Supporting hypothesis generation by learners exploring an interactive computer simulation

WOUTER R. VAN JOOLINGEN & TON DE JONG

Abstract. Computer simulations provide environments enabling exploratory learning. Research has shown that these types of learning environments are promising applications of computer assisted learning but also that they introduce complex learning settings, involving a large number of learning processes. This article reports on an instrument for supporting one of these learning processes: stating hypotheses.

The resulting instrument, an hypothesis scratchpad, was designed on the basis of a conceptual representation of the simulation model and tested in an experimental study. In this study three versions of the scratchpad, varying in structure, were compared. It was found that support offered for identifying variables, in the form of a selection list, is relatively successful: students who used this list were better in differentiating different types of variables. For identifying relations, a selection list of relations offered to the students proved unhelpful in finding accurate relations: students using this list stated their hypotheses mainly at a very global level.

Introduction: supporting exploratory learning with simulations

Learning with computer simulations is a promising application of instructional technology. A main reason is that computer simulations enable the creation of relatively cheap, safe and well-accessible exploratory learning environments (Alessi and Trollip, 1987; De Jong, 1991; Reigeluth and Schwartz, 1989). These types of environments provide complex learning settings involving a large number of specific learning processes. In a recent study Njoo and De Jong (1991; see also De Jong and Njoo, 1990) made observations of students working with a computer simulation. They distinguished the following main categories of learning processes (apart from regulative processes, concerned with planning, and processes involved with operation of the simulation system):

- analysis
- hypothesis generation
- hypothesis testing
- evaluation

* The research reported was conducted in the project SIMULATE. SIMULATE was part of SAFE, a R&D project partially funded by the CEC under contract D1014 within the Exploratory Action of the DELTA programme. The work of SIMULATE is continued in the DELTA main phase project SMISLE.
The process of analysis is concerned with identifying variables and global model properties. In this phase the first, often not yet well-articulated, ideas about the underlying simulation model may arise, leading to the generation of hypotheses about the simulation. Hypotheses must be tested to become a part of the learner's (mental) model of the simulation. This testing includes the design of an experiment which will be performed with the simulation, predicting the outcomes of the experiment, on the basis of the hypothesis, performing the experiment and interpreting the results (Njoo and de Jong, 1992). This may lead to rejection of or support for the hypothesis and may give rise to the generation of a new hypothesis or a reformulation of an old one. Then the process may start over again. Also the learner can choose to investigate another part of the simulation model and state an hypothesis about that part. This process can continue until all parts of the simulation have been investigated and the learner has discovered the complete model. Research has shown that generation of hypotheses and designing experiments to test these are both important and problematic parts of discovery learning (Gorman and Gorman, 1984; Gorman, Stafford and Gorman, 1987; Klahr and Dunbar 1988; Mynatt, Doherty and Tweney, 1977, 1978; Njoo and de Jong, 1991; Wason, 1960).

Hypothesis generation and testing

Klahr and Dunbar (1988; Dunbar and Klahr, 1989; Shrager and Klahr, 1986) studied the formation of hypotheses and the design of experiments to test these, with students discovering the operation of a simple device. Their research results in a theory of scientific discovery as dual search (SDDS), partially based on general theories of problem solving (Newell and Simon, 1972; Greeno and Simon, 1988). They propose it as “a general model of scientific reasoning, that can be applied to any context in which hypotheses are proposed and data is collected” (p. 32). SDDS describes the scientific discovery process as a search process in an hypothesis space, containing all possible hypotheses about the system under study, and in an experiment space, consisting of all experiments that can be carried out with the system.

Klahr and Dunbar's findings indicate that there are two types of strategies for searching these spaces (see also Greeno and Simon, 1988, p. 640). The first is a bottom up strategy (used by what they call experimenters) consisting of a first phase in which an hypothesis is tested, followed by a phase where the subject searches the experiment space without explicitly stating hypotheses. The main characteristic of experimenters is that they perform experiments which rule out all other possible hypotheses before they actually state the correct hypothesis. In other words, experimenters cannot reach certain parts of the hypothesis space without prior experimental validation.

In the second, top-down strategy (used by so-called theorists) experiments are never performed without the prior statement of an hypothesis. Typically, a theorist states an hypothesis before carrying out an experiment and switches to a new