To Improve, We Must Measure

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Editor's note:
This is the fifth in a series of articles by Chris Meyer describing his experiences implementing a reformed physics program. Please e-mail him directly if you have any questions or feedback.

Walk the Walk and Measure the Taught

Most of us feel that we know our students and their abilities quite well. How often have you heard yourself or a colleague make a pronouncement that starts out something like, "My students like to …", or "My students would never …"? But what do we *really* know about our students?

Physics Education Research was founded on the principle that we can make useful measurements of our students' abilities and use those measurements to develop our teaching practices. One standard measurement tool is the **Force Concept Inventory (FCI)**[1], a math-free set of thirty multiple choice questions testing students' conceptual understanding of forces and motion, the core of introductory physics. Results from this test serve as a simple and widely agreed upon benchmark of teaching effectiveness.

The Force Concept Inventory

The FCI was designed to measure the extent to which a student is a coherent Newtonian thinker. A low score indicates strong Aristotelian conceptions or other "commonsense" views typical of students prior to (and too often after!) physics instruction. A score of at least 80% identifies a confident Newtonian thinker[2]. A large study[3] of over 6000 high school, college and university students revealed that:

1) Before any instruction, **high school students on average score about 28%** on the FCI (but closer to 45% for American honours and AP students);
2) The average student starting a first year university physics class scores around 44%;
3) Harvard's beginning calculus-based physics students score 70%.

The FCI is typically administered at the start of a course (the pre-test) and again at the end (the post-test). The **average fractional gain, $\langle g \rangle$**[4], states what fraction of potential improvement over the pre-test scores the students achieved and is useful in assessing the quality of instruction. Traditional methods of instruction yield a fractional gain of **0.23** with little variance across high school, college and university. For example, students scoring 13/30 (43%) on the pre-test would average about 17/30 (57%) after a complete course of physics instruction.

Reformed physics teaching programs of various kinds have a typical gain, <g>, of about **0.48**, roughly double the success of traditional methods. Some finely tuned reformed programs, such as *Workshop Physics* at Dickinson College in Carlisle, Pennsylvania, routinely score gains of **0.74**. These results suggest strongly that a long history of poor student achievement in physics is a direct result of traditional teaching methods having been inadequate or inappropriate.

FCI Results at York Mills Collegiate

This past June I administered the FCI as a post-test in my reformed grade 12 physics course. Students were given no prior information about the test and it did not count for marks. Students completed the test in about thirty minutes with no aids or special instructions. 59 students wrote the FCI; 15 were away that day. The absentees were from across all mark ranges in the class[5]. The average score was **77%**. Three-fifths of the students achieved the level of Newtonian mastery (≥80%), while 93% scored at or above the level of an average incoming first year university physics student (44%). **Figure 1** shows a histogram of the results.

York Mills is an academic school with bright and highly motivated students, and I might reasonably assume an average pre-test score near the upper end of the high school range, 44%. (This school-year I will run the pre-test to find out how accurate this assumption is!) This gives an average fractional gain of **0.60** for the York Mills students. **Figure 2** compares the average gain for a number of teaching practises. These results help confirm the success of the reformed physics program at York Mills. Students showed a clear and sizeable improvement in their conceptual understanding of mechanics: almost triple the improvement generated by traditional teaching methods and better than a number of other reformed practices.

To Improve, You Must Measure

Try it out! I encourage you to run the FCI with your own classes. The test is generally not available online (to

discourage curious students). To get a copy you may contact the authors[6] of the FCI, or contact me and I will send you a copy. Please **don't let the questions out amongst the students**.

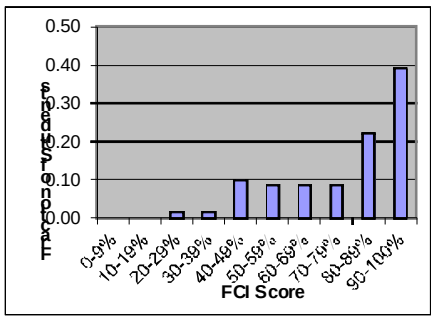

Figure 1: Histogram of FCI scores

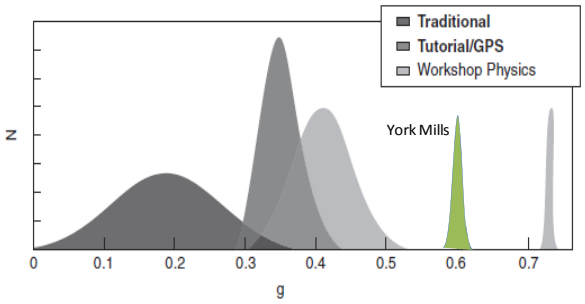

Figure 2: Average fractional gain values for different teaching practices including traditional instruction, the reformed Tutorials in Physics and Group Problem Solving programs, and *Workshop Physics*. (The distant spike is the *Workshop Physics* implementation at Dickinson College.)
Source: Redish, *Teaching with the Physics Suite*. Wiley, 2003

To learn more about reformed physics teaching check out the resources on my website: www.meyercreations.com/Physics.htm and past OAPT newsletters, http://www.oapt.ca/newsletter/, for my articles. Or come and see reformed physics teaching in action: the door to my classroom is open and I welcome any and all visitors; please just send me an e-mail. Good luck and may you collect the courage and data to improve!

[1] FCI "Home Page": http://modeling.asu.edu/R&E/Research.html
[2] FCI results and interpretation: http://modeling.asu.edu/r%26e/fci.pdf
[3] Large collection of FCI results: http://web.mit.edu/rsi/www/2005/misc/minipaper/papers/Hake.pdf
[4] $\langle g \rangle = (\langle S_f \rangle - \langle S_i \rangle)/(100 - \langle S_i \rangle)$, where $\langle S_i \rangle$ and $\langle S_f \rangle$ are the average class percentage scores on the initial and final tests.
[5] Please email me if you would like to see the raw data
[6] Using your school e-mail, please request the password from David Koch FCIMBT@verizon.net.