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# System Dynamics Group Modeling: An Educational Perspective

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**Abstract**

*An application of the SD group model-building methodology in a higher post-graduate course is presented with the purpose of illustrating its value for improving the learning process. The measurements from this experience are collected via a survey and interviews and results are presented to determine if the SD group model-building experience enables transformational, instructive and communicative learning. The experience provides a testament for some important characteristics of the SD group model methodology, namely: its ability to promote changes in perspectives of the course participants via reflection, to substantiate participants' growth in understanding the key principles of investigation and to facilitate interaction between participants.*

Keywords: Group model-building; Experiential learning; Modeling; Reflection; System Dynamics

## Introduction

The System Dynamics (SD) group model-building gained attention among the community of system dynamicists as a valuable methodology to deeply involve a client group in the process of model construction (Vennix, 1999). In a group modeling project, the participants develop one or many models during structured sessions with the help of a facilitator, who must favor the elucidation of knowledge within the group (Rouwette et al., 2000). Group-model building has been tested on a number of cases and situations, but there is still the need to capitalize lessons learnt from experiencing it for educational purposes in teaching and practicing SD to first entrants to the SD discipline and learners of SD. In this context, SD group-model building can prove a valuable and interesting method to learn SD and understand how SD can instruct new ways to solve problems, help change perspectives in policy making, and better communicate understanding of complex situations and associated solutions.

The motivation and originating factor why we are presenting this work is that SD group modeling is still a methodology that requires further improvements when applied to the contexts of higher education. This experience will help understand how SD group modeling can be of value to teach and instruct post-graduate students in learning and using SD. In particular, the SD group model-building methodology is claimed to be instructive, transformative, and communicative: in fact, its goals are learning and mental model alignment, changing attitude, and creating consensus about a proposed policy (Anderson et al., 1997).

This paper presents an application of the SD group model building in an academic setting. The specific case of the application was to model and simulate the mechanisms of diffusion of digital services as part of a PhD class of SD taught at Politecnico di Torino by the authors and attended by 15 PhD candidates from various engineering, architecture and industrial design backgrounds.

The purpose of this research is to illustrate the transformational, instructive and communicative value of SD group modeling via presenting such educational experience. The measurements from this experience are collected via a survey and interviews administered to the course participants and results are presented in order to determine if the SD group model-building experience has been transformational, instructive and communicative to the course attendees.

The purpose is to illustrate the value of the SD group model methodology in a multi-disciplinary teamwork of newcomers to the SD discipline. The ensuing experience provides a testament for some important characteristics of the SD group model methodology: namely its ability to transform perspectives via reflection, its instructiveness, and communicability. In other words, is the SD group model methodology likely to promote changes in perspectives of the course participants? Will it substantiate participants' growth in understanding the key principles of investigation? Will it facilitate interaction between participants?

With the purpose of answering such questions, the paper is structured as follows. First, we define the educational characteristics of the SD group model building methodology along with available literature; then, we give the research methodology and present the survey; and finally we analyze and discuss results and we draw conclusions.

## Theoretical Background

The characteristics of the SD group-model building methodology are described in the following sections to provide a common understanding of these principles and as a basis for developing a measurement

metrics that would be used to evaluate the extent to which such characteristics were considered of value by the panel of course participants.

*Instructive*

In order to be used in an academic setting, a model must foremost be instructive and foster learning in the students. Learning is a complex process, with both internal and external sources, influences, and impacts. However, learning in the field of management is highly correlated with an experience factor. Learning can occur by: "1) elaborating existing frames of reference (or meaning perspective), 2) learning new frames of reference; 3) transforming habits of mind; and 4) transforming points of view, which can occur if people try on another's point of view" (Kitchenham, 2008). Furthermore, there are a variety of methods that are used for instruction, such as: traditional lecturing, computer simulations, internships, and information-technology (IT) related methods; however, each has its barriers. The students and the learning environment will be the primary decision factors as some of these methods are limited in their: degree of reality, ability to promote group related teamwork, and time constraints (Brown, 2000). The SD group model building is used in this academic setting to promote and measure instructive group learning to substantiate participants' growth in understanding the key principles of innovation and technology diffusion processes investigated via case study projects.

*Transformative*

Learning can be defined as two types, namely: action learning and transformative learning. As stated by McGill and Beaty (2000), "Action learning is a process of learning and reflection that happens with the support of a group or set of colleagues working with real problems with the intention of getting things done".

Transformative learning is defined as "a deep, structural shift in basic premises of thought, feelings, and actions" (Kitchenham, 2008), which most often can also lead to behavior change. In the field of management, team works are created as learning events. These experiential learning activities are consistent with the constructivist view of learning, stipulating that the purpose of teaching is not to transmit information, but to support knowledge formation and development (Raelin and Coghlan, 2006). The process of reflection is critical to this perspective as it is an essential link between past action and more effective future action (McGill and Beaty, 2000). Reflection has to be considered as the final goal of the design process and as a tool to provoke a new way of thinking and seeing, for example some interactive experiences are said to provoke or invite reflection (Sengers et al., 2002).

Learning is therefore a process that results in reflection and in a change in perspective, enabling us to handle similar or new situations in the future (Taylor, 1997). The SD group model building as applied

to this case experience seeks to simulate that change in perspective, through instruction (the facilitator's recommendations) and practical experience (the model built by the client group of PhD students).

*Communicative*

In language disciplines, a teaching methodology can be referred to as communicative when it emphasizes interaction as both the means and the ultimate goal of study. In other terms, such methodology envisages a need for students to develop communicative skill and functional competence in addition to mastering structures and rules (Richards and Rodgers, 2001). The SD group model building does not concentrate just on SD principles and structures, but facilitates interactions among participants while developing the skills and competence required to build a SD model and run simulations.

**Research Methodology**

The educational experience of this SD group model building was as part of a SD course given at Politecnico di Torino to 15 PhD students aged from 26 to 37 with various nationalities and diverse master of science level education in industrial engineering, mathematics, industrial design, electronic engineering, architecture, management, and material science. The students were split into three multi-disciplinary groups and assigned the goal of modeling the mechanisms and levers of diffusion of digital services among communities of potential users (Maier, 1998).

The first group developed a model of the diffusion of a digital game that runs on smartphones. The objective of the project is to collect data to be used for smart city services via crowd sensing and smarm intelligence among a community of potential university students playing the game.

The second group developed a diffusion model for a data cloud storage sharing system that would use the available disk space of the computers and devices of a community of users.

The third group explored the diffusion of connected services for the smart home environment.

The three projects were proposed by the TIM Joint Open Lab, a research center funded by Telecom Italia in collaboration with the Politecnico di Torino, who acted as a key stakeholder to the group modeling activity because of being interested in gaining insights from the SD models to further develop and commercialize the three case digital services.

The SD group model building process was planned and run as per Andersen et al. (1997). After composition of the groups, four meetings of about four hours each were held. Participants reported to have worked 50% off site as a team. The groups first developed causal loop diagrams and then quantitative modeling and simulations using Vensim. A preliminary Bass diffusion model was used as a basis for modeling (Sterman, 2000). The two instructors, and authors of this paper, acted as facilitators

of the group activities. No role differentiation was created within the team members (Richardson and Andersen, 1995). The participant overall satisfaction with the process and outcome was scored 4.5/5 as measured by the course quality assessment system provided by the University.

Upon conclusion of the educational experience, an online survey was administered to the class participants and some interviews were carried out.

In line with what was described in the definitions and literature, the survey was designed to measure the claimed characteristics of the SD group model building methodology. Three question sets were asked, further decomposed into 17 questions: 7 questions for the transformative property, 4 questions as per the instructive characteristic, and 6 questions for the communicative ability. A Likert scale, from 1 (strongly disagree) through 5 (strongly agree), was utilized for scoring purposes. Comments were also solicited from survey respondents at the end of each survey.

Interviews were taken from the students in order to gain qualitative feedback. Questions that were asked provided insight into the learning process that took place in the students.

**Data Collection Methods and Measures**

Following are the questions asked with the survey.

1. Question set #1. Transformational: Will it transform participant perspectives?
    1.1. The SD group model building methodology allowed me for the capturing and integrating of diverse knowledge and perspectives
    1.2. The SD group model building allowed for a shared understanding of the problem (Vennix, 1996)
    1.3. My individual participation influenced the final structure of the group model
    1.4. My individual model would have differed from that resulting from the group modeling process
    1.5. The visual representation enabled by SD played a central role in the model building and problem solving.
    1.6. The visual representation enabled by SD played a central role in helping collaboration between team members (Black and Andersen, 2012)
    1.7. The SD group modeling experience easily connects with concepts and frameworks already established in my mindset (Warren, 1999)
2. Question set #2. Instructive. Will it contribute to understanding the key principles of investigation?
    2.1. The SD group model building was a unique way of learning how technology and innovation spreads in a market (Sterman, 2000)

2.2. With the SD group modeling I could understand and study the mechanisms of diffusion of a digital/telecom service faster and easier than with my previous knowledge and skills

2.3. The use of the SD group model building methodology allowed the development of models that can enhance insight in the problem of forecasting innovation and technology diffusion (Maier, 1998)

2.4. SD group modeling significantly contributed to improving forecasting accuracy of digital service diffusion (Meade and Islamb, 2006)

3. Question set #3: Communicative. Will it facilitate interaction between participants?

3.1. The SD group modeling methodology has intrinsic characteristics that facilitate interaction with others

3.2. The SD group modeling methodology creates an environment for effective communication

3.3. With the SD group modeling process, it was easier to communicate my understanding of the problem with the other group members

3.4. The characteristics of the SD group model building process make it very well suited for a multicultural/multinational setting

3.5. A small and limited SD model can enhance communication of model structure and simulation results

3.6. The effectiveness of SD models largely depends on a good communicative process of modeling as a group (Visser, 2007).

**Results**

The responses obtained are illustrated in Table 1. The columns report the average, minimum, maximum and median values respectively.

| QUESTION # | AVERAGE | MIN | MAX | MEDIAN |
|---|---|---|---|---|
| **1.1** | 4.5 | 4.0 | 5.0 | 4.5 |
| **1.2** | 4.0 | 3.0 | 5.0 | 4.0 |
| **1.3** | 3.8 | 2.0 | 5.0 | 4.0 |
| **1.4** | 4.0 | 3.0 | 5.0 | 4.0 |
| **1.5** | 4.2 | 3.0 | 5.0 | 4.0 |
| **1.6** | 3.5 | 3.0 | 5.0 | 3.0 |
| **1.7** | 3.7 | 3.0 | 5.0 | 3.5 |
| **2.1** | 3.8 | 2.0 | 5.0 | 4.0 |
| **2.2** | 3.3 | 2.0 | 5.0 | 3.0 |
| **2.3** | 4.0 | 3.0 | 5.0 | 4.0 |
| **2.4** | 3.0 | 2.0 | 5.0 | 2.5 |

| | | | | |
|---|---|---|---|---|
| **3.1** | 4.2 | 4.0 | 5.0 | 4.0 |
| **3.2** | 4.0 | 2.0 | 5.0 | 4.0 |
| **3.3** | 4.0 | 3.0 | 5.0 | 4.0 |
| **3.4** | 3.5 | 1.0 | 5.0 | 4.0 |
| **3.5** | 3.8 | 3.0 | 5.0 | 3.5 |
| **3.6** | 4.2 | 3.0 | 5.0 | 4.0 |

**Table 1. Results obtained from the survey**

The results of the survey advocate the following analyses and interpretations.

The average median values equal 3.7 for question set #1, 3.4 for question set #2, and 3.7 for question set #3. These suggest that the average class participant recognized a good contribution of SD group modeling to promoting changes in perspectives and to interact with others, while slightly lower ability to help understanding the key principles of technology diffusion.

More in details, the characteristic of reflection emerges from analyzing the first set of questions. The ability to integrate diverse knowledge and perspectives of group members results as the one providing for the greatest value (question 1.1 with median 4.5), followed by the abilities to create educational conditions for shared understanding of the problem (question 1.2), individual contribution to develop the model structure (question 1.3) together with the influence of group work to shaping the model (questions 1.4) and SD visual tools to help the problem solving task (question 1.5). With this regard, it appears that a good aptitude of SD group modeling is to save, or even valuing, integrated individual contributions into the group model building and structuring (from combined questions 1.3 and 1.4). Instead, the respondents gave lower value to the ability of SD visual representation to help the collaboration between the team members (question 1.6), which leads to probably figuring out that the value of group modeling is in the group model-building process *per se* rather than in sharing a visual representation of the model. A little in contrast with the literature, the SD visual representation is likely to be considered a characteristic of the modeling tool rather than a way to collaborate toward a shared model. This is probably due to the fact that the group members were not enough familiar with the visual tool. Finally, the participants did not completely agree with the idea that group modeling connects with concepts and frameworks already established in their minds: rather, it was an experience for paradigm change and for coming up with new solutions to the problem.

The characteristics of instructiveness were assessed with the second set of questions that measure the ability of the SD group model building to help understand the principles of technology and innovation

diffusion in a market or a community of potential adopters. The respondents acknowledged the value of the SD group modeling process to learn the mechanisms of technology diffusion (question 2.1) and models specifically developed to forecast the curve of growth of an adopting population (question 2.3). However, they did not see a primary contribution of the methodology to make it faster and easier (question 2.2) but, overall, some respondents could not capture how the group model can help in accuracy of such prediction models (question 2.4 with mean 2.5 but large variance of responses: min 2 and max 5). It can be concluded that SD group modeling is instructive in the sense of the learning process, but its contribution may be not clear enough when it comes to detailed quantitative simulations of the model: a group model is reported by participants as to be a rather long and elaborated modeling effort that provides great learning advantages, but not as much advantages in the final analytic results of the simulations.

The properties of interaction were measured by the third set of questions. Respondents recognize that the SD group modeling methodology intrinsically facilitates interaction with other group members (question 3.1) and creates an environment for effective communication (question 3.2). They also felt quite comfortable with communicating their understanding of the problem with the other group members (question 3.3) in an international team (question 3.4.). Most importantly, it was recognized that the effectiveness of the model largely depends on interaction and communication established during the group modeling process (question 3.6) and this is confirmed by the fact that small and limited SD models do not help communication and interaction in the group (question 3.7). Rather, the groups produced complex models by interaction process and these models were easy to communicate with the client organization. This has proven the ability of the SD group model building methodology of being communicative: it facilitates interactions among participants while developing the skill and competence required to build a SD model.

Comments provided at the end of the questionnaire revealed also some of the following:

"*I enhanced the skills of my group by adding details (thanks to a previous knowledge of the topic) and ask questions to enrich the baseline scenario".*

*"I was an active member in all the meetings, making decisions together with other group members".*

*"Engineers have dealt much more with the model structure, making sure that it works by applying their experience, already gained on these models*".

To further understanding the degree to which SD group model building proves the given characteristics of reflection, instructiveness, and communication, some interviews revealed that project group members agreed that they experienced a transformative shift in their learning and interaction processes, while they perceived some little lower value from the ability to be instructed on the specific technology diffusion

problems. Students reported that they are better able to think critically and group members shaped their learning and perspectives. Select students' interviews quote:

*"The learning process is more related to understanding the technology diffusion topic rather than the SD methodology. The SD methodology comes second to the topic of the model, as a supporting tool".*

*"The SD graphical tool has contributed to substantially improve interaction among the individuals, identify the main variables and elicit the model equations. It has been a stimulus to group discussion".*

*"The group work on the model has created conditions for changing perspective and moving to more quantitative analysis of the problem".*

*"The group model building dynamics has allowed to rationalize ideas and intuitions into a shared rational of the problem".*

**Discussion and Conclusion**

The SD group model methodology promotes a movement towards reflective, instructive and communicative learning. This value was tested in a higher-education academic simulation of three groups of PhD students modeling the adoption processes of digital services and measured via a survey and interviews conducted among participants.

Results reveal that SD group model building is a very effective methodology for reflective and interactive academic learning and can be used for instructing specific model structures and problems, such as the one of modeling technology diffusion patterns.

This study is an extension of previous studies on SD group modeling with specific and limited application to active learning in higher education contexts. The study is limited to a small sample of learners that cannot be considered statistically consistent so that only preliminary considerations can be made. Future research is directed towards extending the test population and formalizing the process of capturing the feedback from project participants. The instructors are also modifying the course next year for future implementation of SD group modeling into the course curriculum as a result of this experience.

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