Reform of University Physics II (introductory calculus-based electromagnetism and optics, UPII, PHYS 2074) began prior to PhysTEC as a very successful NSF-sponsored CCD project. When the number of physics majors was still falling for most of the country, Arkansas saw numbers swelling (from an average of 2 graduates a year to 10 or more). When given the opportunity to impact teacher preparation, our philosophy is that you never know who will be a teacher in the future, and that almost anything a future science student will end up doing would be improved by not only a better understanding of physics, but some of the skills that make a good teacher. Student reaction to the course supports the idea that labs should often involve materials students could replicate at home (or in a future K-12 classroom) or at least find familiar. The introduction of further reforms made possible by PhysTEC resulted in a doubling of the average graduation rate to over 20 per year. Since PhysTEC, while most of our graduates go on to graduate school, 10% or more decide to enter the K-12 classroom.

The reforms of physics courses also called for what may be the most important reform, that of the preparation of graduate teaching assistants. While some of these have decided to pursue a career in K-12 teaching, many decide to go on to faculty positions where their request for materials leads us to believe they may be becoming part of the revolution!

Two of the introductory classes undergoing development as part of the PhysTEC project are part of the broader education research effort at the University of Arkansas. The goal of that research is to model and thoroughly understand how science classes function. As such, the courses are characterized and measured in great detail. This increases our understanding of the operation of science courses and further informs our development decisions. A worthwhile side-effect is that much of the educational research is performed by bright undergraduates, who have the opportunity to experience research. Several of the projects have been carried out as competitively- funded undergraduate honors thesis projects. Three of the projects linked below were performed by students with the long-term goal of working in education.
For an overview of the research: http://educationalengineering.uark.edu/

To look at some specific examples, including the undergraduate projects mentioned above, see: General Physics Educational Research

AND: Content Independent Tools Research

Reason for Reforming Course

The early NSF reform effort, before the PhysTEC Project began, addressed issues on two levels. Locally, the department saw falling numbers of graduates, and dissatisfaction from the College of Engineering, the largest constituency served by the class. A national problem we sought to address is that strong international competition demands that we give our students the opportunity to develop the broad range of skills and high degree of creativity that are needed to compete successfully, yet introductory physics is often used to “weed out” students. We wanted to improve the level of student learning, confidence, and enjoyment of science, while maintaining the resource level common to large institutions (teaching assistants in labs, large lectures, etc.)

Further reforms for the PhysTEC project have been to try to better understand what is successful and create supporting materials so that the course can be easily replicated. The course operation is understood well enough that it can be used as a sort of laboratory to test the effects of things like course policies on student learning, allowing us to optimize learning for available resources.

Research shows that students use formula-centered problem-solving strategies that differ from those used by experienced scientists, and that the knowledge students gain in introductory physics is a randomly organized set of facts and equations, with little conceptual understanding and many misconceptions. Many approaches have been developed to overcome these problems, and have met with reasonable success in small institutions, or for a particular professor. These approaches are often too expensive or complicated to transfer to large comprehensive universities. Also, graduate students, the future instructors of science, are in general inadequately trained as educators. The goal was to design a teaching system to overcome these problems in a method that could be standardized and made available to larger schools, as well as being appropriate for smaller institutions. The method involves leading the student from concrete "hands-on" examples to conceptual understanding, in the *idea first*, *name afterward* fashion. Concepts are related to everyday phenomena familiar to the student. Students are taught how to think about physics problems. Cooperative learning, found to improve retention of female and minority students, is emphasized. Graduate and advanced undergraduate students are brought into the teaching process as apprentices, with materials to acquaint them with the teaching strategies to be employed.

Implementation Background

The class meets twice a week for 50 minutes in a large group setting, and twice a week for 110 minutes in a lab setting.

The large group setting (a "raked" lecture hall with approximately 160 students) allows for the kinds of things that can be done effectively in a large group. Definitions, vocabulary, and problem-solving strategies can be provided. Quizzes are given at the beginning and end of class to make sure the students are staying up with the material, and thinking about the reading they just did, or the material they just completed. (As a side-benefit, this allows the primary instructor to monitor the progress of all the small-section activities.)

The lab setting (22-24 students) allows students to do inquiry-based labs, carry out guided explorations, work group problems, and participate in things that would normally be lecture demonstrations they could not touch. They are encouraged by class policy and the questions raised in the course materials to argue amongst themselves and with their instructors (either a faculty member, graduate assistant, or advanced undergraduate learning assistant) about course topics.

The class involves careful timing of laboratory with lecture, laboratories designed around hands-on activities, reading material specifically crafted to support conceptual learning while still supporting quantitative skill development, and a careful focus on reliability and cost. Two implementations have been developed and tested. The first covers a restricted set of topics (less is more) such that all the important conceptual, graphical, and quantitative topics can be given support both in lecture and in laboratory. The second implementation includes all topics found in standard introductory textbooks, much greater support for calculus, and all the conceptual support provided in the restricted version.

The class is primarily made up of STEM majors, who have completed one semester of University Physics and one semester of calculus, and are concurrently enrolled in the second semester of calculus.

There is an extensive on-line course guide developed at UA to support the class including all course readings, the study guide, questions, problems, practice tests and examples. The student version of the course guide is available at the website, and an instructor version is available upon request. The activity guide for the course is also available upon request.

The course is taught by a team made up of one faculty member, 3-4 teaching assistants and 0-2 learning assistants each semester.