our study expands the pool of tools available to the critical game designer by introducing the GAS framework, a tool for design and analysis of game worlds through SESs lenses. The framework shows how focus on the components of SESs can inform decisions taken when designers engage in worldbuilding for games, or researchers analyze game worlds. Through focusing on the accuracy, comprehensiveness, and balance of the elements in a game world, it is possible to gauge the correspondence of the game world with a given SES. Not all games aim for historical accuracy or lifelike settings, but by analyzing these elements, designers or analysts can structure their critical reflection on the values and mental models that are embedded in games and how they shape the narratives players create when playing them.

We present a brief demonstration of the framework in the analyst mode by examining the SES of *Nusfjord* (2017), that is, mapping the game elements of *Nusfjord* into the general components of a SES. The demonstration shows how the game has moderate comprehensiveness and consistency, in addition to low balance and accuracy. The game designer has stated that the development of the game began as a stock market game (Weber, 2017), which is visible in the game's catch distribution mechanic. However, in *Nusfjord*, harvest of resources has no lasting consequences, and the function of the environment is to provide resources for the expansion of the players' companies. The underlying paradigm that focuses on development and growth without posing any questions about scarcity and sustainability is, unfortunately, common in games (Kelly & Nardi, 2014). The actions of players will not affect the sustainability of the fish stocks, and while it is possible to deforest the game world, players can reforest the island instantly.

The GAS framework is intended as a tool that can be combined with other approaches and frameworks, contributing insight on how fields pertaining to governance and natural resource management can be combined with game studies. In light of the current focus on human impact on the natural environment, reflection on how human beings understand their relationship with the resource systems human society depends on is too important for games not to treat seriously. In future research, the GAS approach can also be operationalized more specifically on other topics dealing with sustainability.

The GAS framework is a potentially powerful tool for designers (and game analysts alike) to guide the players through the complexity inherent in SESs, as playing (simulation) games is considered a way to understand complex systems of relationships and to acquire a holistic sense of how everything is connected (Schell, 2019). We believe that this move can be achieved through restructuring the design of game worlds around structured reflection about the system to be depicted by the game.

"Through participation in a game, the players experience environments and situations where they have meaningful interactions with the elements that are present in the game, creating a space for questioning the content of the game" (Flanagan, 2009). Such questioning, coined as "critical play," is characterized by a careful examination of social, cultural, political, or even personal themes that function as alternates to popular play spaces. Since the meaning players will extract from their play emerges from the choices made by the designers, it is important to be conscious about what implicit mental models are embedded in the game by these choices. As such, the GAS framework can support designers in their iterations of creating meaningful play by adding reflection points on how the complexity of SESs is considered in the values embedded in their design.

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