

Educating in Bulk: The Introductory Physics Course Revisions at Illinois

Gary Gladding
University of Illinois at Urbana-Champaign

About five years ago, we began a complete revision of the introductory physics courses at Illinois. An initial description of our work on the calculus-based courses was reported in the paper “Parallel Parking an Aircraft Carrier” (Forum on Education of the Am. Phys. Soc., 8-11 (Summer 1997) <http://www.aps.org/units/fed/aug97/index.html> - campbell). This paper presents the current state of the revisions as reported at the AIP Academic-Industrial Workshop in October 2001.

Prior to fall 1996, introductory physics at Illinois was taught in a very traditional manner. Namely, in each course, students attended large (200-300 students) lectures and small (24 students) discussion and lab sections for a total of 6-7 hours per week. The calculus-based sequence was twelve semester hours (three courses) while the algebra-based sequence was ten semester hours (two courses). A total of about 2500 students were registered in these five courses each semester. The lecturer was ultimately responsible for all aspects of the course; this stressful situation was recognized in our policy to rotate faculty into these positions frequently (typically every two semesters). The discussion sections were run by graduate student TAs who were pretty much on their own; usually these TAs spent the time working problems at the blackboard. The labs were intellectually disconnected from the rest of the course. I think it's fair to say that neither the students nor the faculty were happy with this situation.

In fall 1996, the first of the revised courses was offered. By fall of 1997, all courses in the calculus-based sequence were being taught in the new manner. The revised algebra-based courses were first offered in fall 1999 and spring 2000. The defining idea of the revisions was *to integrate all aspects of a course using active learning methods based on physics education research in a team teaching environment*.

Each course is managed by a team consisting of three to four faculty. Each team member has a well-defined individual responsibility (lecturer, discussion coordinator or lab coordinator). In addition, the team meets regularly to keep the course on track and to create the exams. The faculty find this arrangement to be much superior to the traditional one in which the lecturer is ultimately responsible for everything. Pain and gain are shared; burnout has been eliminated. No heroes are needed or wanted. The existing infrastructure lowers the bar for faculty participation in the course. An assignment to an introductory course is no longer dreaded, but rather accepted as an ordinary assignment. More than forty faculty members have taught in these revised courses at this point.

Students also report a definite increased satisfaction with the courses. One quantitative measure of this improvement can be found in the student evaluations of the TAs in these courses. The Office of Instructional Resources at Illinois manages these evaluations and publishes each semester a list of excellent TAs based on the results. This list includes about 30% of the TAs on campus. Prior to the revisions, in spring 1995, fifteen of the seventy-seven physics TAs (19%) made this list. In spring 2001, fifty-eight of the seventy-five TAs (77%) made this list!

A few principles guided the revision of each course. First, each course must be a coherent whole; all pieces of the course (lectures, discussion, labs, homework) must be

cut from the same cloth. Students should see a coherent plan at work. Second, each course must feature explicit instruction (and testing!) on the concepts of physics. Traditionally there is a large gap between what we think we are teaching (physics) and what is being learned (equation manipulation). Finally, active learning methods must be used in all aspects of the course. “Teaching by Telling” is not an effective strategy. There is a research base here (materials and knowledge produced by Physics Education Research groups) that should be used to create the revised courses.

We attempt to actively engage the student in all aspects of the course. In lectures, we introduce interactive segments which we call ACTs. In these segments, the lecturer poses a conceptual question to the students and allows time for the students to discuss the question amongst themselves. We then ask the students to respond and conclude with a resolution. This technique has been introduced in the book “Peer Instruction”, by E. Mazur. In the calculus-based courses, lectures are presented using video projection. Students can buy copies of the slides and bring them to lecture; these slides are also available for viewing on the Web. In the algebra-based courses, we also use “Just in Time” methods as introduced in the book “Just in Time Teaching”, by G. Novak, E. Patterson, A. Gavrin, and W. Christian. Students are asked to complete Web-based “preflights” (usually multiple choice conceptual questions with an explanation) prior to the lecture. The lecture then consists of explanations and ACTs that are designed to address the student difficulties seen in the “preflights”. In particular, specific student responses can be used in lecture to illustrate common difficulties.

The discussion sections have been designed to feature collaborative learning. Students work in groups of four on materials prepared by the senior staff. These materials feature both conceptual and quantitative questions. TAs act as facilitators, not lecturers. For this format to be successful, much attention needs to be paid to TA preparation. Prior to the beginning of each semester, we provide an orientation session for new TAs to introduce them to this new format. In addition, TAs have weekly meetings throughout the semester with the discussion coordinator to work through the material of the week. We have also introduced a peer observation program for TAs in which each new TA is both observed by an experienced team early in the semester and then becomes a part of an observing team later in the semester. This program was designed by Tim Stelzer to feature constructive criticism and has been favorably received by the TAs.

The lab sections have been designed to feature a hands-on approach to the learning of the physics concepts the students find difficult rather than to introduce the students to experimental methods. In this way, the labs can become an integral part of the course. The concepts being addressed in a lab are the same concepts that are also being addressed in lectures, discussions and homeworks for that week. We have also eliminated the dreaded (by all) traditional lengthy lab report. Rather, following the approach of Thornton & Sokoloff, the students can complete the assignment within the class period. Students are asked to complete worksheets in which, given a physical set-up, they first predict what will happen, then they make the observation and provide an explanation. Students are also asked to complete a prelab assignment that is designed to prepare the students for the lab activities.

Weekly homework assignments are done on the Web, using the *Tycho* system developed by Dennis Kane at Illinois. Recent additions to this system are presented in

the article, “The Evolution of Web-Based Activities in Physics at Illinois” (Forum on Education of the Am. Phys. Soc., (Fall 2001) <http://www.aps.org/units/fed/fall2001/stelzer.html>). We now use three different formats, each serving a different purpose. From the beginning, we have used problems that consist of several quantitative questions about a specific physical situation. Brief hints are available upon request and immediate feedback is given. These problems allow the students to test their understanding and change their answers if necessary. While the students appreciate this format, there is the danger that the students come to rely on the immediate feedback feature and fail to develop the ability to assess their own work. To help remedy this situation, we introduced the delayed feedback homework in which students are presented with a set of qualitative and quantitative multiple-choice questions about a particular physical situation. No feedback is given to the student until after the grading deadline for the assignment has passed. These assignments then play the role of “online quizzes”. We have found that, on average, student performance on these delayed feedback assignments are strongly correlated with performance on exams. The third format that we use in homework assignments is the most original. We have developed web-based exercises called “Interactive Examples” (IEs) that are designed to actively engage the students in a Socratic dialogue designed to guide the student to a concept-based approach to problem solving. These IEs can be taken for a test drive at: <http://wug.physics.uiuc.edu/courses/ie.html>. In each of these IEs, students are asked a single difficult (*i.e.*, multi-step) quantitative question. If the student can answer this question, full credit is given for the exercise and some follow-up conceptual questions are asked to test this understanding. If the student cannot successfully answer the initial question, a help dialogue, which takes the form of a series of additional questions, some conceptual and some quantitative, guides the student to develop a problem-solving strategy to answer the initial question. At any time, the student can opt to answer the initial question. Consequently, the amount of help that a student receives is determined by how much help that student actually asks for. Students have received these IEs enthusiastically; they find them to be intuitive and an important aid to their understanding of physics.

We believe that that the revision of the introductory physics courses at Illinois has been a great success. We attribute this success to several factors. First, the design process was a collective effort. A committee of eight physics faculty met regularly for a year to complete the design. These people became the core group; no single person could have done the job alone. Second, attention has been paid to creating an infrastructure (people and computing) that supports rotating faculty participation. Third, the adoption of a true team-teaching environment helps to secure the longevity of the revision. *i.e.*, no heroes are needed nor wanted to effect this change. Pain and gain are shared; burnout has been eliminated. Finally, we have received complete and enthusiastic support from the administration in effecting this change. Initially, faculty were given released time to create the materials. More recently, a new Associate Head position was created to nurture and improve the system as the newness wears off.

I'll conclude this article with a few provocative remarks on the obstacles I have seen to adopting this “Illinois model” elsewhere. First and foremost, we have effected “organizational change” at Illinois, but it's clear to me that this is an unnatural act for most physics departments. Indeed, I think that the major obstacle for adopting this model

lies in character and cultural traits of physics faculty members. Arrogance seems to be a defining character trait of most physicists. This arrogance gives physics faculty members the belief that they can solve most any problem, certainly the problems connected with the teaching of introductory physics. However, it is well known to the folks who work with this problem professionally that what makes effective instruction is largely an empirical issue at this time. Certainly, one cannot hope to create effective materials without listening carefully to the students and learning from others who have created such materials. The cultural problem is revealed when a faculty member utters the words "My Course". An introductory physics course in a research university does not belong to any one person. The course is not just the lectures. The course is a much bigger enterprise. Progress in introductory physics course development comes from the contributions of many. Joy comes from making a worthwhile contribution to a larger enterprise. I believe that if physics faculty can eliminate this egocentric attitude, they will find that trying to improve introductory physics education can be an enjoyable and liberating experience.