Modeling Implicit and Explicit Discovery Learning

Hedderik van Rijn (rijn@swi.psy.uva.nl)
Department of Social Science Informatics; University of Amsterdam;
Roetersstraat 15; 1018 WB Amsterdam; The Netherlands

Abstract

This paper describes the theoretical background of an Act-R model of discovery learning in a simulated, conceptual domain: optics. It is assumed that learning in a simulation context consists of both implicit and explicit learning. The Act-R model under development tries to capture both learning types.

Learning in Conceptual Domains

Current research on knowledge development in complex domains often concentrates on the acquisition of knowledge in procedural domains (e.g., learning how to solve a "Towers of Hanoi" problem). The development of knowledge in these domains can be described in terms of gradual changes of the procedures suited for the task at hand. In conceptual domains the acquisition of knowledge can better be explained in terms of qualitative restructuring of knowledge. During learning, the initially small and unstructured knowledge becomes more structured and is expanded with newly inferred or discovered knowledge.

This process can be described using Klahr and Dunbar's (1988) Scientific Discovery as Dual Search (SDDS) theory. According to this theory the learner discovers new knowledge by alternating between a hypothesis space and an experiment space. By searching the hypothesis space, the learner is able to identify hypotheses about the domain under study. By experimenting in the domain these hypotheses can be tested. Based on this searching and experimenting, existing hypotheses can be tested and new knowledge can be derived from the existing knowledge or from the experiments carried out.

Van Joolingen and de Jong (1997) extended the SDDS theory by specifying in greater detail the structure of the hypothesis space. In their theory, the hypotheses in this space are hierarchically ordered.

Experimental Studies

In projects parallel to the one described here, studies are carried out in which subjects have to discover the rules underlying a real world domain: an optics simulation. Both think aloud and action logs are recorded. To measure the acquisition of knowledge the subjects completed two pre-tests and two post-tests. The first pre- and post-test were constructed to measure definitional knowledge whereas the second pre- and post-test were constructed to measure intuitive "What-If" knowledge as described in Swaak and de Jong (1996). These two type of tests were chosen to be able to distinguish between implicit and explicit learning effects. First analyses show that subjects' performance increases on both tests.

In the experiments of Klahr & Dunbar (1988), there are clear differences between subjects in discovery learning tasks. A subject can either rely heavily on the hypothesis space or on the experiment space. Although Klahr and Dunbar labelled these subjects "Theorists" and "Experimenters", a better distinction between these subjects might be explicit and implicit learners. The explicit learners are using their meta-cognitive knowledge and the hierarchical information in the hypothesis space to deliberately choose a better hypothesis. Whereas the implicit learners only use the hypothesis space to identify possible variables to experiment with.

Modeling Implicit and Explicit Learning

To test these ideas, a model is being developed in Act-R 4.0 (Anderson & Lebiere, in press). Explicit learning is modelled as rules which explicitly search the extended SDDS hypothesis space for a better hypothesis, using the knowledge already gained from the experiment space. Using this knowledge, the model can decide how to manoeuvre in the hierarchical structured hypotheses as proposed by van Joolingen and de Jong (1997). For implicit learning on the other hand, rules are used which "just" select a new hypothesis, without explicitly testing or searching for a better fit between the hypothesis and the external world.

If this model is able to capture the behaviour of the subjects in the optics simulation, this would confirm the validity of the SDDS theories and provide a clearly specified distinction between implicit and explicit learning.

Acknowledgments

This research was conducted while Hedderik van Rijn was supported by a grant of the Dutch Foundation for Behavioural and Educational Sciences (NWO/SGW: 575-22-004).

References

Anderson, J., & Lebiere, C. (in press). The Atomic Components of Thought. Hillsdale, NJ: Lawrence Erlbaum.

Van Joolingen, W., & de Jong, T. (1997). An Extended Dual Search Space Model of Scientific Discovery Learning. *Instructional Science*, 25, 307-346.

Klahr, D., & Dunbar, K. (1988). Dual Space Search During Scientific Reasoning. *Cognitive Science*, 12, 1-48.

Swaak, J., & de Jong, T. (1996). Measuring Intuitive Knowledge in Science: The Development of the What-If Test. *Studies in Educational Evaluation*, 22(4), 341-362.