1. Project Activities

1.1. Background

``Remodeling University Physics'' is a project in a program of continuous research-based reform of introductory physics courses at the college level that is being carried out by the Physics Education group at Arizona State University (ASU). Key components of this reform include:

- studio classroom format
- model-centered curriculum
- systematic use of representational tools
- a unifying link between technology and pedagogy
- techniques for managing student discourse
- creation of a learning community
- modeling approach to problem solving

This reform has as its foundation a theory of instruction known as "Modeling Instruction." Modeling Instruction was first developed for high school physics by Hestenes, Wells and co-workers, and has now been adapted to the college level by Hestenes, Politano, and graduate students, Brewe and Desbien.

We began our program of research-based reform of introductory, college-level physics courses in 1995 in an honors section of University Physics (UP) at ASU. The honors section was chosen because of the small class size (~24 students). The Force Concept Inventory (FCI) was given as both a pre- and post-test in this section. A comparison of the normalized Hake gain on the FCI in the ASU honors section with courses using traditional instruction and with other reform curricula is shown in Figure 1.1. The ASU honors course gains for the academic years 1995-1999 (roughly consecutively) are shown in yellow, the traditional course gains are shown in blue, and the reform course gains are shown in maroon.

In order to test whether the high gains in the ASU honors section were a result of the selective nature of the section, beginning in 1998, a non-honors section of UP at a local community college (Chandler-Gilbert Community College [CGCC]) was taught by Desbien using the same method of instruction as in the ASU honors course. The gains on the FCI for the CGCC course are shown in light green in Figure 1.1. The gain of 0.8 is the highest gain ever reported on the FCI. Even more noteworthy is that of the 19 students in the CGCC section that achieved this extraordinary gain, *7 were female and 5 were Hispanic*. Both the ASU honors and the CGCC sections also scored among the highest in the nation on the Mechanic Baseline Test (MBT), a more quantitative measure of mechanics comprehension.

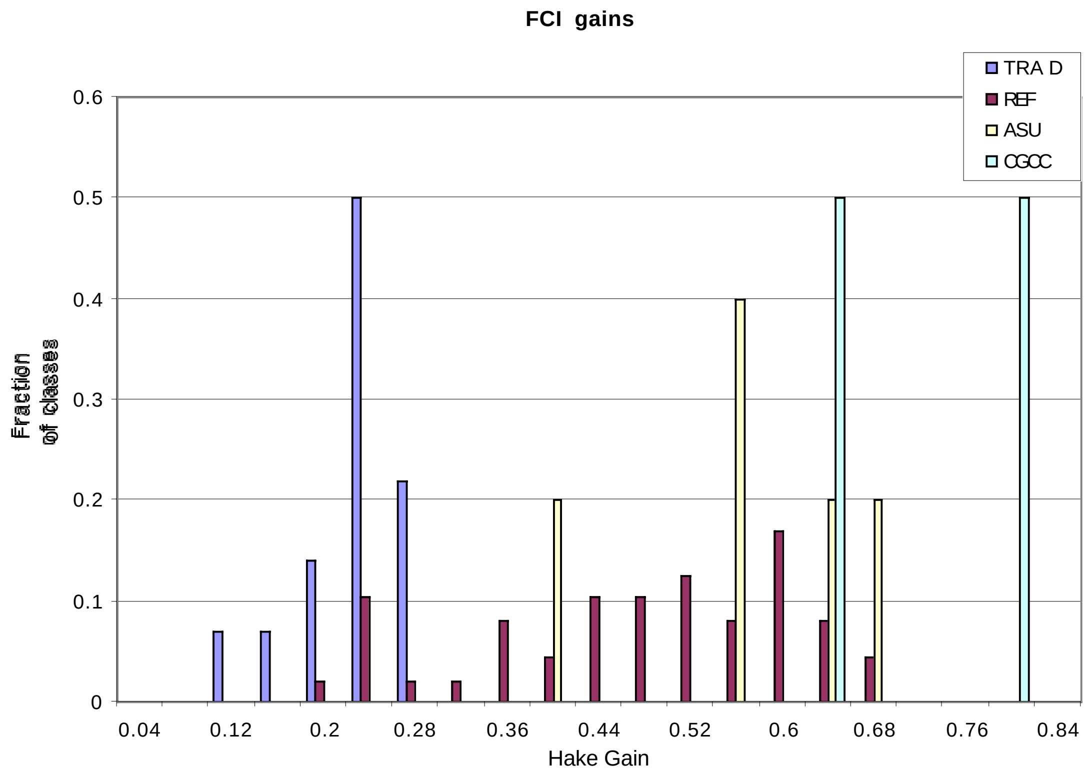

Figure 1.1

1.2. Goals of the Current Grant

Satisfied with the demonstrated success of Modeling Instruction in small classes of UP (~20 students), our next goal was to see if Modeling Instruction could be scaled-up and be as successful in larger class sizes. The present proposal, "Remodeling University Physics," was written with the following as its main goals: (1) to scale-up the Modeling Instruction approach used in the ASU honors and CGCC classes (~20 students) to larger class sizes; (2) to continue our reform of the UP course by unifying and threading the curriculum around two basic themes: energy storage and transfer, and the structure of matter; and (3) to disseminate our method of instruction by designing and conducting three-week workshops for 2- and 4-year college/university faculty in the summers of 2001 and 2002.

1.3. Project Activities during Year 1

1.3.1. Scale-up

We had already demonstrated the feasibility of scaling-up Modeling Instruction to larger class sizes prior to the proposal being written. We had experimented with partitioning a larger section of UP physics (ranging from ~40—80 students) into 3 smaller groups. This section of UP physics is in a program at ASU known as the Foundation Coalition. The Foundation Coalition (FC) is an NSF-funded program to improve undergraduate courses for engineering students. The FC section of UP was chosen because it meets in a classroom that is outfitted with similar technology as the ASU honors classroom, but the classroom contains 40 computers and is much larger. In addition, as we noted in the proposal, the FCI gains in the FC physics course had been quite disappointing, and the current proposal aims to "save the day" by importing our successful Modeling UP course to the FC class.

We continued preliminary experimentation with scale-up in the 1999-2000 academic year, prior to the awarding of the grant. The FC physics instructor, Prof. Nicole Herbots, agreed to use Modeling Instruction in the FC course. Prof. Herbots, who had little formal training in Modeling Instruction, was teamed with Desbien and Brewe, graduate students of Hestenes, who were co-instructors. Desbien and Brewe had several years experience with Modeling Instruction.

In the 2000-2001 academic year, with the award of the grant, Politano replaced Herbots as instructor of the FC course. He teamed with Desbien and Brewe, who again were co-instructors, and full scale-up of Modeling Instruction was implemented. In this year, the FC course had 64 students. As before, the class was divided into 3 groups, this time of ~21 students each. The size of an *individual* group was therefore now very similar to the size of the ASU honors and CGCC courses. Each group was led by an instructor and functioned more or less independently of the other 2 groups. However, the 3 groups were coordinated in that the class as a whole did the same activities each day, received the same homework assignments, and took the same exams. Thus, we achieved small-class functioning within a large class environment.

1.3.2. Energy and Structure of Matter Themes

During year 1, our efforts with regard to these themes have focused on two major activities: (1) to continue our development of the energy thread throughout the curriculum, and (2) to begin to formulate the structure of matter thread and experiment with how to introduce it into the curriculum.

A key reason for selecting energy as a unifying theme is to tie thermodynamics and mechanics more closely together. This has motivated how we have approached the fashioning of the energy thread in the first semester of the UP course. Energy is introduced in the third week of the semester, during kinematics. Modeling one of the simplest of motions—a bouncing ball--elicits a rich discussion of how energy is stored, and leads to the realization that the ball cannot be modeled as a point particle during the bounce. The notions of a "particle with internal structure" (like an atom for example) and "energy stored internally" were raised *by the students* as a natural part of the discussion. Continuing our thread, energy is used, *prior to force*, to measure an interaction. We find that this more naturally introduces the concept of a "system" to the students. The notion of where the energy is stored in "potential" energy becomes clearer to the students as well, as it is stored *in the interaction*. In fact, we prefer the term "interaction energy" rather than potential energy in our curriculum. Further, a natural question the students raise in their discussion groups is "Are all interactions measured by potential energy?" This allows interactions to be classified into those that are "reversible" and those that are "irreversible." Reversible interactions are those which can be measured with a potential energy. Irreversible interactions are those which cannot and in which some of the system's energy is converted into internal energy. Framing the distinction with the terms "reversible" and "irreversible," rather than "conservative" and "non-conservative" clarifies the nature of the criterion used to make the distinction, and directly paves the way for a future introduction of the 2nd Law of Thermodynamics.

At this time, we are still in the process of formulating our structure of matter thread. We do know that we will use potential energy diagrams as a qualitative tool with which to understand the structure of matter. For example, in the second semester we are experimenting with the use of a potential energy diagram for a "classical" atom to understand the idea of a "bound" electron. Extension of this idea to an energy diagram for a one-dimensional array of atoms in a conductor leads to a powerful tool for visualizing the "sea" of free electrons in the electron sea model of a conductor, for example.

1.3.3. Summer Workshop

The charter summer workshop on Modeling Instruction at the college level is to be held at Arizona State University from June 4-22, 2001. The workshop will be limited to 24 participants and is designed for 2- and 4-yr college/university faculty. Politano, Desbien and Brewe, the instructors of the FC course, will lead the workshop, along with Hestenes. A suitable, technology-rich classroom has been reserved for the workshop. Dormitory rooms have been reserved for the participants and off-campus housing is being investigated. A website has been created describing the workshop (see section 3.2). Application forms may be downloaded from this website. Politano created a brochure describing the workshop and the reforms. The brochures were distributed at the recent AAPT meeting in San Diego in January 2001.

In the 1st summer workshop, the participants will learn the skills associated with the three essential components of Modeling Instruction: restructuring the content of a UP course around models, systematic and coordinated use of representational tools throughout the curriculum, and managing classroom discourse using modeling discourse management. In addition, we will describe how to thread energy throughout the curriculum as a unifying theme. Inclusion of the structure of matter theme will be delayed until the 2nd summer workshop (in 2002). This will give us the necessary time to sufficiently develop and refine how this theme is thread throughout the curriculum.

At the time of this report, we have had 15 people respond to our advertisements and state that they are seriously interested in attending the workshop.

1.3.4. Presentations/Talks at Major Conferences

1. "Vectors vs. Coordinates in Physics Instruction," Eric T. Brewe, Dwain M. Desbien, and David O. Hestenes, 121st National Meeting of the American Association of Physics Teachers (AAPT), Guelph, Ontario, CANADA, July 2000.
2. Modeling Discourse in University Physics," Dwain M. Desbien, Eric T. Brewe, and David O. Hestenes, 121st National Meeting of the American Association of Physics Teachers (AAPT), Guelph, Ontario, CANADA, July 2000.
3. "Outstanding Modeling Instruction in Action," Mangala Joshua and Dwain M. Desbien, 121st National Meeting of the American Association of Physics Teachers (AAPT), Guelph, Ontario, CANADA, July 2000.
4. "Hey You in the Front, Shut Your Mouth!" Eric T. Brewe, Dwain M. Desbien, and David O. Hestenes, 122nd National Meeting of the American Association of Physics Teachers (AAPT), San Diego, CA, January 2001.
5. "Lessons Learned from Remodeled Physics," Dwain M. Desbien, Eric T. Brewe, and David O. Hestenes, 122nd National Meeting of the American Association of Physics Teachers (AAPT), San Diego, CA, January 2001.
6. "Epistemology and Scientific Method in Modeling Instruction," David O. Hestenes, 122nd National Meeting of the American Association of Physics Teachers (AAPT), San Diego, CA, January 2001 *(invited)*.