Institutionalizing a Reform Curriculum at Large Universities

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Intro physics at Georgia Tech

Intro Physics I and II at Georgia Tech are the calculus-based courses required for all engineering and science majors. These are large enrollment courses, with up to 1700 students per semester in Physics I & II combined.

The course content (up to Summer 06) has been entirely traditional. The courses consist of large lecture sections (often with more than 200 students), with accompanying small lab sections (about 20 students)

Problems with traditional course at GT

Over the past several years, several problems have been identified with the standard Intro Physics course:

- Significantly lower course GPA and higher failure rates in Intro Physics than other GT intro courses.
- Intro. Physics is often unpopular with students.
- An external review committee criticized the structure and outcomes of GT intro physics.

Matter & Interactions

To help improve course outcomes in introductory physics, as well as modernize course content, the Georgia Tech School of Physics is piloting a new course using *Matter & Interactions* (M&I), a modern calculus-based introductory physics curriculum.

(R. Chabay & B. Sherwood, Wiley, 2007)

Features of *Matter & Interactions*

Modern content: The atomic structure of matter and 20th century physics are major themes of the course.

Modeling: Students analyze complex systems using a small set of fundamental principles.

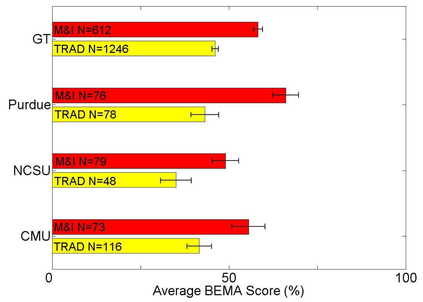
Computer modeling: Students create computer models of physical systems using the VPython programming language.

Implementation

The M&I curriculum has been phased in gradually at GT over the past 2 years. In Fall 2008, approximately one-half of all GT intro physics students will use the M&I curriculum.

Term	M&I Mechanics	M&I Electromag.	Faculty w/M&I Experience
Su 06	40 students	0 students	0
F 06	120 students	45 students	1
Sp07	200 students	150 students	2
Su07	0 students	150 students	3
F07	150 students	300 students	4
Sp08	300 students	300 students	4
Su08	200 students	200 students	4
F08	300 students	450 students	6

Mean Bema scores at 4 institutions



Implementation Methodology

Implementation was initiated in 2006 with the hiring of an M&I experienced post-doc (Kohlmyer) to train TAs, set up M&I lab activities and deliver lectures in the pilot M&I lecture sections.

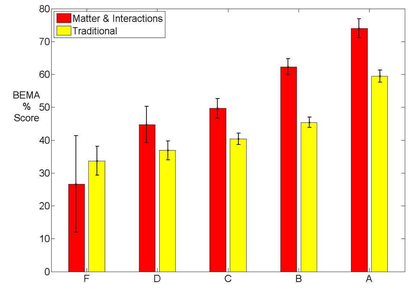
Faculty involvement: The radically different course content of M&I poses a barrier to faculty adoption. To increase faculty acceptance, we have implemented a bootstrap apprenticeship model with the pairing of an experienced M&I instructor and a GT faculty member. Initially, the M&I post-doc served as the experienced instructor, who worked closely with GT faculty on course content and logistics. In subsequent semesters, parallel sections of M&I intro physics have been taught in common by a group of GT faculty containing some M&I experienced instructors, who help faculty new to M&I become accustomed to the curriculum.

Reactions from faculty new to the course have been very positive. By the end of Fall 2006, the GT School of Physics will have six GT tenure-track faculty and instructors experienced in M&I

TA training and management: M&I labs are much different from traditional course labs at GT. In the M&I labs, there is a **strong connection between lab and lecture** content. The M&I labs are in an **interactive studio** style, where students do hands-on **experiments**, **computer modeling** activities and **group problem solving**. Because of this, labs ideally require more than one TA per 20-student section, and special TA training is required.

In Spring 06, a small number of graduate TAs were trained in the labs for both semester of *M&I*. These TAs served as experienced TAs in future semesters, and were supplemented with new TAs who were trained "just-in-time" during weekly course meetings. To make up for TAs lost from the pool each semester, a larger number of TAs new to M&I are assigned to the course each summer. In Spring 07 we hired **undergraduate TAs** to assist grad TAs in labs. These are students who have taken the *M&I* course and performed well in it. They, like graduate TAs, are required to attend weekly meetings.

Bema vs course grade



Assessment via Standardized Instruments

Brief E&M Assessment (BEMA): The BEMA was designed to be valid for both traditional and M&I E&M courses. The BEMA is a qualitative and semi-quantitative multiple-choice test. The questions span the range of content of a typical E&M course, from Coulomb's law to Faraday's law of induction.

The BEMA was administered to both M&I and traditional Physics II sections at the end of the Fall 06 and Spring 07 semesters. The results are shown below in Fig. 1. The M&I sections did significantly better on this instrument than the traditional sections.

%%Why is this here? Talking about BEMA.%%

%%This section should be recast for results.%%

Force Concept Inventory (FCI): Results for *M&I* Intro Physics I sections have not compared favorably with the traditional course. Typical average normalized gains on the FCI in traditional intro mechanics at Georgia Tech have ranged from 0.3 to 0.5, but they were only about 0.2 in the Summer 06 and Fall 06 M&I courses.

There may be issues with using the FCI with M&I:

- FCI was designed for use with the traditional curriculum and is couched in its terminology.
- M&I places more emphasis on momentum and less on kinematics and free-body analysis.

We still feel that M&I students should be able to master the concepts measured by the FCI. We plan to examine possible deficiencies in instruction as well as ways to make more meaningful comparisons.

Acknowledgements

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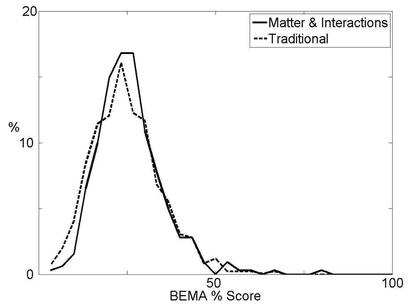
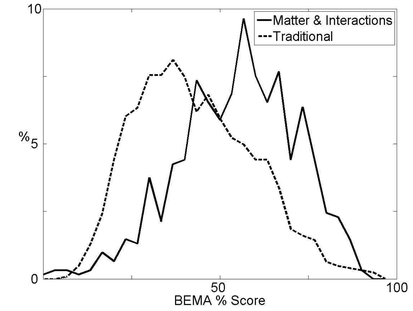
GT Bema distributions

Before Instruction



After Instruction



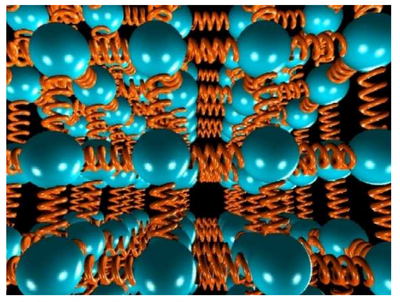


Fig. 2. The "ball & spring" model of a solid is used in *Matter & Interactions* to help students understand a wide variety of phenomena, including elastic deformation, the speed of sound in solids, and entropy.

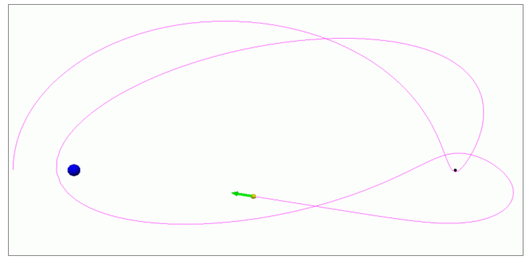


Fig. 3. Graphical output from a student-written VPython computer model of a spacecraft interacting with the Earth (left) and the Moon (right). The arrow represents the momentum of the spacecraft.