COMPILATION: FCI plateau; How can a physics teacher become more effective?

From: David Ennis  
Date: Sun, 21 Sep 2014

What brought me to Modeling Instruction was my own perception of an average "plateau of learning" (as I called it in discussions with my colleagues at the time) shared by my students and the students of other classes taught by other teachers. Despite great differences in our levels of experience, our personalities, and (we thought) our approaches, we all got virtually the same results. My conclusion was that the plateau height must have been determined by the population of students from which we all drew.

But then an accidental but intriguing Google hit on this thing called a Force Concept Inventory led me to a group of physics education researchers who were singing my song. I learned that the plateau was a function of lecture/demo/cookbook lab pedagogy. I took the M.I. training, implemented it in my teaching, and saw my teaching improve in a measurable way. A small gain the first year, as predicted in the literature, was followed by substantial gains for two years, and then only a small gain, of questionable statistical significance, last year.

That rekindled my plateau-wariness. I've read references to a "ceiling" in Modeling Instruction, at the level of about 70% if I remember correctly, regarding either average FCI post-test scores or average FCI normalized gain--I forget which, and I don't know where to find that reference as I write this. As of last year I was at 62% for post test and 51% for normalized gain, so I have lots of room for improvement between me and such a ceiling. I think that my main avenues for further gain now are in the areas of engagement in student discourse and quality of student discourse.

But meanwhile, why would there be a ceiling in the gains achievable in Modeling Instruction? Whatever elements might contribute to such a limitation would more than likely be contributing to my results now.

I can think of two broad elements. One, of course, is the motivation of the population from which we draw. I'm back to that. I'd like very much to know how FCI gains vary as a function of culture. We know that other standardized test scores indicate that some nationalities seem to produce more highly motivated learners. It seems that the cultural hypothesis, and therefore probably the motivation hypothesis, regarding the FCI could be tested relatively easily, and perhaps it has been. Does anyone know?

My second hypothesis is that learning is negatively impacted by inconsistencies, vagueness and lack of integration in some areas of our instruction. If students are forced to accept such lapses in clarity because we have no resolution to offer, then they are more likely to tolerate personal gaps in understanding which could be cleared up with effort and persistence. They probably can't differentiate which lapses and gaps are their own and which are ours, and famously have trouble articulating any of that.

That's why I think that the issue recently raised about energy is more significant than generally acknowledged, as was the one raised about friction some months ago. But I don't want to rekindle debates about those particulars now. My main thrust in this post is my belief that hand-waving diversions and outright declarations of continuity-breaking complexity--generally,
our own tolerance of discontinuity and lack of integration within classical physics--can and does negatively affect student learning of classical physics.

My current attention along these lines was raised by the recent discussions about terminology; model, representation, expression, equation, origin, reference point, etc.. These are not inconsequential nit-picks. I believe that they are profoundly important to the learner. True, many students function below the level much of the time where they are even cognizant of some of the distinctions. Some perhaps don't rise because they sense that the distinctions are more that they can handle and have enough cognitive discord already. But if and when they rise to that level even temporarily, as I'm sure many often do, the consistency *must* be there. Otherwise they are justified in retreating to a lower functional level and staying there.

I do have ideas about our terminology, and one of them is iconoclastic. But I've learned to hold off on particulars until the validity, relevance and significance of the underlying premise are settled. To reiterate, *my main premise here is that incorrectness and inconsistency in the general everyday terminology used in our management of Modeling Instruction negatively impacts student learning to a significant degree.*

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From: Jane Jackson <jane.jackson@ASU.EDU>
Date: Sun, 21 Sep 2014

Today, Dave Ennis posted, "I've read references to a "ceiling" in Modeling Instruction, at the level of about 70% if I remember correctly, regarding either average FCI post-test scores or average FCI normalized gain--I forget which, and I don't know where to find that reference as I write this."

Dave and all,

The highest mean FCI post-test scores that I am aware of, in 1st year high school honors physics, are ~85%, by Michael Crofton, Tim Burgess, and David Braunschweig. These correspond to normalized gain ~.75 to .8.

MODELING INSTRUCTION & similar strategies like ISLE have a dual focus on pedagogy and understanding of the underlying structure of physics. These two emphases seem to be key. Evidence exists that Modeling Instruction can be more effective, when fully implemented, than other student-centered instructional methods in physics. For example:

1. Our modeling colleague and researcher, Dr. Ibrahim Halloun, taught Modeling Instruction to 10 high school physics teachers in Lebanon in the late 1990s. He gave each teacher a 100-question "Modeling Practice Survey" at the end of their first year of implementation. That survey asks questions about the extent to which a teacher implements various components of modeling instruction. For the 3 teachers who had fully implemented all components of Modeling Instruction (i.e., the two broad dimensions of modeling pedagogy and restructuring of content to systematically help students develop models), their students' FCI normalized gain, \(<g>\), was very high: between 0.7 and 0.8. For teachers who implemented less fully, their students' normalized gains were correspondingly less.
2. By 1990, Malcolm Wells' honors physics students' mean FCI posttest score was 78% with normalized gain \(<g> = 0.6\) (for 30 students), and his regular course had 64% with \(<g> = 0.5\) (for 18 students).

3. For Dwain Desbien's community college students in calculus-based physics using Modeling Instruction, their FCI mean post-test average was typically about 80% with normalized gain \(<g> = 0.7\); and for the algebra-based course, 73% with \(<g> = 0.6\).

4. Our FCI data for 20,000 high school students reveal that student FCI normalized gains under Modeling Instruction (after 1 or 2 years of implementation) are typically DOUBLE those under traditional instruction; i.e., \(<g> = 0.4\). Teachers who implement all components of the Modeling Method most fully have the highest student gains: mean FCI posttest scores tend to increase over the first 3 or 4 years of implementation, then plateau. Gains generally persist through the years; they've been tracked in some cases for up to 8 years.

5. Exceptionally high student FCI scores and normalized gains were consistently obtained by two high school teachers and Modeling Workshop leaders, Michael Crofton in a working-class suburban public school in the northern midwest, and Tim Burgess in a suburban private school in the deep south: each had a mean FCI posttest score of about 80% to 85% with \(<g> \approx 0.75\) to 0.8 each year, in a first year honors physics course.

B. ISLE, developed by Eugenia Etkina and Alan Van Heuvelen, was used with Freshman Engineering Honors students at Ohio State University. In fall 2001, \(<g> = 0.56\) with a mean FCI posttest score of 83% (the same for Alan Van Heuvelen with 100 students and for a self-proclaimed former traditional lecturer with 100 students).

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From: Nick Cabot, whose doctoral dissertation was on Modeling Instruction use by teachers
Date: Mon, 22 Sep 2014

To be excessively terse, many researchers seem to agree that teachers' effectiveness plateaus after 3 to 5 years of experience primarily because of the lack of meaningful feedback on their teaching. New teachers and teachers implementing new pedagogy (or, more broadly, anybody doing anything new) reach a proficiency with which they are comfortable after a few years - they get into their (new) comfort zone. There is rarely in place any sort of continuous process improvement mechanism that provides feedback to teachers (for example, observation of their classroom teaching, virtually or in person, by expert modelers on areas for improvement in their instruction (which, by the way, was an aspect of the Modeling Instruction professional development program here in North Carolina)). It appears that in the relative isolation of the classroom and despite any sort of teacher evaluation process, which usually assess teachers' proficiency on factors unrelated to student learning, the lack of meaningful feedback is an obstacle to continuing professional growth.

Perhaps the modeling community should create a network of peer observers. New and experienced modelers could send in videos of their classroom teaching for review by acknowledged expert modelers or teachers in a Local Physics Alliance could set up a system of rotating peer reviewers or what have you. Presumably, ongoing research in modeling instruction will prevent the whole modeling community from reaching its own plateau!
Of course, I've said nothing in this post about the impact of the school context on teaching effectiveness - maybe later.

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From: Joe Morin  
Date: Mon, 22 Sep 2014

Maybe I'm a new teacher, only entering my 11th year, but I totally revamp my courses every single year. I don't have any "meaningful" external feedback (except what I request from my students), and I don't need or want any. I am intrinsically motivated to continuously improve my teaching. I am in a constant state of discomfort, thinking about how I can do better next time; so I know what I need to change and improve. I don't just implement something new and sit on it; I **have a mindset of continuous improvement.** IMHO this is the difference between a professional approach to teaching as a calling and a profession, and thinking of teaching as a 9-5 blue collar job.

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From: Jeff Steinert  
Date: Mon, 22 Sep 2014

David Ennis wrote about his thoughts on student motivation and inconsistencies in the instructional story line as factors that contribute to a ceiling on student FCI gains. I believe there is another, far more important factor. Research on the link between student cognitive ability (as measured by scores on Tony Lawson's Classroom Test of Scientific Reasoning) and individual FCI gains originally published by Vince Coletta and Jeff Phillips establishes **limits on normalized gains based on student reasoning ability.**

Our TPT article on this is available on the ASU Modeling Instruction website <http://modeling.asu.edu/Projects-Resources.html>. Scroll about halfway down the page to the Assessment in Modeling Instruction heading. It is the last link, entitled *Why You should Measure Your Students' Reasoning Ability.*

Obviously, there will be a mix of student reasoning abilities in any class, but I have found that I consistently achieve overall gains that correlate well with student scores on the Lawson Test. The research in the paper was conducted at my former high school in Maine, where physics was an elective course, taken mostly by seniors. Interestingly, I've found that students at my current school, a performing arts charter school in Phoenix where physics is a required course of all juniors, achieve higher FCI gains for the same Lawson Test scores than my students in Maine. I believe this has much to do with the culture of the school and the fact that the vast majority of students have extensive formal music training.

Vince Coletta has recently published *Thinking in Physics*, describing his program to increase the cognitive abilities of students who may struggle in introductory physics classes by integrating activities into his course. He uses a combination of PER methods and interventions developed by Reuven Feuerstein, Michael Shayer and Philip Adey, and others. It is a book everyone should own, especially since, as a high school educator, you can get a free copy by requesting a copy of *Thinking in Physics *(ISBN: 978-0133938890) by emailing K12InsideSales@Pearson.com . Vince made a special arrangement with Pearson to make this happen.
From: David Ennis  
Date: Tue, 23 Sep 2014  

Jeff Steinert wrote, on 9/22/14: …limits on normalized gains based on student reasoning ability  
Jeff, you are right that these differences in reasoning ability will always give a spread in performance on the FCI, but we can still imagine the spread becoming much narrower with a much higher average with breakthroughs in instruction.  
And by the way, Jeff, lest you should think that our email exchange last year and your recent post on tying the FCI to the Lawson for teacher evaluations didn't make a dent, I do give the Lawson as a pre and a post. And based on my results from last year, I certainly do want to relate to FCI to the Lawson when used as a Student Learning Objective. A scatter diagram of my last year's Lawson (based on 13 points) versus FCI gains gives a blob of points which seems to show only a mild correlation. But when the data is partitioned, the message is clear:

<table>
<thead>
<tr>
<th>Lawson average Pre</th>
<th>FCI average</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 6</td>
<td>39%</td>
<td>18</td>
</tr>
<tr>
<td>7 - 9</td>
<td>53%</td>
<td>34</td>
</tr>
<tr>
<td>10 - 11</td>
<td>61%</td>
<td>14</td>
</tr>
<tr>
<td>11 only</td>
<td>71%</td>
<td>4</td>
</tr>
</tbody>
</table>

A good number of individuals from the lowest Lawson group above did actually have higher FCI gains than a number of individuals in the 10-11 group, so motivation and individual growth are factors too, as well as, perhaps, faltering diligence of some seniors toward the end of the year, and bad hair days. All of that is in the soup.

Sunday, Sept. 21, 2014  
From: Jane Jackson  

Dave Ennis posted today: "So if the assumptions above are correct, It would behoove anyone with the nominal results predicted by the 2000 data to try to study the methods of Michael or anyone else like him out there. It would benefit the community if such material could be identified and provided by AMTA. What could be more important? Unfortunately, I don't find anything posted by Crofton in the Modeling Resources….”

Dave Ennis and all:  
Your assumptions ARE correct. It is METHODS; that is the answer.  
I totally agree with you: What could be more important than to study the methods of Michael or anyone else like him?  
David Hestenes has always said how important it is, to identify the BEST FCI posttest scores, and learn how those teachers teach. But how do we get funding to do so? And who is qualified (and has time) to study these expert teachers' methods? Would it be a good doctoral dissertation, if done by a long-time physics modeler?
Michael Crofton is among the most humble, accepting, tactful, and kind teachers whom I know. Since 2001 Michael has led 2nd semester physics Modeling Workshops at Arizona State University, including microscopic models in e&m, models of light, and mechanical waves & Sound (in all three for which he is a chief author & refiner!

He retired (early) in 2011, after 30 years of teaching physics. He is the instructor now, of the distance-learning course "Methods of Teaching Physics" for PhysTEC. He reads this listserv. (I hope he doesn't mind my lauding him -- it needs to be said, and strategies of expert teachers like him need to be revealed.)

In 2006 he sent me, at my request, a 2-page answer to my question, "What do you DO, that accounts for your students' FCI success?" He wrote that his paper wasn't as coherent as he would like, so I will ask him to refine it for posting on the website.

Maybe this will help: you can:
* visit the listserv compilations webpages, for some of his posts, in context.
  http://modeling.asu.edu/listserv.html
  http://modeling.asu.edu/listserv1.html
* download his MNS degree action research report, his AP-C physics syllabus, & his list of e&m supplies at http://modeling.asu.edu/Projects-Resources.html
* download his 5 lab practicums in mechanics at http://modeling.asu.edu/modeling-HS.html
  Click on "Lab Practicums".
* download his "Survey on Waves" at http://modeling.asu.edu/MNS/MNS.html
* get the latest updates of sample modeling curricula in e&m & waves at the AMTA website.
  (Larry Dukerich knows better than I, the recent contributions of Michael to sample curricula. We are all volunteers, you know.)