System dynamics gamification: Lessons learned from the PERCEIVE Simulation Lab development

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Extended Abstract: During the last decades, the attention of the system dynamics (SD) community towards gamification has increased. SD games are predominantly used as decision-making tools with educational purposes (Mayer et al., 2016) for conveying dynamic insights to participants who are asked to intervene into a system and control the impact of their decisions (van Daalen et. al, 2014). *'Stratagem2'* (Sterman and Meadows, 1985), *'Beer Game'* (Sterman, 1992), *'Fish banks'* (Meadows et al., 1993), and *'Climate Action Simulation'* (Rooney-Varga et al., 2020) are indicative cases of successful efforts. However, the authors often utilize different nomenclature to describe their work (Maier and Größler, 2000). This variability hinders researchers and practitioners from exploiting prior knowledge. Moreover, there is an absence of an operational overview of the technical options, as well as of a structured set of detailed principles and guidelines, describing how SD practitioners could transform their models into SD-gamified tools. Scattered descriptions of challenges, pitfalls, and warnings (Andersen et al., 1990; Lane, 1995; Alessi, 2000) that game designers should take into account while gamifying their work constitute the most pertinent evidence. Only recently, van Daalen et al. (2014) further provided an updated aggregate list of gamification options that a game designer should consider.

This dearth of inputs on how to gamify an SD model is of major concern; although it might be relatively easy to build an SD-gamified tool, it is often difficult to build an effective and successful one (van Daalen et. al, 2014). In addition, SD gamification is coming into the foreground as technological and knowledge improvements have put gamification within the reach of a broad range of people. Indicatively, modelling software has rendered simulators even more accessible (van Daalen et. al, 2014); the development of user-friendly interfaces is becoming a common exercise in SD modelling classes. To that end, this article reports our involvement in creating a virtual learning tool based on an SD model, using the available literature indications. In fact, presenting this first-hand experience, along with its positive and negative points, challenges, and outcomes, is anticipated to inspire future SD practitioners, inform them about the difficulties that they might face, and prevent them from repeating errors.

The virtual learning environment has been developed in the context of Horizon 2020 PERCEIVE project (https://www.perceiveproject.eu/). PERCEIVE was a three-year research project (09/2016-08/2019), which was funded by the European Union (EU) and coordinated by the University of Bologna, Italy. The project investigated how the EU implements and communicates its Cohesion Policy (CP) at a regional level, as well as how the European citizens perceive the role of the EU in regional development. Within the project, a whole work package was dedicated to the development of an interactive web-based simulator that was

named *'PERCEIVE Simulation Lab'* (PSL) based on the principles of the SD approach. More specifically, the developed SD model was translated from Vensim® to PHP and converted into a web application based on HTLM5. The PSL simulates different scenarios of CP implementation allowing users to explore the long-term consequences of policy decisions under alternative assumptions concerning: (i) the national and regional macroeconomic and political context, (ii) the organizational characteristics of local entities that manage EU funds, and (iii) the profiles of the potential beneficiaries of the funds. The PSL is anticipated to provide support and orientation to policy modelling as a tool for raising the CP experts' awareness towards an effective decision-making process.

The PSL aims to render the developed complex SD model accessible to the public, since a direct interaction with it that requires knowledge of the SD software is challenging. The PSL was divided into two sections to be adaptable to the different users' learning needs. In the first section (named *'Free simulation'*), the players can freely play with the variables and compare the results with the historical system behavior. In the second section (named *'Target simulation'*), a specific behavior is made available to the more expert players who are asked to manipulate the available parameters to replicate the provided graph. In June 2019, the PSL was presented at the final project conference in Brussels, Belgium. Approximately 20 experts, policy-makers, and practitioners on CP implementation interacted with the PSL in a specially organized workshop. The PSL's layout appeared to be effective as the players were able to navigate the interface, following the guidance, without many queries. Thus, the developed simulator could be used as a reference for future web adaptations of SD models. After the workshop, the simulator became officially available in the project's website (https://www.perceiveproject.eu/simulation/) for free individual sessions. Up to March 2020, more than 700 web visitors played with the PSL.

Nonetheless, few features that hindered the effectiveness of the interface were identified during the workshop. In general, the PSL's target audience were unfamiliar with the SD modelling concept, while they were not engaged in the model building process. Thus, although a careful nomenclature simplification was performed, the fact that the adopted variables' labels maintained a connection with the SD jargon to some extent impeded the players' comprehension. The increased yet necessary number of variables was also challenging for the less expert players. In addition, the most problematic issue was probably the time length of the simulation runs. A waiting time of 7 seconds was rather perceived as a delay by the users; it appeared to decrease attention and engagement as players were often distracted during this time. In fact, the HTML5 architecture was probably not the optimal solution for such a complex model. Finally, although the communication between the SD modelling and the web developing teams started earlier than expected, the actual time span to complete the interface was 3 months as initially planned. In practice, this period appeared to be insufficient for the translation of a complex SD model into a web-based simulator *'from scratch'*. Thus, the inability to perform the necessary beta tests to evaluate the PSL's effectiveness potentially affected the final outcome.

The difficulties faced during the development process arose mainly due to our lack of experience in the translation of the SD model into an interactive web-based simulator, which was further impeded due to the limited available literature. To support future research efforts, we propose a first-effort comprehensive definition of SD gamification ("*SD gamification is the process of developing and designing media-based or mediated learning settings to be used as learning tools based on SD knowledge and formal models*") to contribute towards a more consistent literature taxonomy. The flexibility and comprehensiveness of the suggested definition are expected to provide a common theoretical denominator that has been missing so far. Moreover, based on our experience and the available literature, we rationalize the challenges that SD practitioners may face when they gamify their work. The proposed set of challenges creates an interrelated triple helix (*theoretical*, *operational*, and *managerial* challenges). Finally, we envision the potential future steps towards a more mature development of the SD gamification field. These steps include: (i) the integration of gamification theories with SD (similarly to what happened for group model building), (ii) the construction of a repository containing all previous SD gamification efforts, and (iii) the creation of a comprehensive list of SD gamification possibilities, opportunities, and tools, along with operational guidelines.

In conclusion, our gamification experience, which was built upon the available literature efforts (Alessi, 2000; Andersen et al., 1990; Lane, 1995; van Daalen et al., 2014), highlights the importance of rendering SD gamification as a well-structured and recognized branch of the SD research domain. Specifically, it is crucial that the scientific community should pay attention to the SD gamification to prevent practitioners from *'reinventing the wheel'* through providing them with the skills to learn from past experiences in a new systematic and more efficient way.

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