LETTER TO THE EDITOR

On John Sterman's "System dynamics at sixty": rigor, relevance and implications for education

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In his introduction to the 60th anniversary issue of this journal, John Sterman (2018) provides a profound account of the first 60 years of system dynamics (SD). It contains a valuable historical look at the origins of the SD movement, and an insightful reflection of the current state of SD practice. Sterman emphasizes methodological rigor as the principle on which high-quality modeling rests.

The ultimate plea for rigor derives from the Conant–Ashby theorem: “Every good regulator of a system must be a model of the system” (Conant and Ashby, 1981). In other words, the effectiveness of a policy or intervention cannot be better than the underlying model, except by chance. As a consequence, the quest for ever better models is a must.

Sterman conveys an outline for a more qualified practice of professional modeling. It can be assumed that most members of the SD community strive for being good professionals. But many lack the means for reaching that level. Maybe they are not embedded in an SD group of a university. Or they are not nodes in a powerful professional network. Aspirants are often eager to learn, but too timid to obtain access to knowledge, e.g. by joining such a network. One must acknowledge that the SD community embodies many knowledgeable systems modelers, who are normally generous and share their knowledge. Even so, the barriers to entry may be too high, as it is difficult to find professionals who have the time to explain to an inexperienced person how good modeling works.

The emphasis in fostering and spreading professional competency should be on training and education for high-quality modeling. A high-quality model needs to represent adequately (at an acceptable level) the dynamic issue or problem it addresses. Since absolute truthfulness of a model is neither possible nor meaningful, the level of quality attained can be gauged relative to the model's purpose. An essential quality criterion in SD is whether the model behavior is “right for the right reasons”, in accordance with the principle of a causal endogenous structure driving the behavior. The other main criteria have to do with the acceptance of the model by its stakeholders (users, owners, etc.), and the effectiveness of its use in the “real world”. Sound model building involves both deductive (rational, logic-based) and inductive (empirical, evidence-based) steps (Schwaninger and Groesser, 2008). The quality of a model can be strengthened by questioning, testing

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and improving its successively forthcoming versions. Hence quality improvement is a continuous process, by which a model is substantiated systematically. Via tests and experiments, confidence in the quality and usefulness of the model is gradually built.

Since its beginnings, the SD community has developed a canon of principles and procedures for model testing (Forrester and Senge, 1980; Barlas, 1996; Sterman, 2000; Schwaninger and Groesser, 2018). To leverage these principles and procedures, a sizable repertory of rigorous methods, both quantitative and qualitative, has been developed. A recent sample of the former can be found in Rahmandad *et al.* (2015). Classical examples of the latter are provided in Richmond (1994, 2004). There is still much work to do, to reach more discipline in the use of the qualitative methods, and to make the available advanced quantitative methods commonly used features of modeling practice in our community. Conceptual and methodological knowledge will be key for that achievement.

The process of building confidence in a model is an iterative one. It begins with the start of a project and is not a separate activity to be carried out after a model is “complete”. Model building and model testing are intertwined parts of the process of developing high-quality models: best modeling practices and best testing practices ultimately are one.

The problem is, the above ideas are espoused easily, but rarely put into effect in modeling practice.

Normally, the SD programs at universities have been teaching their students how to build high-quality models. Moreover, our community has introduced some training measures for the improvement of model quality across the field. These measures have been attached to the International System Dynamics Conferences: first, single-event lectures about model quality, calibration and use of data in validation; second, the modeling workshops at the conferences; third, the Summer School, which has preceded the conference since 2016 and contains some good modeling lectures. The single sessions are punctual in nature, and are conscience-building devices rather than measures to foster high-quality model-building skills. The modeling workshops at the conference are very helpful as they make the knowledge of highly qualified system dynamicists available, in a customized fashion, to modelers at all levels—rookies in particular. However, due to the limited time available, these conversations are rarely sufficient for building a bridge toward professional qualification. Finally, the Summer School is focused (a) on elementary model building, which is not at the professional level, and (b) on upper-level technical modeling principles and methods. Overall, not much time and effort in these Summer Schools are spent in taking big steps towards a professional qualification for genuinely systemic model-based studies.

My stringent conclusion: we need more training to achieve modeling excellence—I mean in-depth training. This implies in the long term that we

create more SD courses and programs at more universities. In the short term, we need training events that are long and thorough enough. Probably one day is a minimum robust duration for a workshop or seminar, but it should be followed by more events, for repetition and expansion. Two- or three-day, or even longer training periods may be a more effective alternative. The training should be hands-on. It should rely on standard models and related historical data. It must include the practice of evidence-based reasoning, honed through sustained exercise.

In the past, teachings centered on model building have been dominant, with insufficient attention to rigorous model testing. Henceforth, both components should be weighted equally. Instead of separating them, they should be synthesized in teaching/training activities.

Finally, project-based group model building is a highly effective approach to training, worth pursuing (Vennix, 1996; Hovmand *et al.*, 2012). One main benefit of this concept is that it is very suitable for enabling learner-centered education and qualification (Forrester, 2016).

At some point, the offer of courses and workshops could be structured in modular forms, again for the purpose of learner-centered and customized education. All of this needs a concerted effort. Hence it is important to define this game of SD training and permanent education. Should it be a team effort? Should the SD society office be involved, and how? Who is the catalyst and who is the coordinator?

Obviously, these suggestions for SD training are meant as a complement to the teaching and nurturing of young researchers and practitioners, as provided by academia. Modeling and simulation need to be anchored in the curricula of schools and academies, in the first place.

I am embedding these reflections into the framework, which proposes rigor and relevance as two complementary criteria of good research (Rapoport, 1968; Gulati, 2007) and model building. In addition to the criterion of rigor, I would add the criterion of relevance as a precedent for excellence in modeling.

To be relevant, we need to avoid a recursion of sterile rituals inside the tower of academia. Jay Forrester kept advising us to focus our work on the challenges faced by humanity. There are enough issues and problems out there where improvements should and can be made. I suggest that we should first concentrate on those issues where the cost of modeling and simulation is something like only 10% or less of the benefits. That will give us enough work to do. And the benefits will even be greater, if we adhere to John Sterman's (2018) postulate for "the highest standards of rigorous inquiry".

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