This is an updated version of the U.S. Department of Education's Expert Panel report. (As of Dec. 2002, the Expert Panel report is temporarily archived in the DoED website. Since the archived report is difficult to access, we provide it as a service.)

http://www.ed.gov/offices/OERI/ORAD/KAD/expert_panel/math-science.html
PROMISING AND EXEMPLARY PROGRAMS IN SCIENCE (1-2001)

Modeling Instruction in High School Physics

Modeling Instruction in High School Physics is recommended by the Expert Panel on Mathematics and Science Education as an Exemplary science program.

Program Description. *Modeling Instruction in High School Physics* is grounded on the thesis that scientific activity is centered on modeling: the construction, validation, and application of conceptual models to understand and organize the physical world. The program uses computers and modeling methods to develop the content and pedagogical knowledge of high school physics teachers and train them to be leaders in science teaching reform and technology infusion in their schools and districts. The program relies heavily on professional development workshops to equip teachers with a teaching methodology. Teachers are trained to develop student abilities to make sense of physical experience, understand scientific claims, articulate coherent opinions of their own, and evaluate evidence in support of justified belief. For example, students analyze systems using graphical models, mathematical models, and pictorial diagrams called system schema.

Professional Development Resources and Program Costs. High school physics teachers attend a series of intensive workshops over two years. Most participants proceed to share their new pedagogical insights and techniques with colleagues, and many commit to conducting modeling workshops. The project plans to sustain and extend science teaching reforms instigated by the workshops through the development of local infrastructures to support the continued professional development of teachers. Regional *Science and Technology Education Partnerships* (STEPs) are planned between university physics departments and local physics teacher alliances. Foundations for statewide partnerships already have been established in Arizona and Wisconsin.

The cost for an individual teacher to implement the mechanics modeling program includes tuition for a three- or four-week summer workshop, $20 for instructional materials, and travel/room/meal expenses. For a group of school districts to implement the mechanics modeling program for 20 physics teachers, minimal workshop costs include fees of $1000 per week x two master teacher-leaders and $20 x 20 teachers for instructional materials. Implementation of mechanics in the classroom is best accomplished with computers that have laboratory interface and three MBL probes: motion detector, pair of photogates, and force probe. One computer for every three students is recommended.

Program Quality. Reviewers stated that the program's goals are explicit and reflect current research on learning theory. As a supplement to any physics course, the program's learning goals include reinforcement of the most important concepts with the study of mechanics. The physics content embedded in the units is fundamental to mechanics, physics, and all science. The program's content is aligned with its stated goals, and the instructional approach emphasizes important mechanics problems in depth. *Modeling Instruction in High School Physics* utilizes experimental design, control of variables, and calls for reasoning and application of skills in solving various kinematics and dynamics problems. There is strong use of student discourse, as evidenced by the need for students to present and justify conclusions derived in the laboratory. Multiple strategies for problem-solving are encouraged, reflecting sensitivity to individual student differences and abilities. The program contains a rich, integral system of assessment that is one of its strongest features, and

the multiple modalities it employs provide teachers with ample entry points into the students' learning processes.

Usefulness to Others. Reviewers noted that many aspects of the teaching methodology can be successfully transferred to other settings. The program offers a wide range of teacher support, including information on laboratory, extension, application, and deployment activities. The program recommends teacher training of eight weeks over two summers to accomplish pedagogical transformation and a large infusion of equipment and technology in the classroom. Some school districts may need to seek external aid to meet the costs of the program.

Educational Significance. The goals of the program strongly mirror the vision promoted in the national science standards. Reviewers emphasized that the program is impressive in its awareness of and attention to the national content, teaching, and assessment standards. The program is exceptional in its modeling and emphasis on the skills, attitudes, and values of scientific inquiry. It addresses important individual and societal needs by providing constructivist pedagogy for the fundamental mechanics that are crucial to understanding the physical world.

Program Effectiveness and Success. Reviewers found that the program provided extensive and persuasive evidence of gains in student understanding of science and in inquiry, reasoning, and problem-solving skills. Data also confirmed that an important factor in student learning is the degree of implementation by teachers of modeling methods learned in the workshops. There were repeated findings that greater degrees of program implementation of the modeling methods were associated with larger student gains. Reviewers commented that these repeated findings negated the possibility that student improvements might be attributable to more motivated teachers.

The program presented numerous evaluations that (a) utilized a pre-post measure, *Force Concept Inventory* (FCI), on large numbers of both treatment and matched comparison groups; (b) were carried out in multiple sites during several years; and (c) made empirical connections between implementation of the approach and results. Sample sizes varied from year to year, with most final merged datasets ranging in size from about 1300 students and 50 teachers, for Phase I 1995-97 data collection, to over 3000 students and 70-80 teachers for the larger number of participants in Phase IIa 1997-98 and Phase IIb 1998-99 data collection. Student data came from three major high school course types: regular and introductory physics, honors level physics, and advanced placement physics.

The FCI instrument has high reliability and was developed to assess the effectiveness of introductory physics instruction, specifically the effectiveness of mechanics courses to teach students to reliably discriminate between the applicability of scientific concepts and naive alternatives in common physical situations. FCI data on 24,000 students in courses of hundreds of high school, college, and university teachers indicated that students' naïve beliefs about motion and force are little changed when using traditional instructional methods, while greater changes can be achieved with instructional methods derived from modeling.

Repeated findings demonstrated greater gains for program students in physics content knowledge when compared to physics students of the same teachers in the year before the teachers implemented the program and students in traditional physics classes and alternative reform programs. The *Modeling Instruction in High School Physics* students exceeded the performance of the comparison groups by margins that in some cases exceeded two standard deviations.

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