The social role of simulation models

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Abstract
This paper suggests a classification of the social roles simulation models can play. Two dimensions are distinguished according to the context and use of models: models can be boundary objects or representative objects and they can be epistemic or technical objects. These two dimensions allow a classification of four types of model roles. Models can be ascribed different roles over time and different roles by different stakeholders involved in their development and use potentially leading to misunderstanding and conflicts. The suggested classification framework can be applied to a variety of problems around the use models including the discussion of the differences between System Dynamics models and Discrete Event Simulation models and the comparative analysis of model use.

Introduction

Simulation models and simulation modelling are used in many different ways. Context and objectives of modelling projects vary as much as approaches and tools used. The system modelled is only part of what determines the modelling process and the modeller often is only one of the stakeholders influencing or being influenced by the model. Other model users, such as decision makers or students in a teaching context or participants in a group model building project, may also interact directly with the model. Many other stakeholders might be influenced indirectly by decisions made based on the model. This paper aims to understand the social roles of simulation models and puts forwards a framework to classify these roles. In doing this, the paper continues the work of Zagonel (2002) on group model building and builds on the literature on boundary objects. In addition, this paper suggests that the distinct literature on objects as epistemic and technical objects allows for the development of a classification which captures more of the differences in the social role of models.

The paper assumes that not only would reflecting on the use of simulation models and the role they are given by stakeholders support the modeller in making a modelling project more effective, more implementable or more insightful for the different stakeholders, but could also help to avoid conflicts and misunderstandings if different stakeholders understand the role of simulation models and the modelling process differently or if the role of a model evolves over time within a project.

The paper first discusses the application of the concept of boundary objects to models and then reviews insights from the literature on epistemic and technical objects in order to develop a framework for analysing the social role of models. This framework is then applied to two issues: first the reoccurring discussion on the differences between system dynamics and discrete event simulation and then an empirical study comparing to consultancy projects developing simulation models for the same system with different stakeholders.

Models as boundary objects or as representation of reality

Models can be used to make predictions about the real world and allow decision-makers to experiment in a safe, quick and low cost way with different courses of action. However, as has been shown in the case of engineering, (Dodgson et al., 2007b) simulation modelling can also help to shape the conversation between stakeholders in problem solving and foster collaboration. Zagonel (2002) identified a tension between conceptualising modelling as representing reality and as negotiating a social order. He contrasted simulation models as boundary objects or as micro-worlds (see table 1, summarized from Zagonel 2002).

Table 1: Zagonel's (2002) conceptualization of SD group model building

Models as "micro-worlds"	**Models as "boundary-objects"**
• problems are pre-existent in the system • create a realistic representation • accurately address the content of the issue • strive to find the "correct" solution • focused upon the results and outcomes Therefore, our group process needs to be effective at getting at the answers we need.	• problems emerge from debate and discussion • come upon a shared understanding • understand our complementary and competing views, • build a joined picture reconciling our different views The process we use to "negotiate" this model is as important, if not more important, than the accuracy of the model as a representation of our reality.

Boundary objects are artefacts shared between communities of practice, which have their own specific informational codes (Star and Griesemer, 1989; Carlile, 2002; Sapsed and Salter, 2004). Boundary objects can address some of the difficulties of communicating and creating knowledge across (disciplinary and organisational) boundaries. These difficulties include not only the syntactic and semantic challenges of having to overcome differences in language and interpretation, but also the challenges inherent in creating new shared knowledge and dealing with the negative consequences for the participants arising out of this shared knowledge creation process. (Carlile, 2002) Boundary objects such as repositories of knowledge, standardized forms and methods, objects or models or boundary maps have been shown to support interdisciplinary working (Star 1989). However, while boundary objects can be the basis of negotiation and knowledge exchange, they can also be ineffectual, precisely because their role is at the margins of communities, and their use depends on the frequency of interaction and level of understanding within groups (Sapsed and Salter, 2004).

In a variety of domains, modelling has been shown to be able to support situations where disparate stakeholders need to create new knowledge. In large, complex transdisciplinary arenas, models can become the facilitators of interdisciplinarity, integrating the different knowledge bases (Mattila, 2005). Simulation modelling has been shown to act as a boundary object in engineering (Dodgson et al. 2007a) helping to bridge disparate communities involved in innovation and in particular allowing disparate groups to engage with innovation projects and contribute potential solutions to engineering problems (Dodgson et al. 2007b).

Modifying Zagonel's (2002) use of terminology slightly we can distinguish between models as boundary objects and as representative objects.

This classification of models can be further refined if we draw on a distinction in the science studies literature on objects in experimental systems which makes it possible to speak more precisely about the purposes for which different types of models are used: the distinction between epistemic and technical objects. Epistemic objects help to create knowledge and are fluid, while technical objects are static and seen as unproblematic tools to make knowledge available (Ewenstein and Whyte, 2009; see table 2).

Table 2: Objects in experimental systems (Ewenstein & Whyte, 2009)

Epistemic objects	**Technical objects**
Abstract and evolutionary in-flux artefacts used in expert work to negotiate meaning – usually political	Unproblematic, static, technocratic instruments used in expert work between the boundaries

Boundary objects and representative objects can both also be epistemic and technical objects. These two dimensions therefore allow a classification of four types of model roles. Models which as boundary objects facilitate communication between stakeholders with different knowledge bases can be used to create new knowledge (as epistemic objects) by the stakeholder group or can be used to make knowledge available across the group (as technical object). In the first type of use of a model as a boundary object the emphasis would be on learning as a group while in the second it would be on expression of the knowledge in a form accessible to others and on experimenting with that knowledge in the group, i.e. showing what would happen under different scenarios. Models which are primarily used to represent a reality which is seen as principally unproblematic can again be used in two different ways: to be explored as a micro-world or management flight simulator in order to allow the user to learn or as a predictive tool thereby allowing the user to draw on the knowledge embodied in the model without necessarily requiring an understanding of the relationships within the system.

These four types are ideal types – in practice the social roles of models might not always be clearly fit into any one of these types, but instead be a mixture of them. Different stakeholders might have different views of the role of the model: a client might for example have at the outset a predictive tool in mind, while the modelling process might show that what is required (or maybe in some cases achievable) would be to learn as a group. Over time the role of a model might change: learning as a group might be followed, by expression of knowledge and experimentation, followed by the development of a predictive tool for other users or a micro-world as a learning environment for students to explore.

This paper introduces this framework; the remainder of the paper gives some initial directions and indications on how this framework might be used in research about model use.

Table 3: A framework to classify the social roles of simulation models

	Epistemic Object **(create knowledge)**	**Technical Object** **(make knowledge available)**
Boundary Object (facilitate communication across boundaries)	Learn as group	Experiment and express
Representative Object (represent reality)	Explore	Predict

Social roles and modeling approach

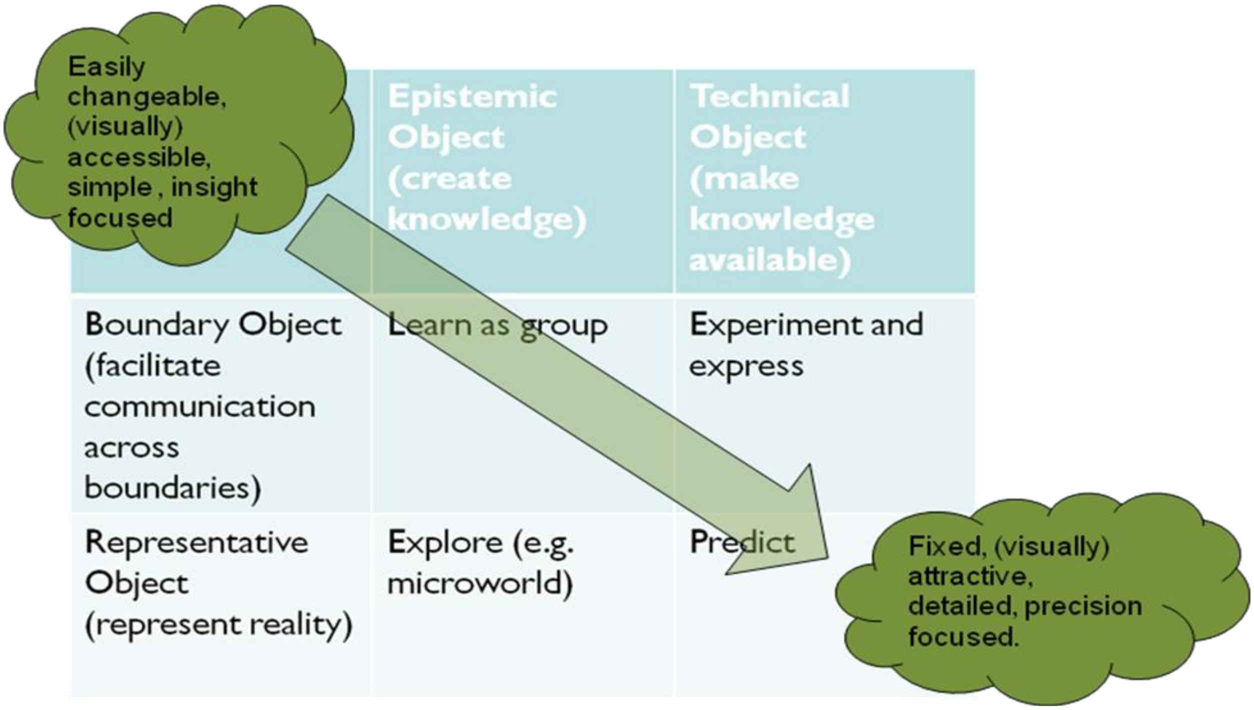
Different roles of models entail different demands for the chosen modelling approach. When considering the ideal types of models in this framework some potential implications can be sketched.

Models can support learning as a group particularly well if they are easily changeable so that suggestions of a group model building group and experiments can be rapidly implemented and interactively explored. Such models would typically be simple and visually accessible to the stakeholder group which might have only limited experiences with simulation modelling or understanding of the mathematical underpinning of models. Frequently in such modelling projects, insights into relationships between variables or parts of the system might be more of a focus than precision of the modelling output. Models used primarily as a tool for prediction might in contrast be more fixed, detailed and precision focused. While the visual interfaces might still be important depending on the context of their use the emphasis might now be more on the visual attractiveness of the output rather than on the degree to which it makes an understanding of the relationships between elements of the system accessible (see figure 1).

The requirements for the other two types of roles in our framework will fall between these extremes. Models used to experiment with and express knowledge off a model used to explore a system should make insights into relationships easily accessible but need not to be easily changeable in their model structure.

While specific models would not be expected to correspond completely to these ideal types and while the exact model requirements will be context specific, nevertheless this classification in ideal types is informative and should be recognised.

Figure 1: Model characteristics and social role



The literature on simulation more widely contains a increasingly lively debate on the characteristics of different modelling approaches, in particular System Dynamics (SD) and Discrete Event Simulation (DES) have been frequently compared. Systems Dynamics and Discrete-Events Simulation can been seen to represent the two ends of a spectrum in their emphasis and explanatory power, though both may be applied to the same situations. There has been discussion and comparison of the methods in the literature since around the mid 90s, most notable early discussions being Sweetser (1999), Lane (2000), and Brailsford & Hilton (2001). These themes become more fully explored by Morecroft &Robinson (2005, 2006) and Tako & Robinson (2009a, 2009b), as well as by modellers subsequently looking at strategies for combining Systems Dynamics and Discrete Event Simulation in hybrid models (for a summary of this literature see table 4).

Several papers offer summaries of the differences beyond the purely technical distinctions between the two approaches, which we class into four areas:

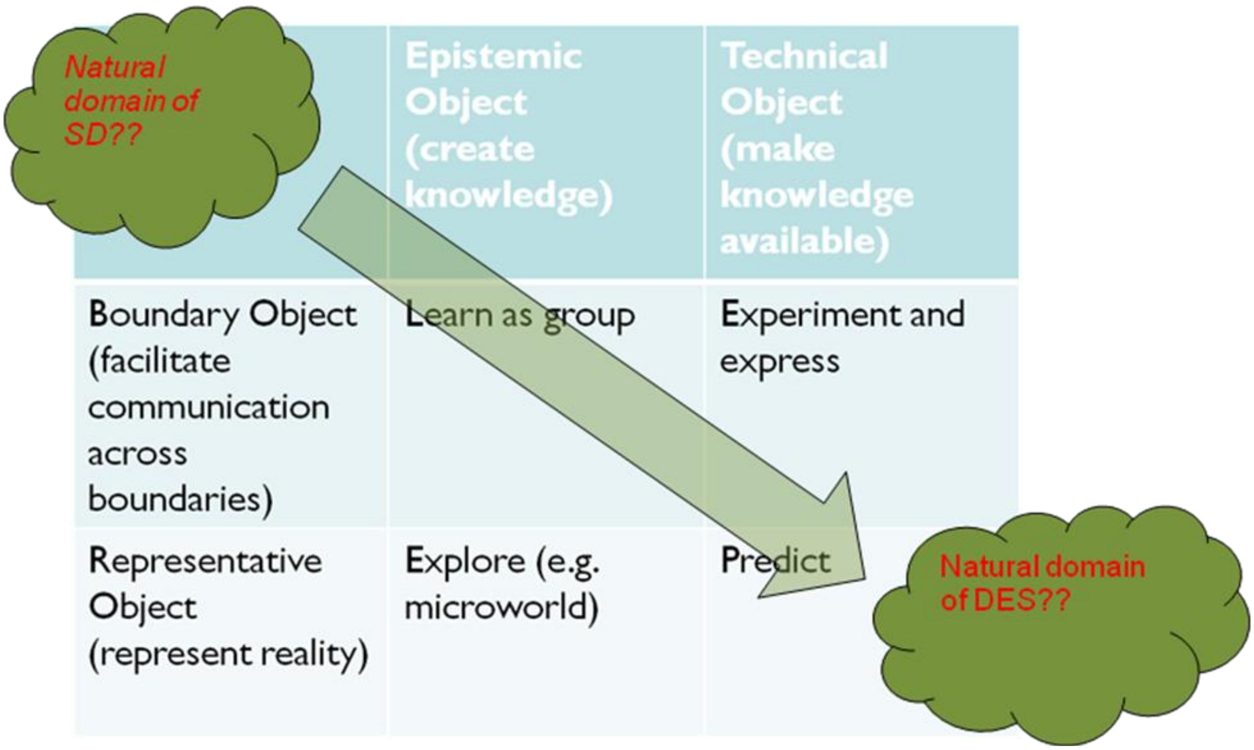
- characteristics of the problem / decision under consideration,
- data requirements and the development process
- type of understanding derived and
- model output and their usability by clients (often based on visual representation).

Table 4: Some differences between SD and DES modelling based on the model comparison literature.

Areas	Characteristic	typical SD use	typical DES use
problem / decision type	**decision level**	strategic decisions in systemic and population levels	operational decisions
	perspective	systemic overviews to population level where individual variation is statistical subsumed	operations level where events impact one another and variations of individuals cumulate or interact
data requirements and development process	**base data sources**	qualitative to identify system behaviour, find feedback loops then supported by data to complete stock levels and flow rates	model build from individual components, putting together entities
	uncertainty and randomness	deterministic runs based on provided parameters, feedback loops and delays	explicit randomness in parameters for each modelled activity and event
type of understanding derived	**key technical learning**	systemic interactions and feedback effects	impact of randomness/variation and potential bottlenecks under runs
	scope of learning	overall population level changes for long-term planning efforts	variation expected for service delivery decisions and contingency planning
model output and usability by clients	**primary usage mode**	not optimisation, understanding influences	playing with the models, what-ifs
	representation	system represented as stocks & flows with explicit feedback	system represented as events & queues with implicit feedback effects
	common user concerns about entities	lack of individuality among human entities	probability distributions for each event and entity
	common user concerns about structure	continuous, smooth curves and stock accumulation does not match perceptions of users	rearranging components completely changes interactions

While it has to be recognized that the actual domains of use of SD and DES might overlap to a wide extent and modelers can successfully apply SD and DES tools to problems across the spectrum from strategic to tactical (Tako & Robinson, 2006), the characterizations of SD and DES literature nevertheless allows formulating a hypothesis about the "natural domains" of both modeling approaches in Figure 2: the top right corner could be suggested as the natural domain of System Dynamics while the bottom right seems more the home of Discrete Event Simulation.

Figure 2: Model characteristics and social role



Empirical work is required to analyse whether this suggested understanding of natural domains of different modelling approaches corresponds to the actual use of these two approaches and to successful outcomes. Clearly such work will also have to consider the differences between stakeholders - in terms of knowledge domains, language used, incentives and social ties - as well as the problem characteristics and the system (e.g. importance of randomness and feedback, relevant level of aggregation; operational vs. strategic focus) together with the goal of planning process or of the modelling engagement.

Illustrative case study of two modelling projects of the same system

We are currently conducting case studies of consultancy engagements using simulation modelling in healthcare planning. In this work we have observed modelling workshops and interviewed of clients, modelling consultants, expert group members and other stakeholders.

As part of this work, we compare two case studies of SD projects tackling the same problem issue, one from a local perspective and the other from a national perspective. In both projects a similar group model building approach was used. However, the composition of the expert groups involved in the model building process was different. The local project aimed to inform commissioning of healthcare services for that particular local jurisdiction, while the national project aimed to develop tool for local commissioners nationwide .Table 5 compares the two case studies and includes some illustrative quotes highlighting the role of the differences in goals and group compostion which influenced the roles of the models in both cases.

Table 5: Comparison of two case studies

Case 1: producing a tool for others – national project	**Case 2: learning as a group – local project**
Goal: "influence policy" and "make a difference", "reflect the work we had done in this", "Provide a tool for local authorities to make a robust business case." Group composition: "it is a reasonably small field" and so "we all knew each other" Some said the model building made them "look at everything", while others don't see a difference from other policy discussion events Welcome broad participation in group (different disciplines) Model is ("looking at full spectrum of interventions") – model can communicate this to others Model can also distract because some find it difficult to understand	Data clashed with perception of participants – learning about wider system, finding about the performance of the solutions, attention directed by modeller towards solutions Iterative process where the boundaries of the model are negotiated with participants depending on changing perceptions of the system "Three key points to help the participants use the model constructively: a well defined issue, people who have the power to make changes to take part in the process and the simplest model to address the issue." " ..... it is a group learning process – if you present it cold through a model without the learning process it is very difficult to own the results ......" "the model works best with those (participants) who have a whole systems view and can articulate what they see ...."

While case 1 (the national project) had the goal of producing a tool for others to use, case 2 (the local project) gave considerable weight to the learning of the stakeholder group. The two groups also differed in regards to the composition of the stakeholder groups. In case 1 the participant were nationally recognised experts who knew each other well from meeting at conferences and other events. Even though they came from different disciplines, they had an understanding of the other participants' knowledge and had developed a shared language from their repeated previous encounters. Case 2 was a local group of professionals involved in implementing the policy on a local level. Maybe surprisingly, the ties between the stakeholders were looser and more work had to be done to create a shared understanding and a shared language. In case 2 the modelling workshops had a function of creating the shared understanding of the problem, while in case 1 the focus was more on codifying the shared understanding which was already there.

The differences in understanding of the goal of the project and in the difference of the composition of the stakeholder group determined the different social roles of the model in both cases. In case 1, the model did not serve as a boundary object but was conceptualized as a decision making tool for others. In case 2 the model was observed to be serving more of a boundary object and an epistemic object role than in case 1: it had some role in bridging the difference of the knowledge bases of the stakeholders and supporting the collaborative production of new knowledge.

Summary and conclusions

In order to classify the social roles of simulation models, two dimensions can be distinguished: models can be boundary objects or representative objects and they can be epistemic or technical objects. The 2x2 matrix of these two dimensions allows a classification of four types of model roles. Models can be ascribed different roles over time and different roles by different stakeholders involved in their development and use potentially leading to misunderstanding and conflicts.

The suggested classification framework can be applied to a variety of problems around the use of models including the discussion of the natural positioning of System Dynamics models and Discrete Event Simulation models in a group model building context. The use of the framework for our illustrative case studies of modelling project has highlighted how the nature of the group composition and the goals also are key in determining the social role of models.

We are currently conducting a larger empirical study which aims to analyze the social role of simulation models in simulation projects using both SD and DES. Through the use of our framework in this study we hope to understand factors influencing the social roles and inform work identifying success factors for modeling projects aiming to support diverse aims: to learn in a group, to express knowledge and experiment with it, to explore systems or to develop tools for decision makers, fostering collaboration and decision-making in diverse stakeholder groups.

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