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.

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\(^3\).

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.