Communicating model insights using interactive learning environments

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Abstract

Much attention is focused on the rational and advisory style of developing and applying System Dynamics models. Even group model building focuses primarily on the formulation and understanding of the model by the group members themselves. There is a dearth of attention for communication of the insights derived during the model building process to those peripherally or (un)involved in this process. In this study, the multi-actor context of model implementation is addressed explicitly. The feedback loop connecting model-derived insights and results back to the problem owners, the client and stakeholders, is explored. A number of principles for use in the communication of models are derived and the rôle of interactive learning environments as a tool in communicating model insights in such a multi-actor context is discussed.

Key Words

Modeling process, multi-actor context, communication principles, learning, multiple stakeholder environments, interactive user interfaces

1. Introduction

Over the past fifty years, the System Dynamics community has devoted attention to the modeling of complex and unstructured problems in which the presence of non-linear feedback can lead to unforeseen and undesirable consequences. Much of this work has its origins in rational style policy making and client advisory studies (Mayer *et al*. 2004, Walker 2009). This presupposes the communication of model insights to a responsible authority or client who then acts to implement results and achieve change (Roberts 2007 pg 134). However, many problem situations may be characterized as having multiple stakeholders or actors. In a multiple stakeholder context, people hold different views, are involved in different ways, have different degrees of knowledge of a system or problem and different areas of responsibility and authority in relation to the problem (Kickert *et al*. 1997). In particular, the perceptions and values of these stakeholders cannot be considered to be represented fully by the responsible authority or client (Dunn 1981, pg 97).

System Dynamics has paid limited attention to the role of these actors in the course of the modeling process and in the acceptance of model-based insights and solutions. Indeed, the fact that the relations specified in a model are the encapsulation of actor-based perceptions was only addressed when group model building gained momentum (Richardson *et al*. 2004, Vennix 1996, Stave 2002). Even in the area of group model building, though, the focus is still on achieving a consensus view of the system under study as represented in the model formulated and (sometimes) quantified by the group. Valuable insights have been gained on synthesizing divergent views into a common model. Indeed, in validating the model, explicit attention is paid to establishing whether the model is fit for its stated purpose by consulting experts and the group themselves. However, the fundamental issue of communicating model-based insights and so establishing how representative the model is of the problem situation from the perspective of multiple stakeholders i.e. the contextualized validity of the model, is still not addressed. The author holds that it is precisely the "wicked" nature of the problem situation (Rittel & Webber 1973, Fitspatrick 2003) that makes quantitative modeling a valuable and potentially effective tool, provided that it is communicated well and due attention is paid to those stakeholders who do not necessarily understand the model, nor appreciate its potential utility. This paper addresses model communication in such a multi-actor context.

In the past, model communication has relied primarily on the inherent authority of the modeler, that is on their ability to convince others of the value and validity of model-based insights and solutions. This is exemplified in Jay W Forrester and many of the System Dynamics pioneers. In turn, the work of Dana Meadows and John Sterman amongst others contributed significantly to making SD modeling more readily accessible and understandable without negating the inherent complexity of the issues addressed (Meadows 1991, 2000, Sterman 2000, 2002). Many advances have since been made in explaining modeling and the modelling processes to school children (Fischer 2005). SD researchers have explored the understanding of model participants of stocks and flows and have analyzed the differences in performance of groups with and without SD training (Sweeney & Sterman 2007). These analyses yield valuable insights regarding the difficulty of communicating an understanding of SD concepts, but do not address the acceptance of the validity of model results and insights by multiple stakeholders in a problem situation. This wider social and policy problem forms the context for this paper. I do not claim to address the situation fully, but aim to indicate how a model as artifact fits within a problem-based, multiple stakeholder context and indicate how an interactive learning interface (ILE) can reveal multiple perspectives and so aid in addressing the related communication issues.

First, the modeling cycle and the choices associated with moving from a wicked problem to a quantified and tested simulation model will be described (section 2). The absence of stakeholders from this process will be highlighted. Next, the requirements imposed on the modeling process and communication of model-based insights by explicit consideration of the interaction with actors will be explained (section 3). This will subsequently be illustrated using an example of a number of interactive learning interfaces designed for communicating one model to a single committee but from the point of view of different delegates (section 4). Finally, learning points relating to the communication of model insights in a multi-actor context will be distilled (section 5).

2. The modeling process

Following operational research practice, the modeling process can be conceptualized as an iterative process or cycle consisting in six steps. These are the problem description, conceptualization, specification, verification and validation, model use and documentation (van Daalen et al. 2006). At each step, choices are made in the items selected for inclusion/exclusion, the precise description of the issues under consideration, the particular perspective taken on issues and the information used. These choices are not viewed simplistically by the System Dynamics community. Since models are simplified versions of reality, the subjective judgements made in developing a model need to be considered carefully. Indeed, the model conceptualization step generally receives extensive attention and explanation in standard System Dynamics textbooks and modeling papers as does the specification stage (Forrester 1960, 1961, 1969). SD modellers are encouraged to describe and document any assumptions made about processes and to test the implications of these assumptions explicitly both prior to, and by, simulation of the model (Sterman 2000, 2002). In the verification and validation phase of the modeling cycle, attention is also paid to testing of model outputs against expert knowledge and establishing whether the model is fit for its stated purpose. This accords well with the understanding of validation that Hodges (1991) exhibits in his discussion on the uses to which even a "bad" model can be put. By viewing the model as the focal object or artifact of a convergent then divergent analytical process undertaken during the modeling cycle (Figure 1), Slinger *et al.* (2008) extend the view of validation to include reflection on the initial problem formulation from modeler, client and external perspectives. However, despite the attention for model validity in the literature and advances therein, the fundamental issue of how representative the model is of the problem situation from the perspective of multiple stakeholders i.e. the contextualized validity of the model remains largely unaddressed.

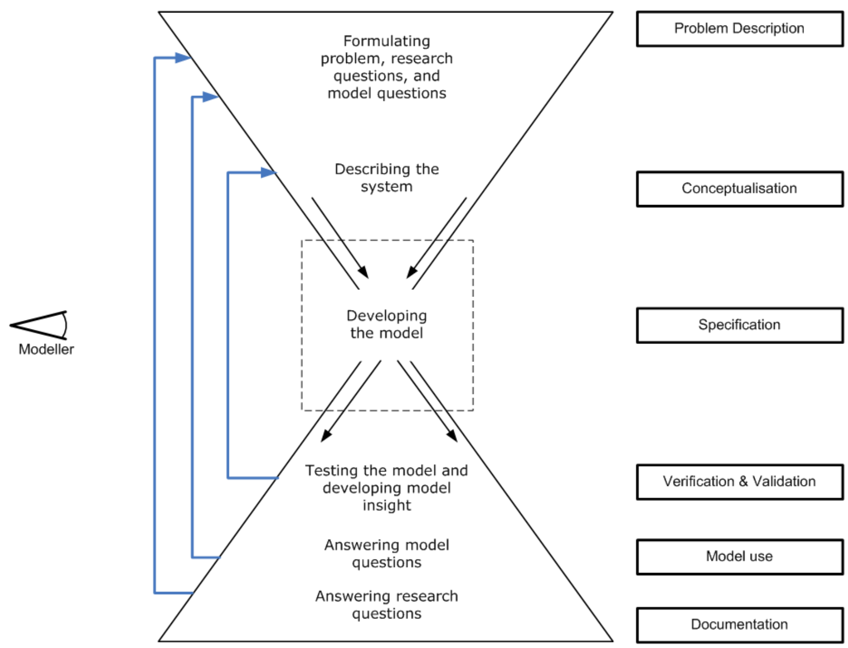

Fig. 1. The model as the focal point embedded in a convergent and then divergent analytical process allied to the modeling cycle (on the right hand side). Following Slinger et al. (2008), in drawing conclusions on the validity of the model and its use, the modeller needs to reflect on the choices made in moving from the problem formulation through the conceptual system description to the model itself. Similarly, in providing answers to the clients' problems modellers need to reflect on the initial assumptions made. The arrows on the left hand side represent these reflective activities on the part of the modeller.

3. Taking multiple stakeholders into account

It is naive to suppose that a model could represent all the views of stakeholders when we are dealing with a "wicked" problem. Some of their views may even be contradictory. As mentioned previously, group model building developed as a methodology for formulating shared models in a group setting. These models are generally consensus-based. Exploratory modeling, on the other hand, came into being in response to the strong differences of opinion expressed regarding system behaviour by different stakeholders. It has developed further as a technique designed to take differences into account and to address uncertainty in model outcomes (Bankes 1993). However, I will not discuss the potential role of these and other techniques addressing different viewpoints of actors **actively** involved in the modeling process. Instead, I will focus on the situation of stakeholders in the problem context i.e. the actors who may experience the consequences of the decisions taken.

These stakeholders are not involved in the conceptualization, specification, verification and validation, and model use steps of the modeling cycle, but they can interact with the model building process through the problem definition and documentation steps. Many a modeler, client or policy maker has discovered to their cost that they did not include a broad enough problem description, chose too narrow a system boundary, too specific project objectives or neglected important effects, when they receive feedback from other stakeholders. Open communication on these issues at an earlier stage can prevent costly misunderstandings and enhance the efficacy of the modeling effort. Additionally, the options preferred by clients or policy makers may differ from those preferred by other stakeholders because of a difference in value systems. Again, it can be advantageous in terms of the communication of model-based insights to have an indication in advance of their potential acceptability.

The awareness that value differences and differences in opinions regarding the scope of the problem and the model purpose are the points of interaction of those actively and those peripherally involved in the modeling process enables the design of an effective two-way communication effort. This does not mean that communication on the modeling process itself can be ignored. Instead, building trust in the quality of the modeling process forms an essential element in the information exchange during these interactions.

4. Interactive Learning Environments

The issues involved in effective communication of model insights within a multi-actor context will be examined by analyzing the choices made by students at Delft University of Technology in designing and presenting a System Dynamics model and interactive learning environment to the Parliamentary-Commission on Sustainability of a fictitious country Corsa. The students were participating in an advanced system dynamics course and were familiar with the principles of ILE design of Alessi (2000).

4.1 The problem context

Corsa is a densely populated country of 365 km^2 in extent. It suffers from a shortage of water and this is exacerbated by a rapidly growing population totaling 900,000 inhabitants in 1998. Groundwater forms the major water resource, but this is contaminated by nitrate seeping from cesspits into the groundwater. This forms a problem for the future when groundwater levels are expected to decrease and nitrate concentrations to increase. An additional problem lies in the scarcity of land. Housing and business interests compete with agriculture for the use of this limited resource. While the efficiency and water-saving measures of the agricultural sector have increased over time, there is less and less land available and this forms a threat to food security.

The newly appointed Minister of Water Affairs is tasked with chairing a Parliamentary Commission on the Sustainability of Corsa. In addition to employees from the Ministry of Water Affairs, this commission comprises delegates from various ministries, namely the Ministry of Economic Affairs, the Ministry of Agriculture and the Ministry of Public Health and Housing as well as representatives from the group “Citizens for Sustainablity”. The commission members are requested to prepare and present their ministry’s standpoint regarding the findings from a model of the water resources problems of Corsa, prepared by a consultant for the previous Minister of Water Affairs at the turn of the century. This System Dynamics model is validated using data from 1975 onwards and has been well documented.

In summary, the problem context clearly incorporates multiple stakeholders and there is an existing model that is well documented but with which they are not all familiar.

4.2 Designing the interactive learning environments

All delegates expressed themselves satisfied with the documentation that they received on the existing model. Indeed, the interactive learning environment designed by the Ministry of Water Affairs, stayed within the bounds of the existing model and concentrated on allowing the user to understand the complex interactions leading to depletion and pollution of the groundwater resource (Blom & Oudijn 2008). In their presentation to the committee, the delegates revealed that they understood that the model was strongly representative of the water perspective and that other views were possible, but made only limited attempts to accommodate these.

The interactive learning environment of the delegates from the Ministry of Agriculture concentrated on demonstrating the constraining influence of the limited land area and that this would influence food security in the long term (Meyers & Diaz 2006). They made structural adaptations to the base model to indicate the influence of current policies regarding the allocation of land between business, housing and agriculture and made a clear case that the model did not fully accommodate their interests.

The Ministry of Public Health and Housing consider the core of the problem to lie in the nitrate pollution of the groundwater and the scarcity of two resources, namely water and land. The interactive learning environment focused on testing three types of policies, namely those related to water, population and nitrate (van Andel & van Hovell tot Westerflier 2006). They potential efficacy of solutions is highlighted and the inadequacy of the existing model in accommodating all of these changes is demonstrated. Structural changes to the model are suggested and made.

The interactive learning environment of the Ministry of Economic Affairs tried to present a balanced approach. They took three perspectives into account in the design of their interface, namely the economic, social and environmental aspects of sustainability (Villegas & Vaezpour 2006). They explained the interconnectedness of the feedback relations in the system and the strong external constraints to sustainability. In so doing they broadened the problem description from that used originally by the Ministry of Water Affairs to include issues of relevance to the present purpose.

The Citizens for Sustainability exhibited a narrow focus on water shortage and pollution issues and appeared to have been led by the provision of the existing model in the design of their interface (Goudsmit & Tiemensma 2008). However, in the presentation to the committee and the discussions, they exhibited deep concern about other aspects of sustainability and indicated that the interests and expertise of their members was widely divergent.

4.3 Distilling lessons on multiple perspectives

Each of the delegates in the above example proceeded from undisputed common ground in the form of an existing model and sound documentation. There was no distrust of the validation procedure of the existing model. Instead the differences in opinion related to the scope of the existing model and doubt as to whether this covered the issues currently under discussion. Analysis of the interactive user environments reveals that two of the five delegations largely confined their interfaces to learning from the effects of different policy options on the existing model. Three of the delegations used their interfaces to illustrate the aspects that were omitted or inadequately addressed in the existing model and to generate learning and discussion of these issues. This demonstrates that provision of a well documented model fit for its original purpose can act to streamline comments and focus the discussion on relevant points of difference.

The study provided clear evidence of divergence in the perspectives of multiple stakeholders on the contextual validity of a model.

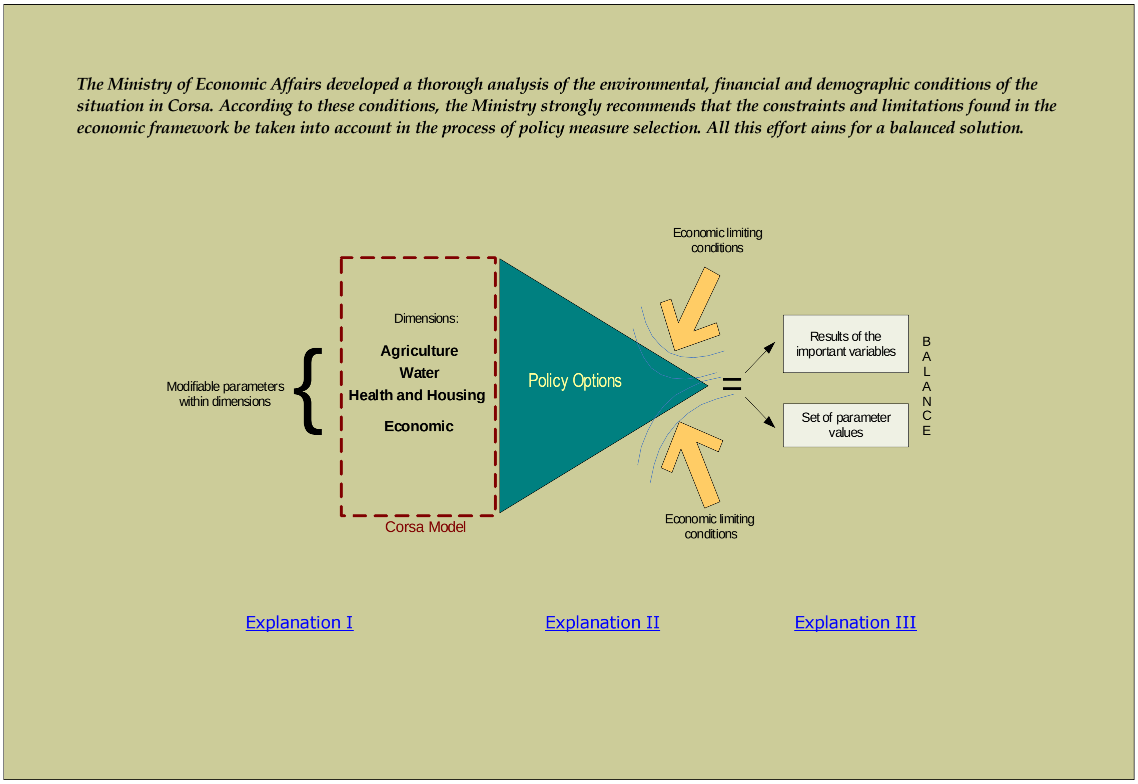

Fig. 2. The problem description or policy analysis page of the interactive learning environment prepared by the Ministry of Economic Affairs (Villegas & Vaezpour 2006). This diagram is a clear indication that this stakeholder does not consider the existing problem definition to cover important limiting conditions**.**

5. Principles in communicating model insights

The following communication principles could be distilled from the literature on models and decision-making or policy processes (particularly, Caywood *et al*. 1971, Greenberger *et al*. 1976, Miser & Quade 1988, Stave 2002) and were confirmed in this study.

5.1 Justifying the model

1. Explain why a modeling approach, why quantification and so why simulation modeling
2. Explain why System Dynamics in particular
3. Show major elements within system i.e. explain sub-systems and how they link to one another (feedback)
4. Name the performance criteria and say why they are selected
5. Give an indication of potential policy options and how they would exert influence on the system
6. Explicitly address the environmental uncertainty to be treated using exogenous scenario variables

5.2 Developing trust the model

1. Explain the verification and validation process briefly
2. Describe the model results

5.3 Using the model

1. Explain new insights. If possible, lead people to discover these for themselves.
2. Demonstrate the efficacy of suggested policy options using the model
3. Compare the effects of different policy options

Those with experience in the use of models in decision-making contexts will recognize that this list is far from complete. Indeed, consideration of the model as an artifact in a design process allows me to explicitly address the multiple stakeholder context and draw further conclusions on the communication of model insights.

5.4 Embedding the model artifact in the multi-actor context

1. Embed the model results in a wider contextual analysis of the problem
2. Pay specific attention to the differences in perspectives of the multiple actors
3. Do not lean to consensus, instead try and capture the diversity of viewpoints and allow participants to find and define common ground themselves (if they wish to do so)
4. Document assumptions made in coming to the model

Ask explicit questions of the stakeholders so as to clarify their opinions and values. These could include: Do you recognize this definition of the problem? Do you agree with the description of constraints and limitations of the study? Do you agree with representation of your interests in the modelling process? What level of involvement would you judge optimal?

For those doubting the wisdom of the open nature of these questions, experience in engaging with the public in model-based communication should form some encouragement (Slinger et al. 2005, Slinger et al. 2008).

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