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Games/Simulations About Environmental Issues
Existing Tools and Underlying Concepts

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1. Introduction

The method of simulation and gaming (Duke, 1974, Heitzmann, 1983, Gredler, 1992, Lane, 1995, Dolin and Susskind, 1992) is well suited for dealing with complex interrelated problems as characterised by Sterman (1990) or Dörner (1989). The method has a significant potential in the application to environmental problems and sustainable development.

This paper gives a survey of simulation games on environmental issues and analyses their objectives, their underlying models and further characteristics (for a detailed description refer to Ulrich, 1998). The intention is twofold. First, to give a practical assistance to all those looking for simulation games on environmental issues, thus fostering their use in education, conflict resolution and related fields. Second, to contribute to a clearer understanding of design characteristics of simulation games and, in particular, of the types of models used as the core of simulation games. In Ulrich (1997a), three simulation games have been evaluated in respect to their underlying models. In this paper, we focus on the particular strength of different model types to specific learning objectives and scopes of simulation games.

2. Survey of existing simulation games on environmental issues

The survey is based on the first 27 volumes of the journal Simulation & Gaming, on searches on the world wide web (WWW), and queries on two e-mail discussion lists (system dynamics list, GSPE-NL list). Only simulation games that included at least some form of social interaction among participants were included in the compilation. Pure computer simulations and one-person simulation games („flight simulators“) that involve no significant social interaction among participants were not included.

Table 1 presents the list of all simulation games. Full details will be published on the internet (http://www.ucs.ch). Every simulation game included was analysed based on the available literature. Whenever possible, original material of the simulation game (game kit, user manual, etc.) was included for the analysis. Some of the older simulation games are no more available. Despite this fact, they were included to demonstrate the development of the field over time.

3. Analysis of objectives, issues addressed, and context of use

In this analysis „objective“ is understood as the (learning) effect that is pursued with a given simulation game. For every simulation game, up to three different objectives were determined based on original statements of the developers, whenever possible. Inspection of Figure 1 shows that „understanding of mechanisms“ is by far the most prominent single objective, followed by „communication skills“, „negotiation skills“, „scientific knowledge“, etc. It is interesting to note that „scientific knowledge“ appears with equal importance among other objectives, despite the fact that the survey was focused on simulation games on environmental issues where scientific knowledge plays an important role. Objectives like „communication skills“ or „decision making“, all of which can be summarised as „transferable skills“, are considered as equally important.

This distribution of objectives reflects the fact that the method of simulation and gaming is suited to communicate a holistic understanding of (environmental) problems. Evidently, not disciplinary knowledge alone, but a broad understanding of the problem of interest constitutes

Name	Reference	Language
Acid Rain	Baba et al. (1984)	English
Classroom Simulations of Environmental Conflicts	Roberts (1996)	English
Climate-Change Policy Exercise	Parson (1992)	English
CO2 - The Interactive Negotiation: GLOBAL WARMING	http://www.law.harvard.edu/Programs/PON/	English
CULTURE CLASH: An Ethical Intercultural Simulation	Goldstein (1996)	English
Deep-Sea Fishing	Kuipers (1983)	Dutch
DFE - The Design for Environment Game	Proctor (1997)	English
DOWEL	mailto: icons@lists.ut.ee	Esthonian
ELECTRA	MEINSMA@sepa.tudelft.nl	Dutch
EMS - Energy Management Simulation Game	Ulrich (1997b)	German
FIRE IN THE FOREST	Smith (1996)	English
FISH BANKS, LTD.	http://pubpages.unh.edu/~amseif/FishBank.html	English
FUTURE VOLTAGE	Benders and de Vries (1989)	Dutch
Gaia	http://www.ibs.ee/chronicle/2e-mail.html	Esthonian
Game Framework for CO2 Issue	Robinson and Ausubel (1983)	English
Global Change Game	http://www.solutions.net/gcg/index.html	English
Global Climate-Change Policy Exercise	Parson (1996)	English
ICONS	http://www.bsos.umd.edu/icons/icons.html	English
IDEALS	Sutherland et al. (1995)	English
JSR - A Simulation Game of the Regional Development	http://www-ir.inf.ethz.ch/research/agrl/agrar/ lehmann/pj.17.html	French
METRO-APEX	Duke (1975)	English
NEPS - National Energy Policy Simulation (NEPS)	Dolin and Susskind (1992)	English
NEW COMMONS GAME	Powers (1992), www.ucs.ch	English/German
Program On Negotiation at Harward Law School	http://www.law.harvard.edu/Programs/PON/	English
SAVE THE WHALES	Ward (1982)	English
SEIDL - The Ecosystem Philosophy Game	Frank and Duke (1995)	English
STRATEGEM	www.ucs.ch	English/German
SusClime	de Vries (1995)	English
TERRA NOVA	Mastik et al. (1997)	English
WQM - Water Quality Management Simulation Game	Sharda (1988)	English
ZAN-TEC'S GAME: Teaching Responsibility for Future Generations.	Donohue (1990)	English

Table 1: Simulation games on environmental issues. "Language" refers to the principal language used for the game kits. References are all in English.

the focus of interest. This corresponds nicely to findings by Kessels (1996, 1997) who reports about „learning functions“ relevant for knowledge productivity in large organisations. Only one out of seven learning functions, subject matter expertise, is directly linked to disciplinary knowledge. The other learning functions refer to issues like transferable skills, etc.

Further objectives mentioned were „motivation“ and „learning experience“. A critical remark should be given at this place. „To provide a learning experience“, as several authors state in their manuals, seems to be a rather fuzzy goal. A clearer view of what should be attained by the use of simulation games would surely help the credibility of the field.

„Other“ refers to a number of specific objectives like electricity market or environmental impact assessment.

The „issues addressed“ (Figure 1, middle part) are the learning contents of a simulation game. Again, up to three issues addressed were classified according to the specifications of the designers for every simulation game. General topics, like „global issues“ (13 out of 48) or „sustainability“ (8 out of 48) dominate while specific topics and local issues like „planning“ or „impact assessment“ are rather scarce. „Specific other topics“ include issues like air/water pollution, fishing and hunting, acid rain, and rain forests.

Several topics that are important in Agenda 21 (see Keating (1993) for a concise summary), like biodiversity, population growth, soil erosion are hardly addressed. Simulation games on local issues are equally scarce.

Apart from a possible bias of the study, the dominance of general topics may stem from some mistrust among developers and users to apply simulation games for specific learning topics and for issues on a local scale (here and now). However, the situation may not be as pronounced in practice. Very often, simulation games are used as a general starting point to initiate an efficient group process, followed by specific issue seminars. Further, simulation games have been successfully employed for most concrete problems (Kuipers, 1983, Dolin and Susskind, 1992).

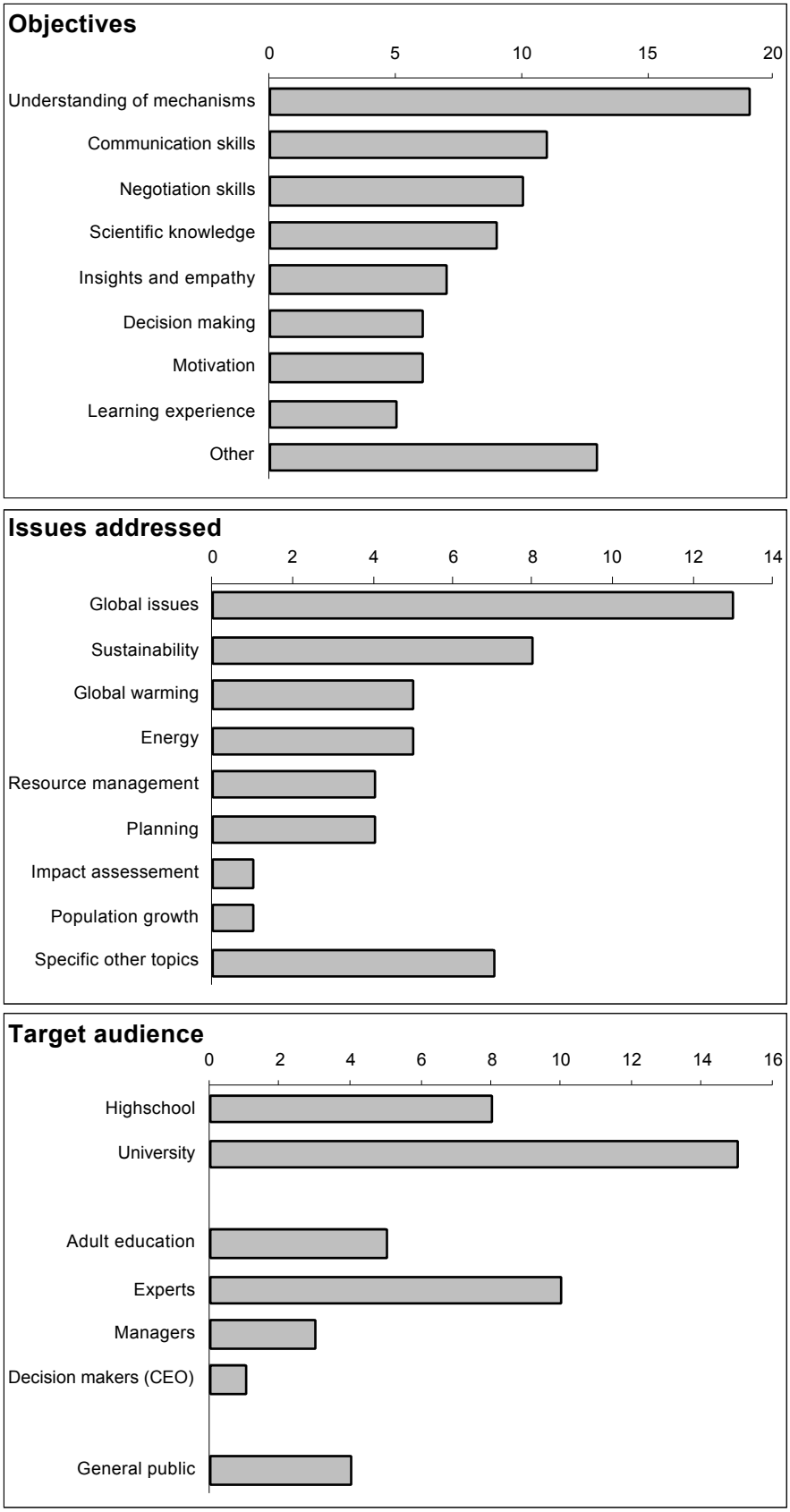

Figure 1: Objectives, issues addressed, and target audience of 31 simulation games on envionmental issues.

The „target audience“ of the investigated simulation games is shown it the lower part of Figure 1. Students in high schools, universities and adult education are the dominant audience. Experts, and general public form a further significant fraction of the target audience. Managers and decision makers on the other hand, are mentioned only at 4 out of 46 instances. This survey may be biased towards the educational sector, as many specific simulation games run for decision makers are not made public. Nevertheless, we should keep in mind, that simulation games are most efficient when dealing with real problems and real people, or as McMahon (1997) put it: „If we need the director of the company in the simulation game, he is there.“

4. Computer Use and Underlying Models

There is a continuum from simulation games without any computer support to simulation games that rely entirely on computers (e.g. simulation games of the „flight simulator“ type). The choice depends on the specific objectives and on the subject addressed. If specific technical or scientific system know-how is the focus of interest, a computer-based simulation game may be preferable. On the other hand, if conflicts among various parties, or a holistic understanding of a system constitutes the centre of interest a simulation game without computer may be more effective (Crookall et al., 1986, Ulrich, 1997a).

Figure 2 shows that roughly half of all simulation games analysed in this survey do not use any computers at all. In these simulation games, the decisions of the participants are evaluated manually, e.g. by simple look-up tables. One third of the simulation games employs computers for the accounting system. In this case, the computer is used in the background to process the decisions of the participants. A still significant number of simulation games uses the computer for communication purposes. Here, the participants are usually located at different places and communicate by means of a computer network (internet or file transfer).

Only one simulation game used the computer in the „flight simulator“ mode, i.e. participants sitting in front of the computer screen and communicating predominantly via computer (Baba et al., 1984). It was included in the survey because the author explicitly stated that students are engaged in some form of social interaction. Many users of „flight simulators“ add them-

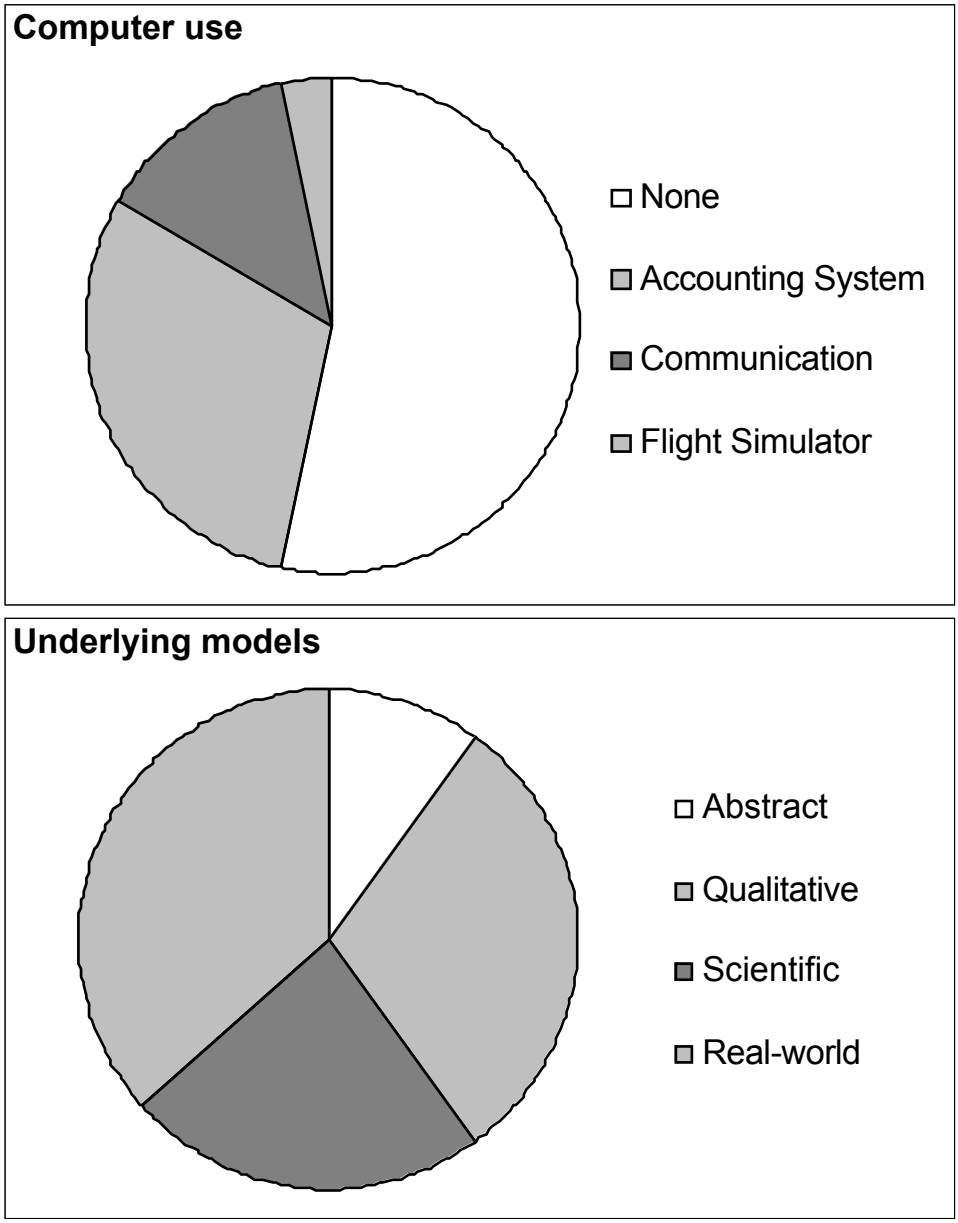

Figure 2: Objectives, issues addressed, and target audience of 31 simulation games on envionmental issues.

selves some form of social interaction among participants. Thus, this type of simulations may be included in a future survey.

Simulation games represent selected aspects of reality. Therefore, they always employ, explicitly or implicitly, a model that represents reality. The models employed can be grouped according to four categories (Table 2).

Highly abstracted models: This type of model may be considered as a special case of qualitative models (see below). In this survey only few simulation games used abstract models (Figure 2, bottom part). Usually, simulation games based on abstract models emphasise one selected characteristic, are general in their focus, and use, if at all, only qualitative numbers. Their strength is a wide applicability and the fact that a given mechanism can be conveyed in a

Strengths	Pitfalls
Scientifically based quantitative models	
· Insight into scientifically validated relations · Communication of complex, interrelated issues	· Overemphasis on numbers · Over-interpretation · Focus on details — missing „the point“
Qualitative models	
· Concentration on essential characteristics · Communication of complex interrelated issues	· Pseudo-accuracy · Hidden model assumptions
Highly abstracted models	
· Lucid communication of selected system characteristics · General applicability	· Oversimplification · No in-depth analysis possible
Real-world models	
· 1:1 correspondence to real world · Specific topic addressed in depth	· Dynamics only indirectly mediated (no model that feeds back the results of decisions)

Table 2: Particular strengths and pitfalls of different types of models underlying simulation games.

lucid way. The New Commons Game (Table 1) illustrates, for instance, the dilemma between short term profit and long term conservation of a resource on a very abstract level.

Qualitative models: A second category of simulation games uses qualitative models that represent the knowledge on the system in a qualitative way. Roughly one third of the simulation games analysed were of this type. The model may be described by means of mathematical equations. However, the values calculated are not interpreted in a quantitative manner. Very often relative scores are used. Certain simulation games use very simple equations that do not require computer programming, whereas others employ computers for the calculations.

Scientifically based quantitative models: About one fourth of the simulation games investigated uses quantitative mathematical models that are directly derived from scientific research. A scientific validity, beyond the simulation game, is claimed for the mathematical equations used. Hence, they might also be used independently to examine the dynamics of the system of interest, exclusive of the simulation game context. De Vries (1995), for example, used the mathematical model of SusClime to examine various strategies that could be applied in the simulation game.

Models directly corresponding to real world: This class of simulation games uses the real world as the model. Usually, a mathematical model is not employed. Instead, reference to the real world serves as the "model". Explicit simplifications or abstractions are not made. Nevertheless, due to time and other constraints, the degree of detail is lower than in reality. A good example is the Deep-Sea Fishing Simulation (Kuipers, 1983). Though not dealing with environmental issues directly, it was included in this study for its illustration of an exemplary collaboration of scientists with practitioners as it is often required when dealing with environmental problems.

5. Conclusions

The survey revealed a large variety of simulation games on environmental issues. Both the large number and the most different topics addressed in different formats should encourage all

those who intend to use simulation games for educational purposes or within the context of decision making and conflict resolution.

Several characteristics of successful simulation games on environmental issues could be distilled out of the results of this study. First of all, a successful simulation game must be „good“ in terms of contents and design. Second, a successful simulation game (with all manuals, etc.) must be available from a professionally operating provider, preferably together with some information available on the internet. Third, for simulation games for decision making and conflict resolution, it is important that they are tailor-made for the given situation. Further, they should not be a „one-day-event“, but they should be part of an ongoing, thoughtfully designed process. A last factor that would enhance success would be the availability in different languages apart from English.

A simulation game alone does not guarantee success. Proper facilitation and embedding in a larger context is mandatory for long-lasting learning effects to occur (Ulrich, 1997c). This is especially true for simulation games on environmental issues, because there is a risk of frustration among participants, leading to frustration and fatalism. If administered properly, however, a clearer understanding of environmental problems, and most useful skills and a self-confident attitude required for solving issues of sustainable development can be expected.

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