

# Initiatives in Education

## Physics Education at ISU

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ISU physics students respond to instructor's question using "flash cards."

In recent years, physicists at U.S. colleges and universities have significantly increased efforts to improve the teaching and learning of physics at the undergraduate level. One of the components of this effort has been the creation of what is now recognized by the American Physical Society as a new subfield of physics: "Physics Education Research," or "PER." Physicists engaged in PER attempt to treat the problems involved in physics education, as much as possible, as they would any other research problem. This involves systematic observation and data collection, and the design and execution of pedagogical experiments that may be reproduced by different instructors in diverse institutions with widely varying student populations. Based on their advanced training in physics, PER researchers are uniquely situated to identify and control many of the variables involved in physics learning, and to carry out in-depth probes and analyses of students' thinking as they engage in the process of learning physics concepts.

The rapidly expanding research literature in PER<sup>1</sup> includes detailed studies of student learning difficulties in a wide variety of physics topics such as mechanics, electricity and magnetism, optics, and quantum mechanics. It also includes reports of the development and rigorous testing of innovative curricular materials and instructional methods

designed to address and resolve many of these learning difficulties.

Numerous investigations have provided strong and consistent evidence that research-based instructional methods and materials can significantly improve the learning of physics concepts by college and university students.

There are now approximately 50 physics departments at U.S. colleges and universities in which one or more faculty members devote a majority of their research effort to PER. About a dozen research universities carry out graduate research programs in PER, including the award of Masters and Ph.D. degrees in physics for dissertations in physics education. The largest of these groups, at the University of Washington in Seattle, has awarded more than 12 Ph.D. degrees in physics education research. Beginning in August 1998, Iowa State University joined the ranks of universities offering advanced degrees in physics education research; our first Masters degree in this field was awarded in May 2001.

At ISU, our physics education research group has engaged in close collaboration with the long-standing ISU chemistry education research group led by Tom Greenbowe, Professor of Chemistry. Since 1998, three physics graduate students and three undergraduates (one

from a neighboring college) have helped carry out the work in our group. Our research group engages in coordinated efforts in a number of distinct, though closely related areas. First, we carry out "basic research" in physics education by exploring in depth students' learning difficulties in diverse areas of physics. Projects currently ongoing or nearing completion include studies of student concepts in gravitation (by graduate student Jack Dostal, now at Montana State University), astronomical scale and lunar phases (by Masters graduate Tina Fanetti), and vectors (by graduate student Ngoc-Loan Nguyen). University Professor of Astronomy Lee Anne Willson has been a principal collaborator in the astronomy education research conducted by Tina Fanetti.

In 2000, with Tom Greenbowe as Co-Principal Investigator, I was awarded a \$149,000 grant from the National Science Foundation to develop innovative curricular materials in thermodynamics. These materials include research-based problem sets that are carefully designed both to elicit common student difficulties regarding the subjects under study, and

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then to lead students to confront these difficulties head-on with tightly focused and strategically sequenced series of questions and exercises.

Another major project for our group has been to develop improved instructional methods and curricular materials for large-enrollment course, including lecture courses in which an instructor faces 100 to 250 students at a time. Our objective is to incorporate active-learning methods in such courses, in which students engage in diverse problem-solving activities during class time. Our current focus is on the algebra-based general physics course, populated predominantly by life-sciences majors. The level of student-student and student-instructor interaction in these classes is dramatically increased by the use of a student response system incorporating “flash cards.” Every single student in the class has a pack of six large

flash cards (5” × 8”), each printed with one of the letters “A,” “B,” “C,” “D,” “E,” or “F.” These flash cards permit the instructor to get instantaneous responses to multiple-choice questions by *all* of the students in the class simultaneously (see accompanying photo). Curricular materials to support this instructional method – including a large collection of specially designed sequences of multiple-choice questions – have been developed in collaboration with Prof. Kandiah Manivannan of Southwest Missouri State University. These materials are incorporated in the *Workbook for Introductory Physics*, now available in a preliminary edition in CD-ROM format. Various assessments employed standardized tests have demonstrated that learning gains by ISU students enrolled in these “active-learning” course are significantly higher than those found in national surveys of students in more traditional learning environments.

Much more detailed information on the work of the ISU PER group is available on our website, <http://www.public.iastate.edu/~per/>. Many of our papers and conference presentations can be viewed at that site, along with details of our NSF-sponsored curriculum project. We would be happy to provide further details and samples of our group’s work, including copies of the *Workbook for Introductory Physics* CD-ROM, to interested readers of this newsletter. Please contact me directly at [dem@iastate.edu](mailto:dem@iastate.edu).

<sup>1</sup> Lillian C. McDermott and Edward F. Redish, “Resource Letter: PER1: Physics Education Research,” *Am. J. Phys.* **67**, 755-767 (1999).

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