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Guest Editorial – Symposium on System Dynamics

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Guest Editorial – Symposium on System Dynamics

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In 2000, Pål Davidsen, Michael Spector, and Konrad Morgan (all of the University of Bergen) guest edited a symposium for *Simulation & Gaming* on system dynamics and interactive learning environments. A little more than a decade later, David Crookall suggested we do a follow-up to that symposium, investigating the intersection of system dynamics with the more general field of simulation/gaming. This symposium grew from that. We started by organizing a symposium session at the 2012 International Conference of the System Dynamics Society in St. Gallen, Switzerland, and continued to recruit other authors doing relevant work. The theme of this symposium has changed over time, evolving into the question of how system dynamics research and methodology is contributing to the field of simulation/gaming.

The field of simulation/gaming, as represented by articles in *Simulation & Gaming* and conferences such as ISAGA (the International Simulation and Gaming Association) and NASAGA (the North American Simulation and Gaming Association) has emphasized learning in organizations and educational institutions. In contrast, the field of system dynamics, as represented by articles in the journal

System Dynamics Review and by presentations at the International Conference of the System Dynamics Society, has historically emphasized the application of simulation modeling to policy analysis and design in complex dynamic systems. However, that has been changing as we see more researchers in system dynamics creating and investigating learning environments based on system dynamics theory, principles, and methodology.

This symposium investigates issues that we believe are central to studying dynamic decision making and improving teaching and learning with system dynamics-based simulations and games. Those issues include learning about the essential features of the system dynamics methodology (dynamics, feedback loops, accumulations and delays, non-linearity, and the relationship between model structure and behavior) as well as currently popular research topics (effectiveness of model transparency, instructional strategies, and understanding accumulations).

The articles in this symposium fall into two main categories, experimental studies investigating important theoretical and methodological questions, and reports of particular applications of system dynamics methodology and interactive learning environments to important problems in learning.

Beginning with the experimental articles on important theoretical concerns, three articles (Strohhecker & Größler, Fischer et al., Stave et al.) address the comprehension problems people exhibit concerning accumulations (stocks and flows). Not only are these problems at the heart of learning from simulations and games, they affect real-world learning and understanding that have great consequences, such as our failure to develop effective policies for water conservation and mitigation of climate change (subsequently addressed in the articles by Bassi et al. and Sterman et al., also in this issue). Improving our understanding of *why* people misunderstand these concepts and designing solutions to improve their understanding is of central importance to all simulations and games which deal with learning such phenomena, whether they are in the area of natural resource management, climate change, business dynamics, public policy or psychology.

Strohhecker & Größler also investigate whether the problems people have understanding stock-flow relationships are due to researchers using abstract tasks (in their case, either graphical or textual presentations). They compared understanding of the relationships in such abstract tasks versus tangible tasks, in which participants worked with and handled actual flasks, funnels, and water to learn about flows, delays, and accumulation. In this study, stock-flow failure (the term system dynamics researchers use to label people's failure to understand the relationship) proves to be very real, even with more tangible tasks.

Fischer and her colleagues investigate whether the format in which stock-flow tasks are presented (graphical versus verbal) affects understanding and performance in the task. The authors' contention is that most people comprehend the phenomena presented in the tasks better than research suggests and that the abstract graphical formats used in most research studies are unfamiliar to people and depress their apparent comprehension. The results of their study support this hypothesis to a large degree.

Stave and her colleagues investigate whether simulation-based learning environments (theirs being fully integrated into a semester-long college course on the environmental sciences) are the solution to stock-flow failure, and will improve students' understanding of accumulations and corresponding concepts in the field of environmental studies. Their results are positive, showing significant improvement in their students' understanding of accumulations within that field.

In contrast to those theoretical and research-methodological issues, Mulder et al. and Kopainsky et al. address specific instructional strategies intended to facilitate the learning and performance outcomes of simulation and game-based learning environments with complex content. Those difficulties include not only the above-mentioned misconceptions concerning accumulations, but also learning the relationships between structure and behavior, understanding delays and non-linear relationships, applying the scientific method in learning environments, and developing skills in model building (in contrast to model using).

Kopainsky and her colleagues investigate prior exploration, an instructional strategy aimed at improving learning that is based on the theories of cognitive load, mental model formation, transfer of learning, and risk avoidance. Mulder and her colleagues investigate two instructional strategies, model progression (using successively more complex models as students progress) and worked-out examples (a strategy long used with considerable success in the field of mathematics education). Coupling these strategies with the success of interactive learning environments demonstrated by Stave et al. gives added hope that the solution to people's misunderstanding of accumulations lies in creating effective learning environments.

Following on that hope are the three articles (Sterman et al., Pavlov et al., and Bassi et al.) reporting particular interactive learning environments and role-playing simulations intended to improve learning.

Sterman and his colleagues address the critical issue of climate change and its mitigation. At the heart of the problem, people do not recognize the phenomenon or its causes, which is in turn due (at least in part) to the aforementioned difficulties people have understanding accumulations. Their role-playing game (with computer simulation support) is designed to address those misunderstandings, as well as social and political attitudes and beliefs. The article illustrates how system dynamics concepts can be leveraged to address such problems. Those concepts include recognizing the effects of delays, the reinforcing and balancing effects of loops, and the critical concept of a tipping point, that is, the point after which a problem (like climate change) may grow beyond our control.

Pavlov and his colleagues apply system dynamics principles to business and industry, addressing the important role of debriefing after a simulation/game. They take a popular and widely used simulation/game known as the LITTLEFIELD TECHNOLOGIES simulation (Miyaoka, 2005). Though the simulation's internal model is not originally based on system dynamics modeling, they test whether learning from that simulation can be improved by a debriefing that is based on system dynamics analysis. Because system dynamics usually (and historically) emphasizes model *building* rather than using models, it has also emphasized transparent (or glass box) simulations rather than opaque (or black box) simulations. The LITTLEFIELD TECHNOLOGIES simulation (as historically presented and used) is a black box simulation, but the debriefing based on system dynamics analysis presents a more transparent (glass-box) view of the model and generates a discussion of the game among students and instructors based on that more transparent model.

Finally, Bassi and his colleagues describe the application of system dynamics principles to the design and use of an interactive learning environment (ILE) to deal with a real and severe community problem, the increasing demand for and decreasing quantity of fresh water on the island of Maui in the state of Hawaii. WATERSTORY ILE is a learning environment allowing various stakeholders in the Maui community (homeowners, farmers, businesses) to collaboratively learn about their water system and via debriefing discussions to generate mutually beneficial policies aimed at preservation of that critical resource. In addition to illustrating the beneficial role system-dynamics methodology can serve in public policy analysis and formation, it demonstrates the value of collaboration through debriefing to foster compromise among stakeholders having competing needs and goals.

The articles in this symposium illustrate how current research and application in the system dynamics community is advancing practices in simulation/gaming for education and decision-making. Principle among them is addressing the difficulty people have understanding accumulation (stocks, flows, delays, tipping points), and the impact of that difficulty on policy analysis and design, such as policies to address climate change. In addition to strategies for addressing those difficulties (e.g., using verbal formats or tangible activities), system dynamics researchers are investigating various instructional strategies (model progression, worked examples, prior exploration) to improve learning outcomes (understanding and performance) from complex simulations in general. Finally, this symposium addresses the important area of debriefing as a means to foster policy analysis and stakeholder compromise, and in the ways that debriefing may be improved. That includes increasing the structural transparency of underlying models so users better understand the relationship between model structure and behavior.

Just as system dynamics researchers speak to the simulation/gaming community (with regards to basic understanding of complex concepts and techniques to enhance their instruction), the simulation/gaming community is influencing practice by system dynamics researchers and practitioners. For example, while the simulation/gaming community has generally emphasized learning by *using* simulations and games, the system dynamics community has historically emphasized learning by *creating* simulations. This is, however, changing. System dynamics researchers and practitioners are increasingly applying the field's principles and methodology to create games that increase the efficiency of learning. Furthermore, they are developing and applying new technology tools to facilitate such learning environments. Whereas the traditional software tools of the system dynamics professionals have been desktop applications, the tools are increasingly becoming web and mobile apps. That will facilitate collaborative model building as well as enable simulation/games that are accessible (via the web or mobile devices) to far greater audiences than they traditionally have been. This is especially important for addressing critical social and political issues like sustainable development of natural resources and mitigation of climate change, which tend to have disproportionally greater impact on the developing world.

However, we may be too enthusiastic about the extent to which system dynamics is contributing to the improvement of simulation/gaming, and even to the advances within the field of system dynamics itself. Though the research and projects reported in this symposium demonstrate some success in creating effective learning and decision-making environments, they also expose some difficulties. We must be aware of the difference between statistical significance and educational (or real-world) importance. That is, we may demonstrate statistically significant differences in a laboratory experiment, but are those effects really large enough to have an impact in the real world on big and complex social issues like better governance, dealing with climate change, or preserving water supplies? Even more powerful instructional strategies are probably still needed to have both the learning and emotional impact required to move people towards solving such problems. Furthermore, the variety of methods used in the research studies in this symposium illustrates that we lack standard methods for assessing learning and performance outcomes, which are needed to allow comparison of studies with conflicting results and implications, and to move the field forward.

To address those and other issues remaining to be addressed, this symposium concludes with a critical reflection by Pål Davidsen and Michael Spector, two of the guest editors from the 2000 symposium. They approach the articles from two different perspectives, that of system dynamics theory (Davidsen) and learning theory (Spector), especially regarding learning of complex systems. Summarizing across their discussion of all the articles, Davidsen and Spector conclude that while the methods and technologies of system dynamics and simulation-gaming have improved dramatically since their symposium in 2000, evidence of improved learning and performance are less obvious. Accomplishing that will require not only improving the design of learning environments, but also improving our measurement of both learning and performance outcomes.

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