Modeling and Simulation for Elementary Education

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Abstract

The Schoolsenses@Internet project explores the creation of georeferenced multisensory information in elementary schools collaborative contexts to promote educational success with a deeper learning at this educational level. Workshops with teachers and children in real contexts play an important role in the design and validation of project tools. This paper reports on the design process of one of these tools to support the use and the creation of georeferenced multisensory simulations and models in elementary education contexts.

1. Introduction

Modeling and simulation have an important role in scientific reasoning. The use of these powerful tools in education can lead students to a deeper understanding of science too [1].

Human senses should also have an important role in education since they are our primary interface with the world and every day helps us dealing with diverse situations. Senses are used by humans to explore and understand the environment and children use them in a particularly natural way. However, the use of senses in learning activities is not effectively promoted in schools yet [2].

We can define multisensory information as acquired information by the human senses [3]. Georeferenced multisensory information refers to specific locations and links the cognitive, emotional, and physical dimensions [3].

Although the use of multisensory approaches in education is increasing, it is still difficult to find educational materials that include such kind of messages or that relate sensory data with more traditional kinds of data [2]. There is still a need to develop multisensory awareness, literacy and communication in educational contexts [4].

Sounds, images, movements and other sensations such as smells and temperatures are very important ways to communicate with others to express our knowledge and ideas and children use this kind of language very naturally and easily. Besides, they want a multisensory experience, because they find it more entertaining and engaging [5].

In the SchoolSenses@Internet project we explore georeferenced multisensory information and communication to bridge the gap between children’s real world and abstract experiences, as well as to integrate diverse learning and expression styles. This project aims to promote both educational success and a deeper learning of complex environmental phenomena in elementary schools.

This paper describes a tool and its design process where a main issue was two workshops that were held to understand how elementary school children interact with simulations, models and geographic information to explore, understand and create this kind of georeferenced multisensory information.

2. Simulation in Elementary Education

Although simulation-based learning environments are powerful tools for learning, we can identify some
issues that have helped back its use, like: difficulties that exist in its utilization, their intrinsic complexity and the lack of knowledge on the specific domain they represent.

Another difficulty that we can find when we use this kind of application is the data collection needed to represent a model. The majority of applications we can find are based on numerical data and represent models by equations, and forget the important role that causal reasoning can have in making predictions, or explaining results [6].

The Quantitative Simulation approach is said to be adequate if students have already a good causal understanding of the domain, but not if they do not possess such knowledge yet.

Science learning in elementary, middle, and high school is based on causal theories of physical phenomena: analyzing what happens, when it happens and what it affects [6].

Science education in elementary school is essentially qualitative. Children need to learn and to know causal theories [7], what kinds of things happen, when they happen and what the consequences are.

Elementary school children do not have the knowledge needed to use tools based on mathematical models, and most modeling software uses numerical analysis to represent and derive results.

Qualitative Simulation, based on Qualitative Reasoning, can supply tools for elementary science education, enable the use of Simulation-based learning environments in elementary schools, allow students to create and use qualitative models and help them to understand systems with basic information.

2.1. Why using Qualitative Simulation in Elementary Education?

Qualitative simulation models offer important educational advantages: using qualitative information rather than (or in addition to) numerical data. Students are stimulated to think about the distinctions that matter. Furthermore, modeling and simulation make it possible to externalize thought [8], allowing students to work through more complex problems than otherwise they could do.

External representations also help them present their ideas to others for discussion and collaboration. This implies that the language in which models are expressed must be kept as simple as possible. The conceptual difficulties students face doing it are already complex enough; they do not need the additional complexity of syntax and obscure technical terminology [8].

3. Simulkids - A tool based on qualitative simulation

The main objective of Simulkids is to allow children explain and simulate the behavior of a system in terms of cause-effect relationships. Children can do relations like ‘A causes B’, “if B changes maybe A changes too”. Causality can have an important role in explaining systems and in helping students understand complex systems.

Simulkids is a Web-based modeling and simulation tool based on Entity-Casual Relationships. In Figure 1 we can see the tool main screen with an example already open. In Simulkids the system under study is represented by entities. Each entity has a number of qualitative-states (see Figure 1), each specifying a particular state of behavior.

An entity can be a cause-entity, which means that it can change the system, or an effect-entity. In this case the value can change due to the change of a cause-entity. Entity values increase or decrease in adjacent values (continuous over states).

Figure 1 –Entity-properties Window.

To represent the system behavior Simulkids uses a table, the Relationship Table (see Figure 2). The Relationship Table shows all the cross-products between the qualitative-states of its entities. Each entity qualitative-state is combined with all the possible behaviors of other entities. The range of the final values of these cross-products is the qualitative-states of the effect-entities.

The user can define the execution qualitative time of the model too. He can define the duration of the simulation: hours, days, months or years. This option is only to help children understand the time process needed to execute the simulation in the real world.
In Simulkids the user can also associate the evolution of the model to geo-referenced data. This enables him/her to understand that the evolution of a model depends on geographical information and location (GPS coordinates).

4. Simulkids Design Process

In order to better design Simulkids we first developed a georeferenced multisensory simulation after which the Simulkids prototype was developed. Two workshops with teachers and children were carried out in their real contexts to validate the work done and redesign the tool if needed. The first workshop took place in Viseu and the second one in Guarda, two interior towns of Portugal.

4.1. Workshop 1 - using a georeferenced multisensory simulation in elementary education

In this workshop children were invited to explore georeferenced multisensory information by the way of a prototypical simulation developed in Adobe Flash.

In a previous workshop of the SchoolSenses@Internet project children have created stories about the curricular topic “climate and climate change”. A whole class has been involved. This has two major benefits: evaluate the tools by a broader audience and test if they can be used in their current curricula activities. The prototyped simulation represented a watershed of the center of Portugal and the potential impacts of climate changes in the region. Children could control some simulation variables such as temperature and precipitation (increase and decrease). When the temperature increases, the water in lakes diminishes as well as the river flow, and the sea level rises. When the precipitation increases too much, a flood happens. The simulation uses colors, animations, icons and sounds to convey information such as the raise of temperature or precipitation, the water movement that inundates houses or the drought of fertile fields, and the increase of the wind speed (in Figure 3 the wind mill icon moves with varying speed to represent this).

Children did not need any help to start the exploration of this simulation and understood very well the objectives of the software. Indeed, they understood the multisensory data used to represent the situation, like colors, sounds, movement, etc [4].

However, they showed difficulties in understanding the differences and the relations among the diverse portrayed processes, such as droughts, sea level rising and river floods. The exploration of this simulation allowed also the identification of some misconceptions and helped us to come to the conclusion that this simulation underlying model should only represent a cause-effect relation, otherwise it would be too difficult for children to understand all the complex relations represented in such a model.

The main conclusion obtained was that this kind of simulations can be made easy to operate and understand as children did not present any difficulties in interpreting the multisensory cues present and in relating them to environmental events.

All these data influenced the design of Simulkids.

4.2. Workshop 2 - using models in elementary education

In this second workshop we invited children to develop and create models that represent the impact of sewage in rivers, using the Simulkids tool.

The workshop took place in a computer lab and 22 children attended a two-hour session. Falta referir as idades das crianças.
For this workshop we identified a set of tasks that children should undertake in order to create a model that represented the impact of sewage in rivers.

To create the model children should perform the following tasks:

- Identify the entities that represent the model.
- Define the qualitative state of each entity. All entities have qualitative states; they represent possible variations of an entity.
- Associate multisensory information like color, text, a smell icon, image, sound, movement or animation to each state. Choose multisensory information to represent each entity state.
- Fill in the Relationship Table. This table represents all relationships among model entities.
- Represent the model in Simulkids.
- Define the time.
- Associate georeferenced data with entities. This allows evaluating the evolution of the model in another region and inferring the impact of georeferenced information on model behavior.

The session began with a small presentation of the subject matter, showing different situations involving the treatment of sewage.

After this presentation children were asked to identify the causes of river pollution. All children identified the sewage as the main cause of river pollution. That enabled children to identify the cause-entity sewages and the effect-entity river.

Then children associated with each entity states that represented the behavior of the entity in the system. They also added multisensory information that helped them understand each entity state (see Figure 4).

The majority of the children identified three states for each entity (see Table 1).

<table>
<thead>
<tr>
<th>Cause-Entity</th>
<th>Effect-Entity</th>
<th>Qualitative State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewages</td>
<td>River</td>
<td></td>
</tr>
<tr>
<td>No Sewages</td>
<td>Not polluted</td>
<td></td>
</tr>
<tr>
<td>Domestic Sewages</td>
<td>Polluted</td>
<td></td>
</tr>
<tr>
<td>Industrial Sewages</td>
<td>Very polluted</td>
<td></td>
</tr>
</tbody>
</table>

In the next task children filled in the Relationship Table. That was the most critical issue for us. This table represents all the states of the model (see Figure 5). That is, all the possible behaviors (qualitative states) of each entity are combined with all the possible behaviors of other entities. For example, if river is not polluted but then is Domestic sewages present, the river changes to a polluted river and if sewages are not treated the river changes to a very polluted river after.

<table>
<thead>
<tr>
<th>Cause-entity – River</th>
<th>Not polluted</th>
<th>Polluted</th>
<th>Very polluted</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sewages (just some discrete no dangerous discharges)</td>
<td>Not polluted</td>
<td>Polluted</td>
<td>Very polluted</td>
</tr>
<tr>
<td>Domestic Sewages</td>
<td>Polluted</td>
<td>Polluted</td>
<td>Very polluted</td>
</tr>
<tr>
<td>Dangerous Industrial Sewages</td>
<td>Very polluted</td>
<td>Very polluted</td>
<td>Very polluted</td>
</tr>
</tbody>
</table>
Simulkids and showed no difficulty in using the tool: they created entities, defined their qualitative states, filled in the Relationship Table, used several forms of visualization for each qualitative state (brush, shape, images, animations, sound, text, etc.).

Next steps of Simulkids development will be to make some small changes, like interface redesign of some icons and dialog boxes that were identified as problematic, integration with the project website, and using it for more learning activities with more children.

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7. References