Implementing *Matter and Interactions* at Georgia Tech

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We describe our motivations and efforts to implement a modern, innovative, calculus-based introductory physics curriculum, called *Matter and 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 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:

- *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 and 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
---|---|---
Winter 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 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 style studio, 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 sections 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 taking the course 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**
   - Force Concept Inventory (FCI): Results for M&I and traditional Physics I sections have not compared favorably with the FCI score of students using traditional physics 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.

2. **Standardized instruments**
   - 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 semiquantitative 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.
- Responses were low (due to low attendance) for both instructor D’s sections in Spring 07.

### 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 these results. We also plan to revise how problems are chosen in future comparisons.

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>M&amp;I mechanics</th>
<th>M&amp;I EM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter 06</td>
<td>1 section, 40 students</td>
<td>None</td>
</tr>
<tr>
<td>Fall 06</td>
<td>1 section, 120 students</td>
<td>1 section, 45 students</td>
</tr>
<tr>
<td>Spring 07</td>
<td>2 sections, 200 students total</td>
<td>1 section, 150 students</td>
</tr>
<tr>
<td>Summer 07</td>
<td>None</td>
<td>1 section, 150 students</td>
</tr>
<tr>
<td>Fall 07</td>
<td>1 section, 150 students</td>
<td>2 sections, 300 students total</td>
</tr>
</tbody>
</table>

**Key**

- Matter & Interactions course
- Traditional course

**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.

**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**

<table>
<thead>
<tr>
<th>Trad. EM sect.</th>
<th>M&amp;I sect.</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=157</td>
<td>N=152</td>
</tr>
<tr>
<td><strong>Completely correct (magnitude and direction)</strong></td>
<td>17%</td>
</tr>
<tr>
<td><strong>Used correct approach to find magnitude (or possible minor errors)</strong></td>
<td>32%</td>
</tr>
<tr>
<td><strong>Used wrong principle to find magnitude</strong></td>
<td>43%</td>
</tr>
<tr>
<td><strong>Correct direction w/ correct reasoning</strong></td>
<td>36%</td>
</tr>
</tbody>
</table>

**Acknowledgements**

This effort is funded in part by the National Science Foundation and by Georgia PRISM (Partnership for Reform in Science and Mathematics), Atlanta Metro Region. It is part of a collaboration with NC State University and Purdue University, both Matter & Interactions adopters, to examine the challenges of implementing curricular change at large institutions. See poster by Chabay and Sherwood at this session for more information.