Implementing *Matter and Interactions* at Georgia Tech

Matthew Kohlmyer[1], Michael Schatz[1], Richard Catrambone[2], and Jack Marr[2]

[1]School of Physics, Georgia Institute of Technology, Atlanta, GA, 30332-0430

[2]School of Psychology, Georgia Institute of Technology, Atlanta, GA, 30332-0710

We describe our motivations and efforts to implement a modern, innovative, calculus-based introductory physics curriculum, called ***Matter & Interactions*** (R. Chabay & B. Sherwood, Wiley, 2007) in the School of Physics at Georgia Tech.

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 course, 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:

- Course GPA in Intro Physics is significantly lower than other intro courses at Georgia Tech.
- Typically, D/F/W rates are high.
- The courses are often unpopular with students.
- An external review committee criticized the structure and outcomes of GT intro physics courses.

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.

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

Offerings of Intro Physics using the *Matter and Interactions* curriculum began in Summer 06 with a small pilot section and have since expanded. In Fall 07, *M&I* sections will comprise one third of all Intro Physics enrollment at GT.

Semester	M&I mechanics	M&I EM
Summer 06	1 section, 40 students	None
Fall 06	1 section, 120 students	1 section, 45 students
Spring 07	2 sections, 200 students total	1 section, 150 students
Summer 07	None	1 section, 150 students
Fall 07	1 section, 150 students	2 sections, 300 students total

Implementation issues

Faculty involvement: The radically different course content and structure of *M&I* can potentially be a barrier to faculty adoption. We have tried to overcome this through variations on an apprenticeship model. We convinced two new faculty hires, who both would be teaching Intro Physics for the first time, to teach *M&I* courses (one in Spring 07, one in Fall 07). One of us (Schatz) would also teach an *M&I* course in the same semester, and would work closely with the new faculty on course content and logistics. In Summer 2007, one of us (Kohlmyer) co-taught a *Matter & Interactions* Physics II course with a veteran professor. Grant money from the *M&I* collaboration effort (see Acknowledgements) was used to supplement the professor's summer salary. We plan on using this model in future semesters.

Reactions from faculty new to the course have been very positive. By the end of Fall 2007, the GT School of Physics will have five faculty and instructors experienced in *M&I* (increased from one in Summer 2006).

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 addition, 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.

Assessment

Ongoing assessment has been focused in two areas:

1. Standardized instruments

2. Common exam questions

Standardized instruments

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.

Brief E&M Assessment (BEMA): Unlike the FCI, the BEMA was designed to be valid for both traditional and *M&I* E&M courses. 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.

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.

Note:

- In Fall 06 and Spring 07, *M&I* Physics II was taught by the same instructor. Instructors new to *M&I* Physics II will teach it in Fall 07.
- Instructor C's Fall 06 *M&I* class was a pilot section of 44 students.
- Response rates were low (due to low attendance) for both instructor D's sections in Spring 07.

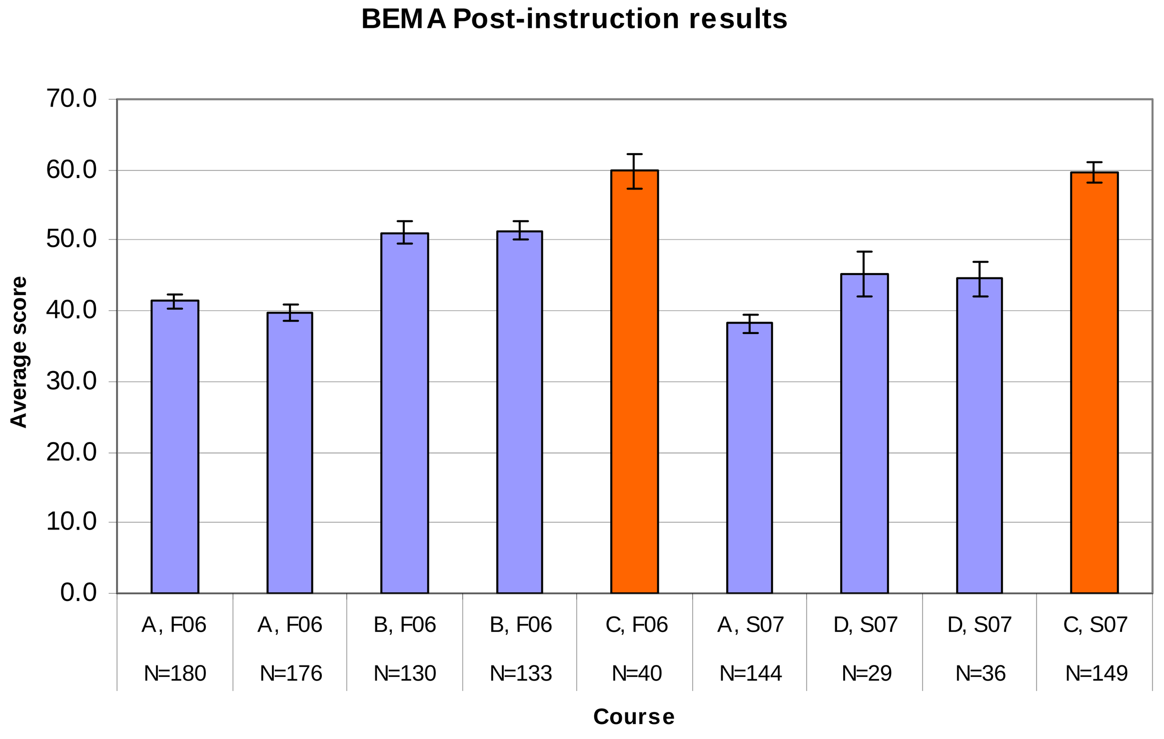
Fig. 1: BEMA post-instructional results for nine different Intro Physics II courses over two semesters.

Key:

- *Matter & Interactions* course (orange)
- Traditional course (blue)

Letter (A, B, C, and D) refers to instructor

Instructors B, C, and D used the Personal Response System for interactive engagement during lectures; instructor A did not.



Common Exam Questions

Several common final exam questions were given to both traditional and *M&I* courses, both in mechanics (F06 and S07) and E&M (S07). Results from one such question in E&M (see Fig. 2) are presented in the table below. Although both sections had difficulty with the problem, there were some striking differences in performance, particularly in the choice of fundamental principle used to tackle the problem.

Results from the common mechanics problems are less conclusive. Because there is limited content in common between the *M&I* and traditional mechanics courses (a less serious issue in E&M), the chosen problems were often ones that students in the traditional course had seen many times before (e.g. ballistic pendulum). Students in *M&I*, who were less familiar with these problems, seemed to write more detailed solutions that developed from fundamental principles, whereas traditional course students' solutions were often terse, as if solved by rote.

Further examination of these problems are required to confirm this. We also plan to revise how problems are chosen in future comparisons.

A uniform magnetic field is present in a circular region of radius 6 cm. In this region at any given time, the magnetic field may be pointing directly out of the page (in the +z direction), directly into the page (in the –z direction), or it may be zero. The z-component of the magnetic field in this region changes with time according to the function $B_z = Kt^2 - P$, where t is time, $K = 0.12$ T/s^2, and $P = 3.0$ T. Outside of the 6 cm radius, the magnetic field is always zero. A thin metal ring of radius 11 cm is concentric with the region of magnetic field. The ring has a resistance of 1.3 x 10–3 Ω.

(a) At time $t = 3$ s, find the magnitude of the induced current in the metal ring.

(b) At time $t = 3$ s, find the direction of the induced current in the metal ring (clockwise, counter-clockwise, or zero), and briefly explain your reasoning.

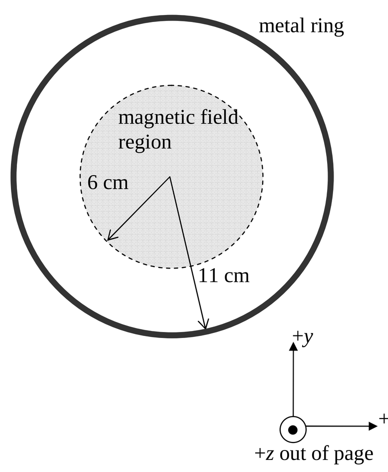


Fig. 2: Final exam problem given to both traditional and M&I Physics II courses in Spring 07.

Common EM final exam problem, Spring 07	Trad. EM sec. N=157	M&I EM sec. N=152
Completely correct (magnitude & direction)	17%	28%
Used **correct approach** to find magnitude (w/ possible minor errors)	32%	51%
Used **wrong principle** to find magnitude	43%	15%
Correct direction w/ correct reasoning	36%	57%

Acknowledgements

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