How effective is modeling instruction?

> *By comparison to traditional instruction, under modeling instruction high school students average about 1.5 standard deviations higher on standard instruments for assessing conceptual understanding of physics.*

The effectiveness of modeling instruction in enhancing student learning of physics is being continuously evaluated with well-established standardized instruments. Among these instruments are the *Force Concept Inventory* (FCI)[1] and the *Mechanics Baseline Test* (MBT)[2].

The FCI was developed to assess the effectiveness of mechanics courses in meeting a *minimal teaching performance standard: to teach students to reliably discriminate between the applicability of scientific concepts and naive alternatives in common physical situations.* Questions on the FCI were designed to be meaningful to students without formal training in mechanics. In contrast, the MBT emphasizes concepts and skills that require formal knowledge of mechanics. The MBT was developed to assess the effectiveness of mechanics courses in meeting a *higher teaching performance standard* than the FCI: *to teach students the qualitative reasoning underlying quantitative problem solving in Newtonian mechanics.*

The FCI has consistently shown that students bring into their physics courses a wide array of naive beliefs about the motion of physical objects that are incompatible with Newtonian theory. In high school, the average FCI pretest score is about 31% (Figure 1). This score is slightly above the random guessing level of 20%, and well below the 60% threshold for understanding Newtonian mechanics.

Figure 1 shows that traditional high school instruction (lecture, demonstration, and standard laboratory activities) has little impact on student beliefs. The national average FCI posttest score is about 48%, which remains below the Newtonian threshold after instruction[1,3]. Hake[3] has documented FCI data for over six thousand high school and college students. His data support the original findings[1,4] about the *failure of traditional instruction in meeting a minimal performance standard* for mechanics, and the fact that this failure is largely *independent of the instructor's knowledge, experience and teaching style*.

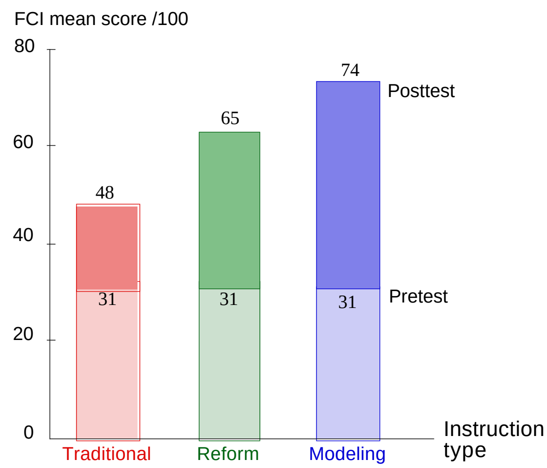

Figure 1. FCI mean scores under different instruction types.

Hake's data[3] show that, in *reform* courses using non-traditional teaching methods, high school students average about 65% on the FCI posttest, 17% better than students in traditional courses (Figure 1). In the academic year 1995-1996, a number of high school teachers started a systematic shift from traditional instruction to modeling instruction, following their first summer workshop on modeling instruction. After their first year, workshop teachers considerably outperformed not only traditional instructors, but also those reform teachers reported by Hake. The average FCI posttest score was 74% for the 696 students of teachers who tried to implement systematically all components of modeling instruction. That is 26% above the posttest average in traditional courses, and 9% above the posttest average in reform courses (Figure 1).

Figure 2 compares the performance of similar groups of students on the MBT. The original MBT findings[2] and Hake's data[3] show that, following traditional mechanics instruction, high school students average about 36% on the MBT posttest. In reform courses, high school students average about 50% on the same posttest[3]. Following a year of modeling instruction, high school students who were given the MBT averaged 59% on the posttest, 23% better than their peers under traditional instruction, and 9% better than those under reform instruction[3].

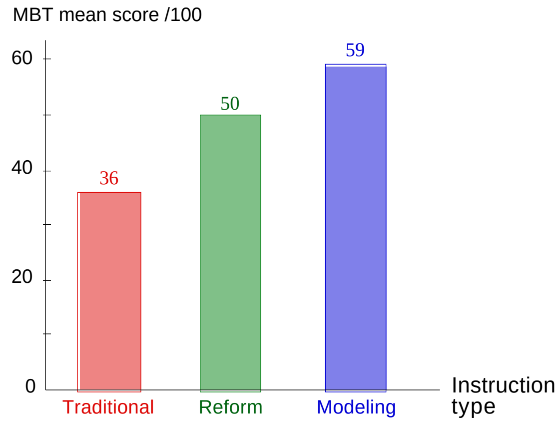

Figure 2. MBT mean posttest scores under different instruction types.

Efforts are underway to improve the results above in modeling instruction. Still both the FCI and MBT posttest means are about 1.5 standard deviations higher for the modeling group of students than the traditional group. These results are outstanding, especially for teachers in their first year applying a complex innovative method. It remains to be seen what they can do with more experience.

1. D. Hestenes, M. Wells, & G. Swackhamer. (1992). Force Concept Inventory. *The Physics Teacher*, *30*, 141-158.

2. D. Hestenes & M. Wells. (1992). A Mechanics Baseline Test. *The Physics Teacher*, *30*, 159-166.

3. R. Hake. (1996). *Interactive-engagement vs. traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses.* In press.

4. I. Halloun & D. Hestenes. (1985). The initial knowledge state of college physics students. *American Journal of Physics*, *53*, 1043-1055.

How effective are the modeling workshops?

> *According to an independent evaluator for NSF, participants in the Modeling Workshops have formed a very cohesive group of teachers that are seriously engaged in reflective analysis of their own teaching and the physics content. As a result, they have developed high quality teaching materials that are more coherent than traditional materials and more easily accessible for the students. They have also aligned their teaching practice with the student-centered modeling methodology which participants are convinced is intrinsically motivating both for them and their students, and especially helpful for lower level students.*

A series of Modeling Workshops is currently underway at Arizona State University and other sites throughout the country. Forty eight high school teachers from 23 states formally participate in these workshops that started in the summer of 1995 and will continue through the summer of 1999. The effectiveness of the workshops is being assessed with regard to their impact on participating teachers' practice and the performance of their students.

Prof. Frances Lawrenz, Assistant Vice President of the University of Minnesota, is an independent external evaluator of the Modeling Workshops for the National Science Foundation. Below are excerpts from her annual evaluation reports reflecting her findings from site visits.

Teaching materials structure

"The participants felt that the program with its specific repetition of major models, goals and formats provided the reinforcement that the students need to become adept. The participants also felt that the philosophy and format provided a strong thread that tied the physics concepts together and provided a more coherent and more easily accessible format for the students". (1996 report, p. 2).

Instruction materials "seemed to be consistent with the modeling approach and were detailed enough for the readers to use easily. I was impressed with the research articles supporting the units and the overall high quality of the materials ... These [materials] should be an asset in recruiting teachers to future workshops and in making the project's approach accepted nationally". (1995 report, p. 7)

Teaching methodology

"The participants...are enthusiastic about the modeling approach and believe it will help to stimulate student learning and interest in physics". (1995 report, p.8).

"The participants felt that the modeling approach was in and of itself motivating...since the students get to develop and defend their own ideas". (1996 report, p. 2).

"Many [teachers] were surprised at what lower level students could do and reported that the students themselves were surprised and pleased at their ability to reason". (1996 report, p. 4).

Teachers "certainly did seem to have a good grasp of what type of questions would lead to the most learning on the part of" their students. (1995 report, p.4).

Teachers "felt that the program did demonstrate technology but that the emphasis was on effective teaching and how technology could accomplish that rather than emphasizing just the technology." (1996 report, p. 2).

Involvement of participating teachers

"The participants seem to be forming a cohesive group that should provide good support for all in the coming year. There is truly a strong esprit-de-corps among them". (1995 report, p. 8).

"The teachers had formed a very cohesive group and were actively engaged in the development of their concept materials... The discussions...showed clearly the in-depth level of thought engaged in by the participants. Excellent, thought provoking discussions about content, pedagogy and the interaction of these two were the norm. It was a very intellectually stimulating experience for them". (1996 report, p. 3).

Participating teachers "commented that the opportunity to share teaching and content ideas with a group such as this of dynamic committed physics teachers was an excellent opportunity... They also appreciated the expertise and experience that the group provided. If one had a question, it was almost assured that someone would have an answer." (1996 report, pp. 3, 4).

"The participants are clearly supportive and helpful to each other, providing a wealth of experiences that cover almost any situation. Most importantly [participants] are seriously engaged in reflective analysis of their teaching and the physics content. This is pedagogical content knowledge at its best." (1996 report, p. 5).

"The diversity of the participants also provides an opportunity to determine how well the materials and methods will work with teachers with more diverse backgrounds." (1995 report, p. 8).

Overall impressions

"I believe the modeling approach to teaching is a good one that will result in better understanding of physics topics. The institute is well designed to help the teachers understand how to use this new approach". (1995 report, p. 12).

"The participants were very positive about the program. They were convinced that the modeling approach was an exciting, innovative and highly effective approach to teaching. They found the use of this approach motivating both for them and for their students." (1996 report, p. 3).

"The project is clearly successful. The participants have changed their approaches to teaching and are avid advocates of the modeling approach... Teachers are clearly motivated, believe the project expects them to be leaders in the physics community and advocate for the modeling method, and they are very willing to do this." (1996 report, p. 5).