ABSTRACT

Title of dissertation: DYNAMICS OF STUDENT MODELING: A THEORY, ALGORITHMS, AND APPLICATION TO QUANTUM MECHANICS

Lei Bao, Doctor of Philosophy, 1999

Dissertation directed by: Professor Edward F. Redish
Department of Physics

A good understanding of how students understand physics is of great importance for developing and delivering effective instructions. This research is an attempt to develop a coherent theoretical and mathematical framework to model the student learning of physics. The theoretical foundation is based on useful ideas from theories in cognitive science, education, and physics education. The emphasis of this research is made on the development of a mathematical representation to model the important mental elements and the dynamics of these elements, and on numerical algorithms that allow quantitative evaluations of conceptual learning in physics.

In part I, a model-based theoretical framework is proposed. Based on the theory, a mathematical representation and a set of data analysis algorithms are developed. This new method is called *Model Analysis*, which can be used to obtain quantitative evaluations on student models with data from multiple-choice questions. Two specific algorithms are discussed in great detail. The first algorithm is the concentration factor. It measures how student responses on multiple-choice questions are distributed. A significant concentration on certain choices of the questions often implies the existence of common student models that are associated to those choices. The second algorithm is model evaluation which analyzes student responses to form student model vectors and student model density matrix. By studying the density matrix, we can obtain quantitative evaluations of specific models used by students. Application examples with data from FCI, FMCE, and Wave Test are discussed. A number of additional algorithms are introduced to deal with unique aspects of different tests and to make quantitative assessment of various features of the tests. Implications on test design techniques are also discussed with the results from the examples.

Based on the theory and algorithms developed in part I, research is conducted to investigate student understandings of quantum mechanics. Common student models on classical prerequisites and important quantum concepts are identified. For example, many students interpret the quantum wavefunction as the representation of the energy of a particle. Based on the research results, multiple-choice instruments are developed to probe student models with model analysis algorithms. A set of quantum tutorials are also developed and implemented instruction. Results from exams and student interviews indicate that the quantum tutorials are effective.