Nontraditional Approach to Algebra-Based General Physics

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In order to improve the degree of conceptual learning in our algebra-based general physics course, the second semester (of a two-semester sequence) has been taught in a nontraditional format during the past year. The key characteristics of this course were: 1) Intense and continuous use of interactive-engagement methods and cooperative learning; 2) coverage of less than half of the conventional number of topics, 3) heavy emphasis on qualitative questions as opposed to quantitative problems, 4) adjustment of the pacing of the course based on continuous (twice per week) formative assessment.

The students enrolled in the course were relatively poorly prepared, with weak mathematical skills. Open-book quizzes stressing qualitative concepts in electricity and magnetism were given twice per week; most were given in "group quiz" format, allowing collaboration. Exams (also open-book) were all done individually. Most of the class time was taken up by quizzes, and by interactive discussion and group work related to quiz questions. New topics were not introduced until a majority of the class demonstrated competence in the topic under discussion.

Despite lengthy and intensive focus on qualitative, conceptual questions and simple quantitative problems, only a small minority of the class ultimately demonstrated mastery of the targeted concepts. Frequent testing and re-testing of the students on basic concepts disclosed tenacious persistence of misconceptions.

STUDENT PREPARATION

Students had completed the first semester of a two-semester sequence in algebra-based general physics. The first semester concentrated on vector concepts and Newtonian mechanics. Students had completed college algebra and trigonometry.

As measured by post-tests on the Force Concept Inventory, students' grasp of mechanics concepts was weak (mean post-test score = 39%). Students' mathematical skills were weak as well, as they generally had difficulty using elementary trigonometry (Pythagorean theorem, finding unknown sides of right triangles) and elementary algebra.

CP399, *The Changing Role of Physics Departments in Modern Universities*: Proceedings of ICUPE, edited by E. F. Redish and J. S. Rigden

"REDUCED SYLLABUS"

The number of topics covered was much smaller than the conventional number. Moreover, only the basic features of each topic were emphasized, with few details or applications:

1. Coulomb's Law; Electric field and force in two dimensions.
2. Electric potential and potential energy.
3. Capacitance; Ohm's law; Elementary series and parallel circuits; power.
4. Magnetic field of: straight current-carrying conductor; coil; current loop.
5. Magnetic force on straight current-carrying conductor and on moving charge.
6. Torque on current loop in magnetic field; induced currents.
7. Electromagnetic Waves (spectrum; $c = f\lambda$); Law of Reflection; Snell's Law.

Problem Types

- Emphasis on qualitative and "proportional reasoning" problems.
- Elementary quantitative applications: only elementary (high-school level) algebra and trigonometry used.
- Multiple-choice questions, typically with 7-12 answer options.
- High level of redundancy: slight variations of basic problems given repeatedly (up to ten times) throughout semester, on quizzes and exams.

Instructional Methods

1. Highly "interactive" classes:
   - Little lecture; much student-faculty interaction using "flash cards." [Cf. Meltzer, D.E. and K. Manivannan, *Phys. Teach.* **34**, 72-76,]
   - "Tutorial" format: students work in groups as instructor circulates throughout room and responds to requests for help.
   - Most of class time taken up by quizzes, and by interactive discussion and group work related to quiz questions.
2. Incessant formative assessment:
   - Quizzes twice per week (20% of class time).
   - Every quiz and exam "cumulative" (all topics may be covered).
   - All quizzes and exams "open book" and "open notes."
   - Most quizzes were "group quizzes" (done collaboratively); all exams done individually.

- Tremendous redundancy of questions: basic problems given in slightly revised form up to ten times over the course of the semester.

3. Exam and Quiz questions all had "extra credit" option: If student chose this option, correct answer counts extra, but incorrect answer results in 50% of value of question being ***deducted*** from exam score. This encouraged students to reflect critically on their confidence in their responses.
4. In addition to qualitative, conceptual questions being assigned for homework and review, selected "back of the chapter" quantitative problems were recommended for additional study.
5. Pacing of course continuously adjusted, guided by ongoing assessment. Concepts revisited repeatedly when testing revealed inadequate mastery.