Understanding and Changing Systems Through Hybrid Simulation Game Design Methods in Educational Contexts

Willy Christian Kriz and Werner Manahl

Abstract This paper presents an innovative university curriculum for systems management education. Over the course of three consecutive semesters, Master's degree students take one seminar per semester about systems thinking techniques, system dynamics, and agent-based modeling. The design of hybrid simulation game prototypes is part of this didactic approach. In the first parts of the paper, we discuss the building blocks of gaming simulation, principles of gaming simulation and learning, and gaming simulation's potential to improve the understanding of and ways to change systems. In the last part, the structure, contents, and game design approach of the university curriculum are shown in detail.

Keywords Systems thinking • Management • Education • Simulation game design

1 Gaming Simulation for Understanding and Changing Systems

Public policy makers and leaders of organizations increasingly face difficult problems and highly complex situations and dynamics. Unfortunately, abilities and strategies to deal with complex dynamic systems have not improved to the required extent. Leaders and managers fail to handle the complexity of a modern world in crisis, and they are not dealing with limited resources in a sustainable and humane way. Many decision makers do not take into account the interconnectedness of systems processes and have difficulties integrating knowledge from various scientific disciplines.

To survive, people, groups, and organizations need to adapt continuously to changing internal and external conditions. Therefore, human beings and social systems must be able to learn. Leaders and managers increasingly need methods they can use to:

- Make complex system dynamics understandable

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- Support problem solving and decision-making
- Investigate the long-term and side effects of decisions
- Develop and explore alternative change strategies for possible better futures
- Create learning environments to instill players with the required knowledge and skills for implementing and sustaining the desired changes

Gaming simulation methods have the potential to fulfill these needs and to contribute to the transformation of organizations and other real-life systems. Klabbers (1989, p. 3) pointed out 25 years ago:

> *As problems and issues are becoming increasingly complex, how can we improve our individual and collective competence in steering and self-steering our societies, organizations and institutions? . . . Gaming and Simulation have proved to be a powerful combination of methods and ideas in dealing with complex and unique issues . . . Gaming Simulation provides a language for combining the social-human domain with the physical, technological and economic domains and provides a shared language for communication between the natural and social sciences.*

Including reference to the interconnections among different life areas in decision-making processes is called systems thinking (Senge 1990). Systems thinking involves a holistic and cybernetic approach, taking into account as many different factors as possible to avoid interpreting problems from a single point of view. A range of likely outcomes and possible effects of planned actions can thus be considered. Furthermore, it requires an appropriate culture of cooperation, communication, and dialog within organizations. Systems thinking fosters the exchange of mental models and the understanding of social systems. This indicates the need for and value of suitable learning environments to assist the development of relevant competencies ("systems competence"; Kriz 2003).

Richard Duke is considered the founding father of ISAGA. In 1971, he gave his talk at the 2nd ISAGA Conference on "Systems Theory and Gaming-Simulation" (Becker and Goudappel 1972). Duke's classic book "Gaming: The Future's Language" (1974) pointed out the need for gestalt and multilogue communication in dealing with complex systems. Duke detailed why and how gaming simulation supports the holistic understanding of complex systems and the decision-making process for policy makers in different contexts.

Robert Armstrong, one of the organizers of the 8th ISAGA conference, recalled some memories at the organization's 25th anniversary conference. Armstrong stated (1995, pp. 213) that systems thinking, in particular, is one of the core elements of gaming simulation:

> *In retrospect, it is difficult to define precisely the expectations of those who gathered in Bad Godesberg 25 years ago. We were a diverse group brought together by a common interest in the use of gaming-simulation. . . I suggest that there were three concerns in the minds of participants providing us with the common ground for discussion of problems:*
>
> - *A feeling of dissatisfaction with the restrictive nature of the analytical approach to problems in our subject areas*
> - *A wish to explore the potential of a systems approach to societal problems as a framework for the consideration of multi-disciplinary problems*
> - *A desire to refine and extend the use of gaming-simulation in our areas of interest.*

Modern approaches of gaming still refer to these fundamental concerns and arguments (Duke and Kriz 2014; Meijer et al. 2014; Kikkawa 2014). For example, Tsuchiya (2012) discusses principles for organizational transformation by using a combination of policy gaming, game design, and system dynamic modeling.

Klabbers (2014) describes the science of design perspective that puts an emphasis on the usability of simulation games. The focus is on dealing with an interdisciplinary and practical approach to simulation game design as a science, art, and craft that builds on local knowledge and the unique problems or challenges of a social system. He distinguishes two levels of design: "design in the small" and "design in the large." Design in the small produces gaming simulations (gaming artifacts) as interventions and interactive learning environments to enhance education, training, and decision-making. Used with that goal in mind, they contribute to the change and development process ("design in the large") of social systems (Klabbers 2006).

In addition to system dynamic modeling, agent-based modeling and social simulation are combined with the classical approaches of gaming simulation (Deguchi 2004; Kaneda 2012). These modern forms of hybrid gaming simulation are especially promising when used as a group model-building methodology (Fischer and Barnabé 2009) to solve real-life problems together with different stakeholders.

2 Methodology of Gaming Simulation

"Gaming simulation" is the simulation of the effects of decisions made by players who assume the roles and represent the interests of real-life actors, with the latitude to act these roles out being subject to specific rules (Klabbers 2008; Rizzi 2014). Gaming simulation originated with war games. The Prussian army was one the first to use it systematically and widely to plan military strategies and tactics. After the end of the Second World War, gaming simulation expanded into other fields of application. This growth started with the corporate sector and urban planning and later branched into a variety of educational contexts at universities and schools.

In practice, the term "simulation games" refers to a large number of different approaches. These approaches include computer simulation, behavior-oriented role-plays with or without computer-assisted simulation, hands-on board games, practice enterprises, and more recent approaches such as digital and non-digital educational games, game-based learning, and web-based simulation games.

Simulation games represent dynamic models of real situations. They help to mimic processes, networks, and structures of specific existing systems. In addition to mirroring real-life systems, simulation games incorporate players who assume specific roles of real-life actors. The prototype gaming simulation combines role-play and simulation. True simulation games include actors, rules, and resources (Klabbers 1999). Therefore, despite their diversity and variety, all simulation games contain three fundamental elements:

Simulation Resources: A model is a description or representation of a (real) system and/or process that can help to understand how the system and/or process works. A simulation game is a model that is used to simulate an existing real system and/or process (Klabbers 2008, p. 24). With the aid of simulation, it is possible to replicate and investigate systems processes that could or would not be carried out in real life. These processes include simulations of military maneuvers, disaster situations, or pilot training in flight simulators. Simulation games thus offer an opportunity to make the best possible use especially of limited resources and to make the long-term effects of decisions tangible and transparent. Simulation games encourage holistic, interconnected thinking and systems understanding.

Roles for Actors: Besides simulation, role-playing is an integral element of simulation games. In every real-life system (e.g., an organization), the actions of different people or stakeholders with different interests, information, and perspectives are always interrelated. It is precisely this interaction that simulation games replicate. In the game, the players assume the roles of real-life actors. They have a certain freedom as to how they fill the role and interpret the situation. This freedom is necessary for there to be any behavioral and decision-making alternatives, the effects of which can then be observed. With modern concepts of hybrid simulation games, real human actors can also interact with simulated actors.

Game Rules: A game is an activity involving one or more players who assume roles while trying to achieve a goal. Rules determine what the players are permitted to do – including their interactivity, communication, and feedback – or define constraints on allowable actions. The rules may also impact the available resources (Klabbers 2008, p. 24). As early as the 1930s, Johan Huizinga characterized humans as "Homo ludens" and saw games as a fundamental human achievement. Unlike pure play such as a soccer match or a poker game, the simulation game serves to represent reality. Therefore, the frequent bias against simulation games – that they are merely play or that gaming is related to gambling – is unfounded. Simulation games use gaming forms (e.g., role-play, rule-based play) to simulate real-life systems.

Figure 1 illustrates gaming simulation's use of games to simulate system dynamics. Game artifacts are designed as an abstract qualitative and/or quantitative model of a reference system of the real world (i.e., design in the small). The play and debriefing of the game are exercises that allow participants to practice behavior and experience the effects of their decisions in order to understand and transform the simulated system and to implement transformations in the real system (design in the large) in the future. Players represent actors of the reference system and interact while playing different roles, applying rules, and utilizing resources.

Figure 2 shows the perspective of gaming as a process. A part of the existing situation of reality is selected as a reference system for the designed simulation game. The final aim is to change systems structures and processes. To carry out design in the large in the real world, a simulation game (including a specific game

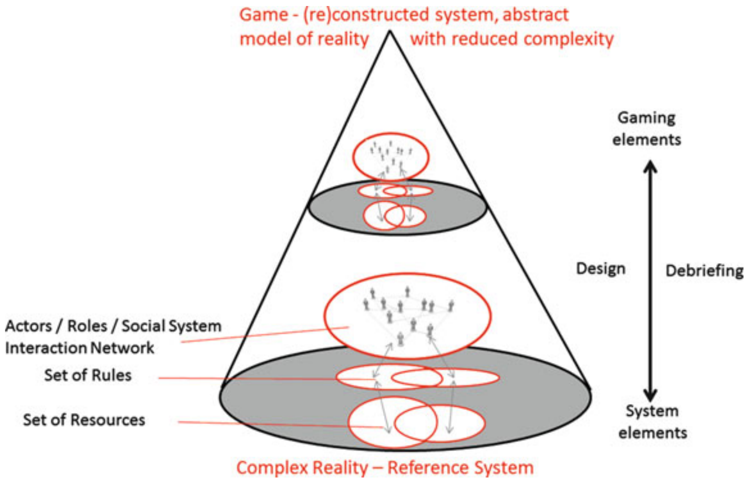

Fig. 1 Building blocks of games and real systems (based on Klabbers 2008; Duke 1974)

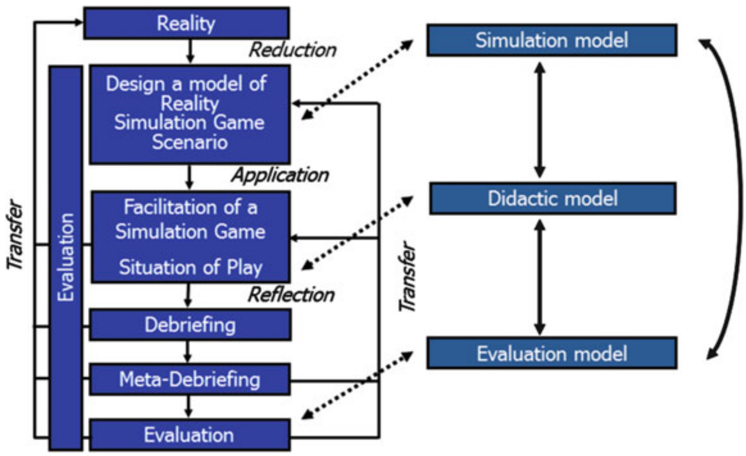

Fig. 2 Process of gaming simulation (based on Kriz 2003, 2012)

scenario) as a dynamic model of reality is created. In the design part of the process, a simulation model is created. This model defines the relationship between system elements and gaming elements.

The designed game is applied through facilitation. To play the game means to use a game artifact (*form*) to simulate (*function*) systems processes. Debriefing is conducted to enhance the learning process (see below) and to apply newly gained insights, knowledge, and skills within the design in the small aimed at changing reality, i.e., design in the large. In this part of the process, known as facilitation and debriefing, a didactic model is applied. This model defines how the game is used with a specific target group and within a specific context.

In the secondary phase of debriefing, referred to as meta-debriefing, an evaluation is required to encourage players to further reflect on the linkages between design in the small and design in the large and to measure profits of changes in reality. In this part of the process (evaluation), an evaluation model is defined. This model defines how the potential effects of the game are investigated and how and why the game works in given contexts of use (Hense and Kriz 2008).

By inviting stakeholders and opinion leaders to participate in the design process, their contributions as agents and actors are more naturally accepted. Participating in the design, play, and debriefing allows the players to take part in the design in the small process while ultimately contributing to the next phase of the social systems processes' design in the large.

3 Gaming Simulation and Learning

Learning experiences need to enhance learners' personal development as they gain the capacity to question the validity of acquired knowledge and develop a sensitivity toward social processes. Unlike situations of passive knowledge transfer, learners are drawn into an active, experience-based learning environment. The orientation is oriented toward the discovery of what is personally important (Kriz et al. 2014; Schwägele 2014). Simulation games enable self-organized or self-directed learning, based on one's active experience to nurture competencies and skills. The key principles are:

- Self-activation and learner activation (i.e., the autonomy of learners in designing their learning activities)
- Learner orientation (i.e., building on the learners' previous knowledge and experience and being guided by the learners' interests, e.g., arousing curiosity)
- Being close to real life (i.e., being oriented toward reality; a key idea is that thinking develops from taking practical action in realistic and authentic situations)
- Holism and purpose (i.e., enabling complete action sequences, the systemic observation of connections, and the integration of cognitive, affective, and psychomotor processes while learning) (Kriz 2010)

To support the acquisition of skills, simulation games provide practical and relevant learning environments with realistic complexity and scope for decision-making and action. Gaming simulation is an interactive and learning environment that makes it possible to cope with authentic situations that closely mimic reality. At the same time, it is a form of social learning because it challenges and provokes team-based problem solving.

The ability to make mistakes is necessary, especially when it comes to innovating and developing solutions to problems. All that needs to be ensured is that the consequences of the mistakes – desirable mistakes that teach lessons – do no harm. Simulation games represent so-called mistake-friendly environments and enable collaborative, cooperative trial action, i.e., the planning of action strategies as well as their execution and optimization.

Another advantage of simulation games is the immediate feedback of action effects; the accelerated pace of simulation also creates tangible long-term effects. Simulation games are thus experimental and experience-oriented learning environments. A single simulation game allows multiple contexts of use, and newly gained knowledge can be used to enter unfamiliar domains. This learning under multiple perspectives creates flexibility with domain-specific knowledge. Learning from multiple perspectives, as in gaming simulation, provides players with the intellectual tools they need to transform new knowledge into action. The major rationale for using gaming simulation is not only to define objectives and strategies for achieving learning goals but also to implement actions to achieve them. Furthermore, gaming simulation aims to diagnose, analyze, and assess responses to critical situations that occur and to make the consequences of decisions transparent.

Gaming simulation research shows that learning is enhanced above all by additional reflection and transfer modules during and after the simulation game (Kriz and Hense 2006; Auchter and Kriz 2014). “Debriefing” has become a widely accepted term for these processes of reflection and transfer. Key debriefing processes are game analysis (what happened? what did the players feel?), game reflection (how to explain the course of the game? how to evaluate the game result?), transfer (how are game and reality related? what aspects of the game were (un)realistic?), and learning effect (what did we learn? what decisions and solutions will I actually implement in my real-life, everyday work environment?) (Kriz 2010; Thiagarajan 1993).

Participants enhance their systems thinking and skills for understanding and changing systems through discussion of lessons learned and problem-solving strategies during the debriefing. Debriefing offers more time for players to share multiple perspectives and to construct common mental models through social interaction (Kriz and Brandstätter 2003).

Evaluation research has shown how simulation games create a motivating learning environment. The chosen methodology should inspire players to assume a role in the game. This is important; role-taking fosters long-term interest in the educational content of the simulation game and promotes the acquisition of knowledge (Kriz et al. 2008; Hense et al. 2009; Knogler and Lewalter 2014).

Learning with gaming simulation can include game design. In the case of “open games,” the simulation model, rules, and the course of the game are not specified a priori. Instead, they are co-constructed by the participants with facilitation from seasoned simulation game designers. The participants thus become “experts” who construct systems and pedagogical models in the sense of a shared social representation of reality. This self-organizing learning environment not only shows the contextual nature of knowledge but also the connection between perspectives and changing contexts of knowledge (Klabbers 2008; Kriz et al. 2004).

4 Case Study: FHV University Curriculum on Systems Management Through Hybrid Gaming Simulation Design

The curriculum module is part of the so-called module library for the Master's degree programs at the FH Vorarlberg University in Austria. This innovative module library offers a total of more than 20 modules. In addition to the standard curriculum, students are free to choose several modules as part of their program at the beginning of their studies. In this way, they assume partial responsibility for their personal, academic path. Because of this approach, students of different programs are mixed in the module seminars. Students of business and management, media design, social studies, computer science, engineering, and so on broaden their horizons in interdisciplinary collaboration with students from other academic areas. No other Austrian universities offer students this opportunity. Each module consists of three consecutive seminars taught over consecutive semesters (duration of one and half year). Modules have nine ECTS credit points (ECTS = European Credit Transfer System), which ensures a minimum workload of 250 h. About 20–25 students participate in each module.

The main contents and objectives of the systems management through hybrid gaming simulation design module are fostering systems thinking (especially skills for analysis and sustainable development of complex system dynamics), fostering teamwork skills (especially training of competencies for better problem solving, decision-making, communication, and exchange of mental models in project teams), and learning about methods of gaming simulation. The titles of the three consecutive seminars are:

First semester: Fundamentals of Management with Systems Thinking
Second semester: Cause-and-Effect Diagrams, Simulation, and Modeling
Third semester: Hybrid Simulation and Gaming

In general, we follow an approach described by Klabbers in the 1970s. He argued that interactive gaming simulation is an integration of a computer simulation, human-computer simulation, and gaming. Klabbers also proposed a three-stage model of simulation game development (Klabbers et al. 1979, pp. 118–120):

- Stage 1: Development of a simulation model (with a focus on simulation and analysis of quantitative aspects of socio-technical systems)
- Stage 2: Embedding the simulation model in an interactive (computer-assisted or computer-simulated) simulation (with additional focus on more qualitative individual aspects of human behavior in coping with complex systems, strategy development, and decision-making)
- Stage 3: Embedding the interactive simulation in a game (with additional focus on group dynamics and communication in policy formation and organizational learning)

During Seminar I, students participate in different simulation games to gain basic skills in systems thinking and to learn about methods of gaming simulation (e.g., policy exercises, role-play, pure games, and experiential learning activities, simulation games, and played simulations, as well as computer simulations). In this seminar, teachers lecture on theory, present various techniques (e.g., tools for building models and systems analysis, brainstorming techniques, decision-making techniques, and debriefing methods), and run illustrative simulation games. Learning outcomes are that the students become acquainted with the fundamental principles of systems thinking and that they can analyze systems behavior in different disciplines and areas of application. Students learn how to create simple multi-relational feedback loop models of systems. Students learn in theory and practice about important factors for cooperation in interdisciplinary teams as they have to work together in mixed discipline teams with coaching by teachers. Students learn about systems archetypes (Kim 1994) and can analyze, predict, and display simple systems behavior and develop intervention strategies in systems. Lectures with discussions are held on different forms of systems theory (e.g., system dynamics, chaos theory, synergetics, cybernetics) and their application to management questions (Figs. 3, 4, and 5).

Exercises are conducted to learn about simple modeling techniques. For example, exercises are conducted on multi-relational cause-and-effect structures (feedback loop diagrams), behavior-over-time diagrams, graphical functions diagrams, policy structure diagrams, computer models, management flight simulators, and so

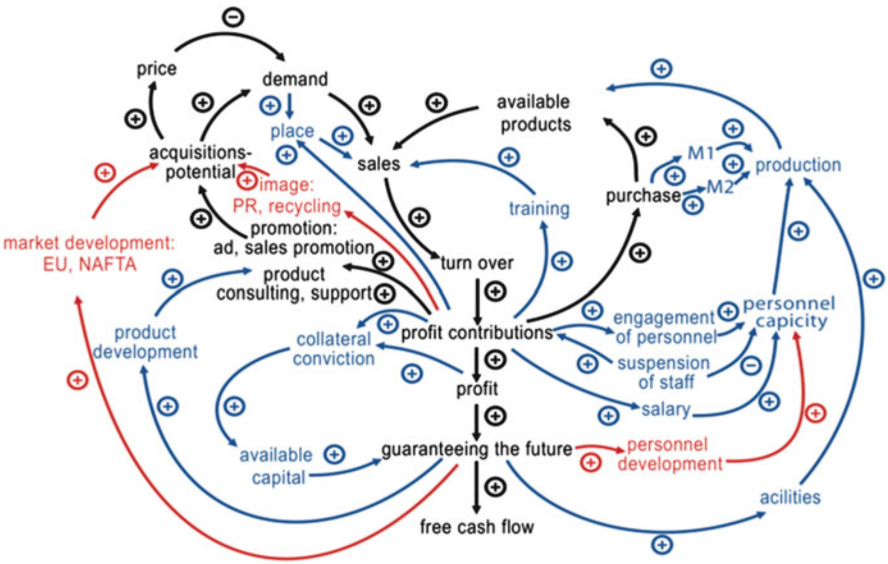

Fig. 3 Feedback loops diagram as the basis for the Visim business game

Fig. 4 Students develop and present simple system dynamic models

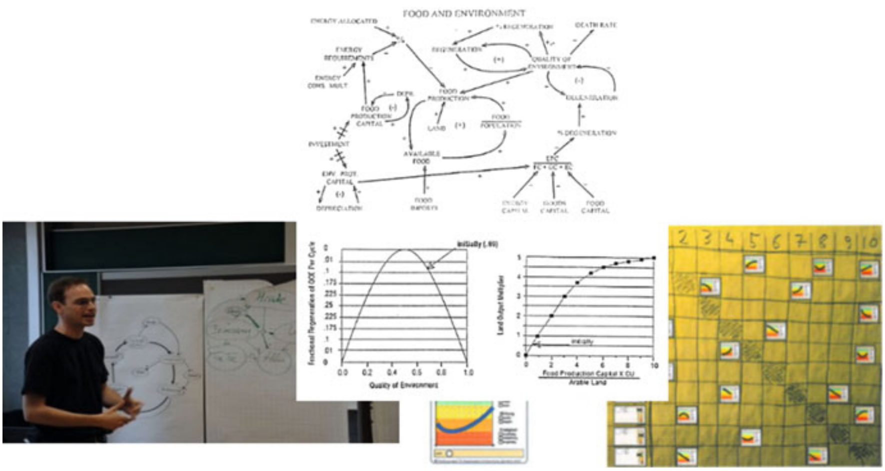

Fig. 5 Students playing Stratagem game; parts of Stratagem simulation model

on (Vennix 1996; Sterman 2000). The simulation games that are facilitated by the teachers are predominantly based on system dynamic models such as Ecopolicy by Frederic Vester (1994), Fish Banks and Stratagem by Dennis Meadows et al. (1993; Meadows and Toth 1985), and Visim by Thomas Maier (2011).

During Seminar II, the students work on real-life problems of real clients in small interdisciplinary project teams with coaching by their teachers. Students learn about advanced simulation methods of system dynamics and agent-based modeling. They start to build simulations and develop models with the support of different computer simulation software tools and use additional techniques like stakeholder analysis, balanced scorecard, and more. They learn about the simulation of scenarios, definition of adequate decision-making strategies for management, and the change of simulated and real complex and dynamic systems, as well as related practical problems of actual systems processes and structures (Fig. 6).

Although several researchers have proposed frameworks for the optimal design and structure of simulation games, Duke and Geurts (2004) proposed a total of five phases (and 21 steps). This is the approach we use most often in the university module. In Seminar II, we put the first two phases into practice. Students start with an initial, approximate clarification of the simulation game's objectives and target group. During this stage of problem clarification and problem formulation, project teams are formed and can introduce different perspectives and aspects of the problem. The teams then agree with real clients on the key questions ("defining the macro problem"). Systems analysis and model construction are next and include the selection of appropriate content and the analysis and definition of the systems and system elements to be simulated. The team discusses factors and elements that influence the problem to be solved or that interact with the system that is to be simulated. This serves to explore the problem environment and to integrate relevant factors and relationships into the model. Another key aspect is the graphic visualization of the system elements and their interrelationships through charts, schematics, and cause-and-effect diagrams. This visualization of the problem environment is also important because it shows the limitations of the simulation model. Based on the outcomes of different simulations and scenario techniques,

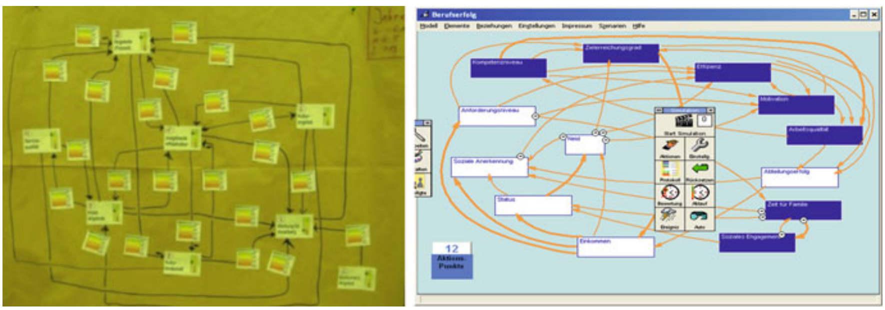

Fig. 6 Simulation models are transferred into computer simulation software, and different simulation approaches and scenario simulations are carried out

students learn to give decision-making recommendations to the client, as well as recommendations about how to change socio-technical systems.

During Seminar III, the participants remain in their teams and learn how to design simulation games. Self-created prototype games are presented, conducted, and tested. The teachers facilitate a continued meta-debriefing within the design process.

Since simulation is the only one aspect of a simulation game, a concrete game method has to be selected in Seminar III. Following the steps proposed by Duke and Geurts (2004), a blueprint is then created. The blueprint includes identifying both the actors and the concrete roles of the players. Teams must determine which actors are played and which are simulated in a different way (the game leader, e.g., can play several actors or represent them via computer simulation or event cards).

Rules need to be determined to define the players' scope for action and decision-making. Teams must also decide which resources the players can use during the simulation game, either concretely or symbolically, and how this will happen. Additionally, the chronological sequence (steps of play) of the simulation game needs to be considered. The accounting system must also be decided by the teams and should be used to record system changes and the course of the game. It is also possible to have simulation games that do not proceed via similar rounds of activity but as a sequence of continually novel scenarios or a combination of both approaches. The scenarios themselves also need to be defined.

Features of scenarios include specific starting situations (states of system elements), defined momentum of system elements, defined events that are to happen independently of players' decisions, and defined actions that can be triggered by players (e.g., by measures determined by decisions). Ultimately, all these necessary definitions feed into the development of a system components/gaming elements matrix; a systematic overview of the game structure that illustrates how the system components and interrelations are represented as gaming elements and their relations (gaming elements include rules, roles, events, and so on).

During the next step – the concrete development or building of the simulation game – a simulation game prototype is created, tested, and modified. Once again, many different aspects play a role, from assessing the adequacy of the model's contents, to the graphic design, to the technical evaluation. In the final analysis, it is about constantly optimizing the simulation game. Then, the finished simulation game is ready for use. The game is presented together with a game concept report Greenblat (1988), manuals, and a scientific paper that must be based on research in the subject area of the game (Fig. 7).

Fig. 7 Hybrid prototype simulation games are tested and presented

5 Conclusion

Designing a hybrid simulation game requires constructing a model of reality. Gaming simulation is a suitable method for making the interpretations and perspectives of the many different individuals contributing to the design process, including the client, visible. During the construction of a simulation model, it is possible to gain information about the social, but otherwise largely subconscious, construction of reality in a social system, which may be new for everyone involved. From a constructivist perspective, it is conceivable to have several different models of a reality segment represented in a simulation game, although none of the models may be capable of giving a full representation of reality. Priorities need to be set. Contradictory assumptions about reality are made explicit during the game development. Through the game design process, it is ultimately possible to create a tangible shared mental model.

The simulation game is based upon a solid systems analysis and tested simulation models. The design process is practice oriented because it deals with real-life problems of clients and offers support for their problem solving and decision-making. At the same time, the simulation game must be connected with research findings. In this way, students learn important skills for their future careers, for systems management with gaming simulation, and for scientific thinking. They specialize in the particularly interesting field of systems thinking, group model building, and gaming and attain qualifications relevant to their profession. Evaluation results of the module show that the students who have completed the program thus far were very satisfied with their learning experience.

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