

University Physics I (PHYS 2054)-First-semester calculus-based introductory physics

Reason for Reforming Course

Area high school physics teachers often let us know who is coming to UA that might be a good physics major, or physics teacher. Several of these students were not making it through UPI into UPII. Students were coming out of UPII with good attitudes about physics and teaching, but still with complaints about UPI. ([UPII was already reformed, and underwent further development with PhysTEC](#)). One new teacher of chemistry, prior to PhysTEC, got asked to teach physics and came back to her UPII instructor to say while she felt very comfortable teaching UPII topics, the course she had been asked to teach was primarily UPI, and she just didn't think she understood it well enough and needed remediation. Since the department doesn't often stay in touch with those that are not majors, and the vast majority of the high school physics teachers in the state are not majors, it seemed that this course desperately needed revision.

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 200 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 (24-27 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, often two instructors in the 27-student sections) about course topics.

The class is primarily made up of STEM majors, with approximately 5% high end pre-med majors. Overall 20% of the class is part of the one of the university's honors programs. While many of the students may have had physics or calculus in high school, the course assumes no preparation. Entering FCI scores support this decision.

The course is co-requisite with the first semester of calculus, and addresses the important calculus concepts used. The textbook for the course is Eric Mazur's Physics: Principles, which addresses introductory mechanics from the conservation principles first, and an extensive on-line course guide developed at UA to support the class including study guide, questions, problems, practice tests and examples. The student version of the course guide is available [here](#), and an instructor version is available upon request. The activity guide for the course is also available.

The course is taught by a team made up of one faculty member, 4.5 teaching assistants and 0-3 learning assistants each semester.

Scholarly Basis of Reform

The class uses a conservation-principles-first approach¹, and uses the following innovative techniques, many from UPII:

1. A course structure designed to get the gains in student learning seen in completely integrated courses in an affordable and instructor-independent fashion.

The characterization of the class must be complete so that we are not encouraged to optimize a characterized area at the expense of another. For example, traditional mechanics exams measure problem solving. This incompleteness has encouraged optimization of problem solving at the expense of conceptual understanding. There is research suggesting students do not optimize their learning for understanding when a correct answer is most of the grade.^{2,3} “Going for the number” instead of for understanding may lead to the well-documented differences in expert and novice problem solving.^{4,5,6} Students are encouraged to prepare some of their problem assignments with some of the same attention to structure, logic, and components present (such as qualitative discussion) as they might use in preparing a written assignment, taking the best from, and enhancing, problem-solving formats.^{7,8,9,10,11,12}

2. Activities and laboratory exercises based on familiar phenomena or utilizing everyday items to illustrate new phenomena.

We utilize the value of hands-on experience¹³ at the very moment its impact would be the most effective by careful course scheduling, center the dialogue and hands-on experience on concepts related to everyday life, and thoroughly involve the student in the learning process.

Another significant feature of our program is that the structure of the course emphasizes the cooperative nature of scientific research. The class encourages the students to work together. In traditional lecture-based courses, even when the grading is not on a curve, students often still assume they will be graded on the curve.¹⁴ The competitiveness this engenders makes the classes less attractive to women and minorities, groups which are particularly sensitive to “class climate.”¹⁵ It is found that the largest percentage loss of minority students pursuing an engineering degree occurs in introductory courses.^{15,16}

3. An emphasis on fulfilling the goals of higher education to promote overall intellectual development by providing a medium to encourage the transition from concrete to abstract thought.^{17,18,19}

In order to make the transition to formal thought, concrete operational students must think, but since they think only with concrete objects, events and/or situations, providing the opportunities for concrete exploration before abstract concepts are presented will gradually lead them toward formal thought.²⁰ This type of cooperative learning is found to improve retention of all students, but particularly of female and minority students.²¹ The UA has a large number of non-traditional students. These

students respond particularly well to the nurturing environment we try to establish.

Repeated exposure to traditionally taught physics courses does not lead to gains in conceptual understanding^{22,23}. Arons²⁴ has said “The appropriate starting point is not the model, but the observed fact.” It is very important that the mental process of going from the demonstration to the known fact is carried out actively. Answers available from rote memorization must be challenged. An experiment which is not a “canned lab” and that demonstrates the concept and corresponding model is carefully chosen.²⁵ The success of the materials when they are moved to a different environment is far from assured.^{26,27} Any innovative curriculum can suffer unless the detailed features that make it valuable are understood and the actions it is supposed to produce in students are defined and measured. In high school physics, this has been documented in Hestenes “modeling” curriculum.²⁸ Students utilizing all the components correctly (22%) make impressive gains on the FCI, but the remaining students show no benefits from the special instruction. Despite an intensive training program, later observation of many of the teachers participating shows a regression to traditional teaching methods of which they are apparently unaware.

Students’ self-reported enjoyment of educational activities related inversely to their own estimates of educational value of those activities.²⁹ Their estimates of value were found to be reasonably in line with the instructors’ opinions, though with some interesting, and worrisome, differences.³⁰ A call has been made to introduce the same kinds of standards and measurements in physics education that we have in physics.³¹

Use of demonstrations with pre- and post-demonstration questioning designed to make the students predict what they expect to happen and confront their misconceptions, coupled with inquiry-based laboratories has been very successful for introductory mechanics.^{32,33,34,35,36,37,38}

4. The training of graduate students as true teaching assistants in the classroom, including an apprenticeship.

The personal communications skills developed through discussion and group work represent areas in which engineering graduates are often found lacking³⁹ and which are of ever increasing importance.⁴⁰ Moreover, since large universities already make extensive use of graduate students in teaching roles, changing their roles to one of interns will have a positive impact on education quality.⁴¹ It is also possible to utilize senior undergraduate students, either science education majors or physics majors interested in education, as apprentices. This allows students who do not plan to pursue a Ph.D. to gain valuable teaching experience and decreases the cost of implementation, particularly at very large institutions.

5. A large body of carefully crafted homework and test problems to allow self-evaluation by the students of their own progress, as well as instructor evaluation.

6. Moving the first semester of physics back to the first semester of college, designing it to be taught concurrently with first-semester calculus so that the two courses reinforce each other, without the difficulty inherent in team teaching.

[\[Link to UPI References.htm\]](#)