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Applying Cognitive Models to Support Teaching and Learning

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INTRODUCTION

Cognitive modeling is both hard and important. That is, deriving valid and reliable estimates about what a student knows and doesn't know requires a large array of good student data, as well as sophisticated inferencing tools and technologies to filter the mountain of data and make sense of it. Cognitive modeling is important because when teachers or computer-based instructional systems know how students are progressing and where the students are having problems, they can use that information to make necessary instructional adjustments such as re-teaching, trying alternative instructional approaches, or offering more opportunities for practice. This is called formative assessment, and it has been shown to improve student achievement (Black & Wiliam, 1998a; Black & Wiliam, 1998b; Wiliam, Lee, Harrison, & Black, 2004).

As co-chair of the SIG TICL 2006 conference, I organized several symposia that were intended to examine cognitive modeling to support teaching and learning from a variety of perspectives. Participants in these symposia did not fail to deliver. The presentations and papers were high quality and represented a diverse mix of ideas and methodologies in relation to the topic.

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The call for papers that was distributed prior to the conference included the following working definition, "Cognitive models are representations of what's inside the learner's head—in relation to thinking, knowing, and learning. They help predict, and/or control complex human behavior—including skill learning, problem solving, and other types of cognitive activities. To the extent possible, the kinds of cognitive models proposed should apply across various domains, serve different functions, and model ill-defined knowledge (e.g., design problems). The focus should be on creating and/or applying such models to shape the design and development of educational materials (assessments and instruction) and associated technologies to support teaching and learning."

This special issue comprises a group of four papers: (1) Russell Almond's paper on, "Cognitive Modeling to Represent Growth (Learning) Using Markov Decision Processes;" (2) Ron Stevens and Vandana Thadani's paper entitled, "Quantifying Student's Scientific Problem Solving Efficiency and Effectiveness;" (3) Susanne Lajoie, Genevieve Gauthier, and Carlos Nakamura's paper on, "Cognitive Models and Cognitive Tools in Educational Applications;" and (4) Dirk Ifenthaler, Pablo Pirnay-Dummer, and Norbert Seel's article on, "The Role of Cognitive Learning Strategies and Intellectual Abilities in Mental Model Building Processes."

IN A NUTSHELL

To summarize briefly, Almond focuses on cognitive modeling to support instructional planning—something that is sorely needed by teachers in the classroom. That is, the best diagnostic assessments in the world will not be that useful unless they are connected to suggestions for instructional interventions (i.e., information about what to do next). Towards this end, Almond describes a general framework based on decision analysis (i.e., partially observed Markov decision processes, or POMDPs) that supports instructional decision making or planning. There are two primary provisions of this proposed framework: (a) *filtering* student data to yield valid estimates of current proficiency level(s), and (b) *forecasting* where the student is likely headed given past and current states.

There are some high-level similarities between Almond's article and the one by Stevens and Thadani—particularly in relation to the derivation of mathematical models of students' learning and problem solving (current and projected), as well as using that information on which to base instructional interventions. Stevens and Thadani, however, focus on formulating useful descriptions or indices of students' problem solving efficiency and effectiveness. These indices are immediately available to teachers and students, and provide meaningful comparisons within and across educational systems and science domains. The authors additionally present empirical tests of their measures—the EI (efficiency index) and QV (quantitative value)—in relation to standardized test performance.

Lajoie, Gauthier, and Nakamura examine cognitive modeling in the context of a computer-based learning environment called BioWorld. This program has been designed to support teaching and learning of biological systems (i.e., human patient cases) by different cohorts of students/users. The students vary in their levels of expertise, from high school students studying biology to medical interns and physicians. The article describes using cognitive models as the basis for developing cognitive tools to support diagnostic and scientific reasoning. The focus of the paper is on the validation of the cognitive models used in BioWorld. This is especially interesting given the ill-structured nature of the problems (i.e., medical diagnoses) with multiple solution paths possible. The authors note that they are currently integrating different experts' visual representations to render a more comprehensive representation of the various paths through which a patient case can be solved. This is intended to lead to better assessment and feedback routines that may be adapted to individual differences in terms of diagnostic reasoning.

The final paper in this special issue, by Ifenthaler, Pirnay-Dummer, and Seel, is like the Lajoie et al. paper in that it looks at cognitive modeling of complex tasks. However the focus of the Ifenthaler et al. article is on the role of learning strategies and intellectual abilities in relation to model-centered learning and instruction. Specifically, they present the results from an empirical study examining the effects of the more intractable intellectual abilities and learning strategies in relation to students' model building efforts, and their findings may be rather surprising (I won't give away the punch-line here). In any case, their findings have implications for future work in this area—particularly with regard to the use of methodologies that employ new approaches to eliciting information to populate concept maps for model-based teaching and learning environments.

CONCLUSION

In conclusion, I am pleased to present this collection of novel and thought-provoking articles that provide fresh thinking on ways to harness the power of cognitive models for use in real educational contexts. Currently, the state of the art of cognitive modeling tends to be too complex—rarely leaving the rarified world of laboratory environments. Each of these four papers brings cognitive modeling out of the laboratory and potentially into the hands of those who can really benefit the most from such models—the teachers.

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