THE USE OF MODELS IN TEACHING NEWTONIAN MECHANICS

by

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ABSTRACT

The use of models in a student-centered teaching strategy is shown to improve the effectiveness of college physics instruction. The content of a college mechanics course is formulated as a theory of mathematical modeling with explicit construction and deployment rules. An accompanying teaching method that accounts for individual differences in students' preinstructional knowledge base is also formulated. Groups of college physics students were trained following the proposed strategy, and compared to control subjects taught by conventional methods. The comparison was made with respect to students' performance on course examinations and on a set of diagnostic tests. The diagnostic tests were validated to assess students' initial knowledge state and changes brought about by college physics instruction. Trained students are consistently shown to perform significantly better than control subjects both within and outside the context of the training program. A competence-performance comparison revealed that average and low competence students benefited most of the training.

To Thy Glory

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Preface

College physics courses suffer from high rates of attrition, and the performance of a good proportion of students who complete their courses is unsatisfactory to physicists. At Arizona State University, the rate of withdrawals ranges from 30% to 40% in the various introductory physics courses. Furthermore, 20% to 30% of the remaining students complete their courses with a final grade of "D" or "E". Overall, over 50% of students who register for college physics courses fail or drop out. Similar rates are reported in the literature for colleges and universities across the United States. This crisis triggered a number of investigations in the last two decades (Barowy and Lochhead, 1981; Champagne et al, 1980 through 1982; Chi et al, 1982; Clement, 1977 through 1982; Gunstone and White, 1981; Hudson and Lieberman, 1982; Larkin et al, 1978 through 1981; Lawson et al, 1980, 1981; Lochhead et al, 1980, 1981; McCloskey et al, 1980, 1981; Trowbridge et al, 1980, 1981; Reif et al, 1978 through 1981). Most researchers focus on the investigation of students' knowledge about a limited number of isolated Newtonian concepts. Some try to improve students' understanding of these concepts. This dissertation is concerned with: (a) assessing students' knowledge state before and after instruction about particle

models of the Newtonian theory, rather than isolated concepts, and (b) validating a teaching strategy intended to improve the effectiveness of college physics instruction.

The dissertation is divided into three parts. In part I, students' deficient understanding of Newtonian Mechanics is analyzed (Chapter 1); then a teaching strategy is proposed (Chapter 3) and validated (Chapter 4) to improve the effectiveness of physics instruction. The strategy emphasizes the use of models in representing and deploying the Newtonian theory (Chapter 2). Part II reviews the literature on related research in physics education (Chapter 5) and cognitive psychology (Chapter 6), as well as the historical development of Classical Mechanics from Aristotle to Galileo (Chapter 7). Part III documents the validation of diagnostic tests used for the purposes of chapters 1 and 4 to assess the competence of college students and predict their performance in conventional physics instruction (Chapter 8).