Scaffolding Causal Reasoning

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The Role of Causal Models – Causal Reasoning

Students' misconceptions of scientific phenomena result from their tendency to use intuitive reasoning strategies, instead of causal reasoning (Nisbett & Ross, 1980). Students' limited models of causality and process of inquiry account for the difficulties in their construction of conceptual knowledge (Perkins & Grotzer, 2000). In contrast to scientific causal models, the models that students possess are too simple and linear to deal with the complex nature of causality that is commonly seen in science concepts. To understand a science concept conceptually, students have to be able to make "epistemic moves" that go beyond a surface understanding of the concepts to appreciate the nature of "complex causality" (p. 4) in domains such as air pressure (Basca & Grotzer, 2001), ecosystem (Bell-Basca, Grotzer, Donis, Shaw, 2000; Green, 1997), motion (White & Frederiksen, 1995), social studies (Barton & Marks, 2000) and others.

Causal reasoning is an essential cognitive skill that is central to understanding the physical world (Brewer, Chinn, & Samarapungavan, 2000; Carey, 1995; Corrigan, & Denton, 1996; Schlottmann, 2001; Thagard, 2000; Wellman & Gelman, 1998). Reasoning causally enables an individual to predict, infer, or explain the events or phenomena that he or she has encountered or observed. There are two major conceptual frameworks for studying causal reasoning. The first is a covariational framework in which learners induce the influence and directionality of one or more variables on others (Ahn, Kalish, Medin, & Gelman, 1995). The other conceptual framework is mechanism-based in which the underlying mechanisms of the causal relationships are conceptually explained to learners (Thagard, 2000).

Two studies

Two studies are designed to compare the two approaches for helping students to think causally – covariational vs. mechanism. Covariational representations examine causal relations quantitatively, while the mechanism-based representations convey causal relations qualitatively (Thagard, 2000). While it is important that students understand the direction and extent of covarying patterns of the causes and effects, they must also understand the mechanisms underlying the cause-effect relationships. Without understanding of the underlying mechanisms of those relationships, students would have difficulty constructing coherent conceptual models (Perkins & Grotzer, 2000).

Study 1

This study was conducted utilizing pretest-posttest, control group design. The participants were randomly assigned into two experimental groups, the mechanism-based group and the covariational group. Two versions of computer-based environment (simulations and influence diagrams) were developed in Flash 5.0. In each version, two rotational motion problems (a pulley system problem and a merry-go-round problem) were provided to students to supplement in-class practice.

Study 2

The second study takes place in an introductory undergraduate course in biological anthropology. The study focused on alternative representations of the effects of environmental forces on the genetic constitution of populations. We constructed models of gene flow and natural selection using STELLA by High Performance Systems. The simulations are web-based "black box" models where students interact with a user interface to the model while the underlying model is hidden.

Discussion and Conclusions

In two separate studies, we compared the cognitive effects of simulations representing covariational models of causality with influence diagrams representing mechanism models of causality. We found that mechanism models fostered conceptual understanding of domain principles, but neither treatment provided any advantage in solving quantitative problems. Future research will compare combinations of treatments and examine the effects of quantitative problem solving as well as qualitative.

References

References upon request