Designing Interactive Simulations That Integrate Physical and Computational Media

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ABSTRACT

Frequently, the design of interactive simulations focuses exclusively on computers and the virtual environments they provide, excluding the physical environment. In this paper we present our efforts in exploring the integration of physical and computational media for the design of interactive simulations to support learning about complex domains. We demonstrate some examples of our work and present preliminary results.

Keywords

Interactive simulations, physical and computational media, situated learning, complex systems

1 INTRODUCTION

The notion of interactive simulations is quickly gaining importance as a means to explore, comprehend and communicate complex ideas (Turkle, 1997, Casti, 1998). Economics, ecology, epidemiology, and project management, all typically involve complex, dynamic systems and they are just some examples out of an infinite universe of questions that can be explored with simulations.

Since the late 1980s, cognitive scientists, educators and technologists have suggested that learners might develop a deeper understanding of phenomena in the physical and social worlds if they could build and manipulate models of these phenomena (Bransford, et. al, 1999). Simulation learning environments are having a profound impact in the way we learn and teach about complex problems, both in the social and in the natural sciences (Repenning et al, 1999). Programs like Stella, Powersim and StarLogo enable users to experiment with complex systems and develop better intuitions about the mechanisms that govern dynamic interactions.

'This paper describes work that builds on our previous work of using computationally-augmented objects in the real world. However, where much of the previous work focuses on how children interact with physical objects that have computational capabilities (Milrad, 1999), this work extends in the direction of integrating physical and computational media for the design of interactive simulations to support learning about complex domains.

2 INTERACTIVE SIMULATIONS FOR LEARNING

Jonassen et al, (2000) argue that drill-and-practice technology has turned out to be largely ineffective, and that simulation technology based on constructivist learning principles provides measurable learning advantages. The key feature of an educational simulation is that it makes use of a model to represent a process, event or phenomenon, which has some learning significance. The learner is able to interact with this representation and the simulation provides intrinsic feedback that the learner can interpret as the basis for further interaction.

Our effort involves the design of interactive learning environments to integrate systems supporting alternative ways of interaction with simulations- with an emphasis upon support for shared interaction to mediate social aspects of learning, knowledge construction, reflection and design. These interaction paradigms would integrate the use of computationally-augmented physical objects

(Blauvelt et al., 1999, Resnick, et. al, 2000) - to support and encourage face-to-face interaction among learners- with virtual objects- to provide computational support for the model underlying the simulation. Many models of learning and collaboration need to emphasise the creation of shared interaction, social structures, and cultural embeddings for meaningful learning (Dillenbourg, 1999). In the next section we briefly illustrate our work.

3 IMPLEMENTATION

We have implemented a couple of interactive learning environments (ILE) for school children and adults which involve some data modelling, LEGO construction and computer simulations. These rich technological environments provide an experimental arena for learning in and about complex systems. The learning environment has a LEGO-ROBOLAB (Portsmore, 1999) component supporting experiential learning and an experimental setting with sensors linked to computer modelling and analysis tools to support inquiry-based learning. Another component of the ILE is a system dynamics simulation, which supports decision-based learning and promote transfer of learning to other complex domains.

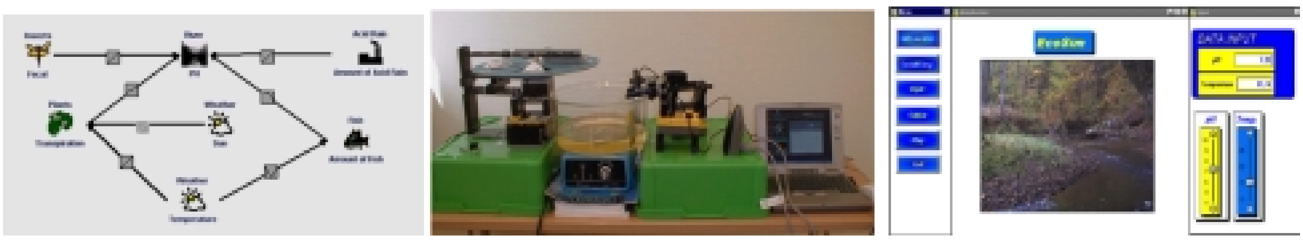
The different components of the ILE are all problem-based but address different aspects of problem solving activities and behaviour. These aspects are related to problems directly associated with a concrete and specific environment, to problems associated with hypothesis formulation in a concrete setting, and then to problems associated with abstraction, generalisation, and deep understanding of underlying structural causes for observed model and actual behaviour.

In order to promote meaningful learning in this kind of environment, we believe learners may begin with concrete operations, physically manipulating objects in order to solve specific problems. As these operations are mastered, they can then progress to more abstract representations and solve increasingly complex problems. Using this underlying framework, we describe below a learning environment for adults learning about issues related to marine biology. Figure 1 gives a few glimpses of the ILE by demonstrating some uses of the environment in the domain of water quality.

The technological tools that are suggested to the learners are: Model Builder, the LEGO-DACTA Robotics System, the ROBOLAB ™ programming language, and Powersim. Model Builder (Quintana et al., 1999) is a Java application that supports learners in building and testing dynamic models of complex systems. The heart of the LEGO Robotics system is the RCX, an autonomous LEGO microcomputer that can be programmed using a PC. This device can be connected to different sensors to take input from its environment, to process data, and to control signals and devices involved in different processes. ROBOLAB is the software for controlling the RCX and is based on LAB VIEW ™. Powersim is a modelling and simulation development environment for PCs.

We are pursuing a new effort, in implementing a new piece of the learning environment, in addition to those presented before. This new component will be a web based simulation using system dynamics to facilitate understanding of particularly difficult aspects of the system (second order delays, non-linearities in the system, etc.). Furthermore, we are exploring the possibility of transferring real data from the sensors in the LEGO Robotics system to the Powersim model in order to used this data during the simulation process.

We have been conducting empirical studies, by means of observations and interviews, of how and what children and adults learn through their interactions with this learning environment. These studies gave us some evidences showing that the students could use these ILEs and develop an understanding of the science inquiry process and the complexity of the problems we have analysed. However, more empirical research is needed to support our evidences. More broadly, we hope that these studies will help us to develop a richer theoretical framework for understanding the role of this new kind of learning environments for learning about complex domains.



Modelling the problem *Lego Construction* *Simulation*

Fig 1. The different components of the interactive learning environment

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