Roles of modeling in inquiry learning

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Abstract
In modeling environments, learners create models that are executable, i.e. that are able to generate behavior, with STELLA as an archetypical example. In this paper the different roles that a modeling tool can fulfill in an inquiry environment are discussed, along with the specific requirements the integration with inquiry puts on the modeling tool.

Creating models as a learning activity

The creation and manipulation of models by learners is increasingly recognized as a potentially powerful technique within constructive learning environments. Modeling requires coordination and integration of facts with scientific theory rather than a mere passive collection of facts and formulas [1]. Because a model is a conceptual representation of a real system that behaves in accordance with physical laws creating models will help learners to focus on conceptual reconstruction of reality and thus help constructing a unified and coherent view of science [2].

In this paper the goal is to investigate the possible roles of modeling within environments for inquiries learning, as well as to investigate requirements on tools for modeling.

Roles for modeling in inquiry learning environments

Inquiry learning is a form of learning in which the learner constructs knowledge by investigating a phenomenon, by experimentation or other forms of study. In literature, several forms and roles of modeling for this kind of learning are described. Bliss[3] distinguishes two kinds of modeling. She defines exploratory modeling as investigating the properties of a model by changing parameters and observing the effects of these changes. This kind of modeling is actually identical to scientific discovery learning using computer simulations, as described above. Learner is actually not constructing any external model themselves, but discovering the properties of a model made by an author. Furthermore, Bliss defines expressive modeling as the creation of models to express one’s (scientific) ideas about a domain. For instance, a learner could use a modeling tool to express the idea of population growth. In this case, the learner is free in choosing the terms for expressing these ideas and the way the model is constructed. The model then basically functions as a means to see the consequences of the ideas expressed in the simulated behavior of the model and as a vehicle for discussion.

I see expressive and exploratory modeling as two ends of a continuum, with more roles and forms of modeling in between. The scales of modeling are defined by the use of variables and relations in the relevant models. In exploratory modeling, both the variables and relations are fixed, as they are set by the author of the model. The learner can only observe them, not change them. Murray [4] presents another form of exploratory modeling. In a system on forest modeling, learners are able to observe the development of species of trees, and explore these. Moreover, they can inspect an explicit representation of the modeling rule, a set of formulae, and make changes to these rules. However, they cannot change the structure of the model, only the rules that are used to compute the values of the variables. Murray refers to this as a glass box model, as opposed to a black box model, which would in the current terminology be called an exploratory model. We see glass box modeling as a separate form of using models.

Yet another kind of model use involves the presence of a well defined target for the model to create. For instance, when a learner is experimenting with a phenomenon, the target of modeling will be a model that can actually predict the outcomes of the experiments that the learner does. Actually such a kind of model use quite accurately mimics the behavior of scientists: constructing models that explain experimental outcomes and predict new ones. We can label this kind of model use inquiry modeling.

In Table 1, the main differences between the various kinds of modeling are depicted, with respect to the model characteristics and the availability of data. Inquiry learning stands out because of the presence of a clear target, that can be made concrete by the learner within the learning environment, as an executable model.

The specific position of the model in inquiry modeling puts some specific requirements to the modeling environment used. These requirements are:

- Matching. The environment must allow the learner and the system to match the model the learners make with the data obtained from the phenomenon investigated. Matching can be done at the level of structure (does the model resemble a standard model of the phenomenon) or at the level of data (does simulation of the model yield
the same behavior as observed in the phenomenon).

- **Incremental model development.** No phenomenon of realistic complexity can be understood all at once. Therefore a modeling tool in an inquiry environment must allow for incremental model building, and allow for matching of partial models.

- **Levels of precision.** Because learning environments to reason about the phenomenon quantitatively AND qualitatively, the modeling tool should cater for both, and allow matching at both levels.

These requirements lead to the definition of a modeling tool that is highly integrated into the inquiry process, as they demand that the model “knows” the structure of the model that is being explored by the learner. The next section will briefly discuss two cases in which inquiry modeling is being put into practice.

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**Table 1 Comparison of the different types of modeling with respect to model and data characteristics**

<table>
<thead>
<tr>
<th>Main goal</th>
<th>Model variables</th>
<th>Model rules</th>
<th>Available data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory modeling</td>
<td>Discovering properties of a model</td>
<td>Fixed</td>
<td>Only from given simulation</td>
</tr>
<tr>
<td>(Black box simulation)</td>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>Glass-Box simulation</td>
<td>Investigating a model structure</td>
<td>Fixed</td>
<td>From given or changed simulation</td>
</tr>
<tr>
<td>Inquiry modeling</td>
<td>(Re-)constructing a model from a.</td>
<td>Contains common set with target model</td>
<td>From target model and own model</td>
</tr>
<tr>
<td>Expressive modeling</td>
<td>Expressing ideas and concepts</td>
<td>Defined by modeler</td>
<td>From own model only.</td>
</tr>
</tbody>
</table>

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**Modeling in Co-Lab and SimQuest**

In two inquiry learning environments, Co-Lab[5] and SimQuest[6], modeling has been integrated with inquiry. Co-Lab offers a general modeling tool, based on system dynamics, integrated in a collaborative learning environment that offers access to phenomena that can be explored, such as simulations, but also to real life experiments. The Co-Lab modeling tool offers qualitative modeling, but no explicit matching. The SimQuest environment offers less variation in phenomena, but a more sophisticated modeling tool that makes use of the internal structure of the model of the phenomenon to help generating the internal characteristics of the learner’s model, increasing the predictive power of the learner’s qualitative models. SimQuest can, by limiting the choice of phenomena to simulations (that are modeled by an author in the SimQuest modelling language) offer more advanced support to inquiry modeling, and match the criteria[7].

Shaping inquiry modeling in these two different environments reveals the role and limits of the position of the modeling tool. Matching at a structural level is only possible when there is a tight integration with a reference model. Qualitative modeling can be strongly supported by using information from such a reference model. On the other hand a more open environment opens access to more different kinds of phenomena to be explored.

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