Developing Some of the Skills and Values Needed for Success in Introductory Physics

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Introduction

- Why do some students show lower normalized gains than the others?
- Is there a way to identify those students who might be at risk before the semester?
- What can we do differently to help those students?

- To address these questions, Vince Coletta and I studied various correlates with conceptual understanding and created, *Thinking In Physics*, which helps students develop the necessary skills and values.

How to measure student learning?

– Assessment Tools

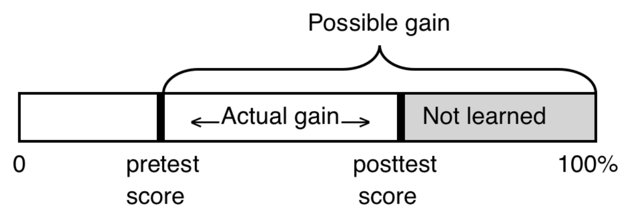
- Are mainly in the form of multiple-choice surveys, have been created for nearly all parts of introductory physics. (Other common forms of STEM assessment can be found in The Field-Tested Learning Assessment Guide.)
- Go beyond typical word problems found at the end of chapters, and probe students' understanding and misconceptions, rather than their ability to follow examples.
- Are typically given pre & post instruction to give a better sense of what changed during the semester.

How to measure student learning?

– Normalized Gain

- One way to gauge students' improvement over the course of a semester. Think of it as the the fraction of the concepts learned that were not already known at the beginning of the course.

$$G = \frac{\text{actual gain}}{\text{possible gain}} = \frac{\text{postscore\%} - \text{prescore\%}}{100 - \text{prescore\%}}$$

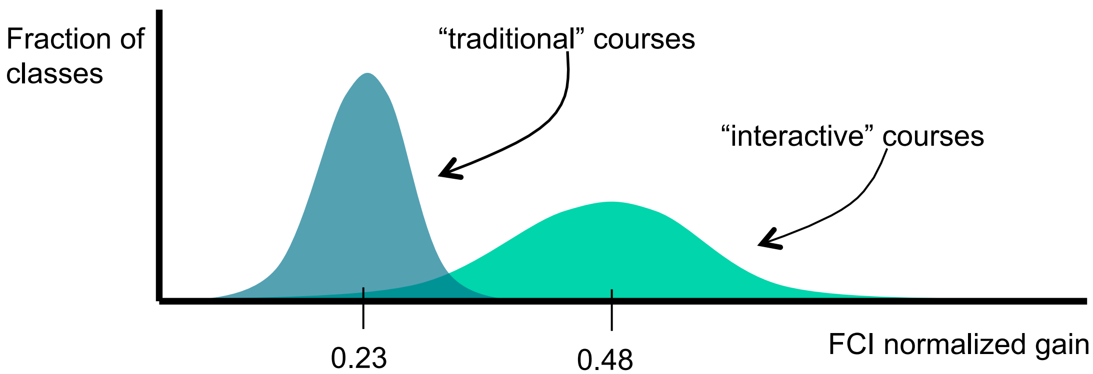


- Examples:
  - A student with a prescore of 20%, and a postscore of 60% would have a G of 0.50.
  - A student with a prescore of 50% and a postscore of 75% would also have a G of 0.50.

How to measure student learning?

– Example data

- Dick Hake published one of the first analysis of FCI results from colleges & high schools. One of his findings was that "interactive" courses, no matter what techniques were used, yielded higher gains than "traditional" courses.

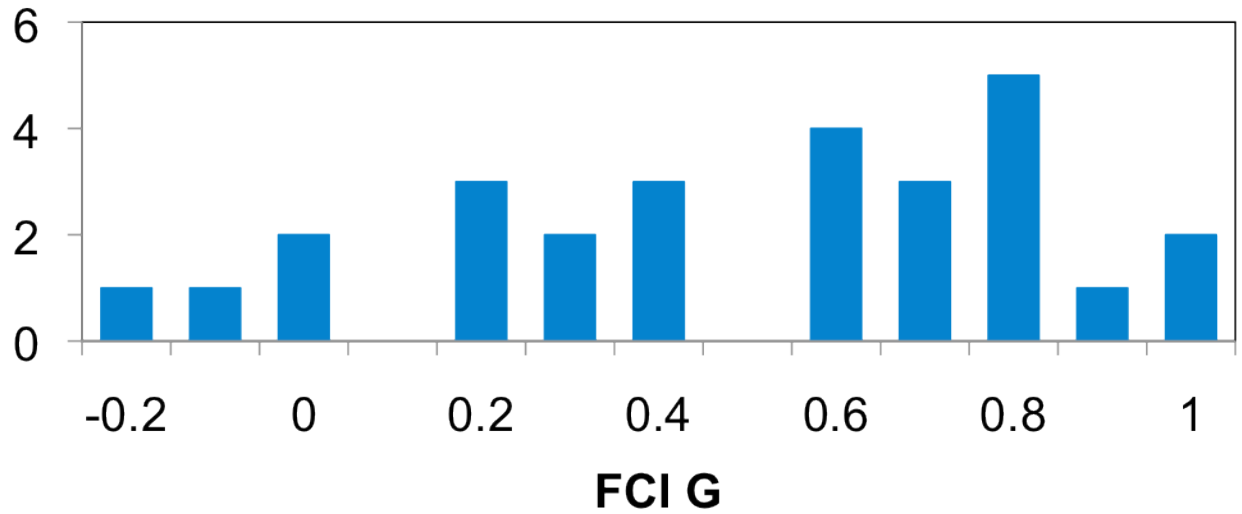


- Despite the fact that most students in a class show improvements in their understanding of physics concepts, there are often students who struggle to grasp the fundamentals. Even with interactive teaching techniques often a fraction of the class is not able to perform at the expected level.

How to measure student learning?

– Example data

- Within each course there are, of course, variations among the individual student gains. For example, here is an example histogram from one of my recent *Introduction to Mechanics* courses that shows students' normalized gains on the Force Concept Inventory (FCI):

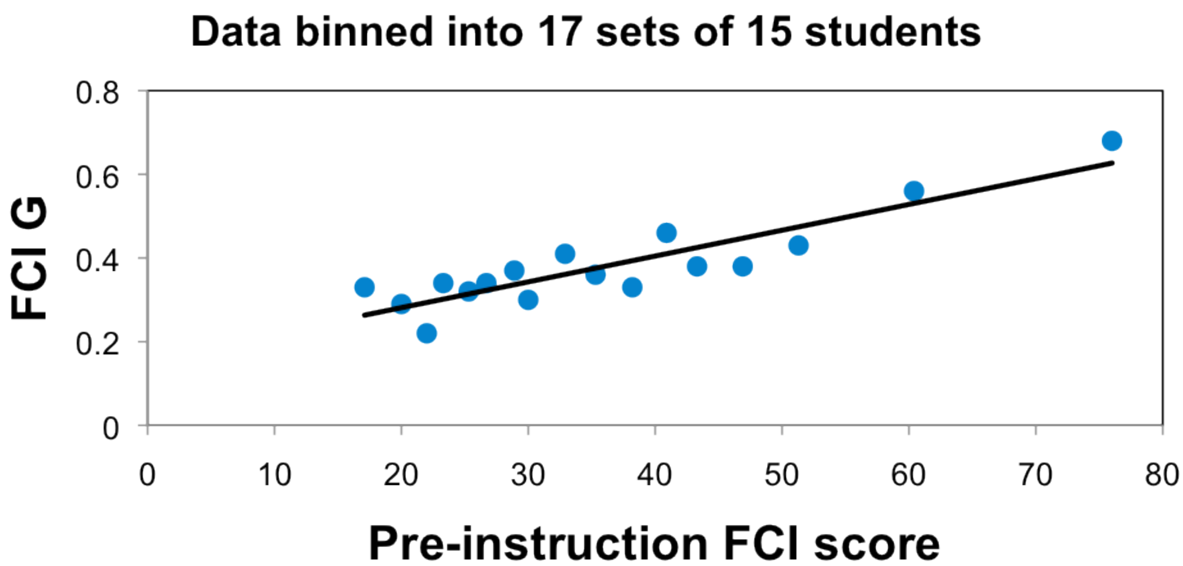


Knowledge

- Individuals build their knowledge by making connections to existing knowledge. This previous knowledge must be considered when trying to learn new content as it may not be correct, or students may not understand how to make the connections.
- A few misconceptions seen in mechanics, which are easily revealed with the FCI:
  - Impetus is supplied by “hit”
  - “More active” agent produces the greater force
  - Greater mass implies greater force

Knowledge

- The impact of previous knowledge can be seen when the normalized gain is plotted against prescore. Below is an example of this from our research.
- This correlation is not always seen. In classes that are taught with traditional methods (lecture), the gains are small for *all* students.
- This correlation does not rule out the strong possibility that both the prescore and normalized gain are dependent on a third variable.



Skills

–Reasoning

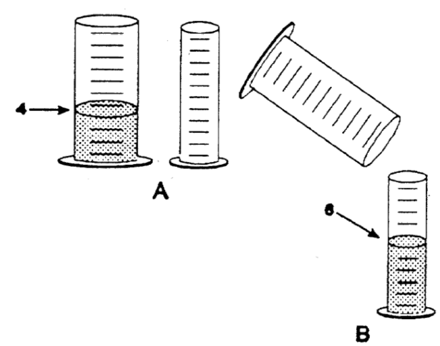
- Like playing sports, reasoning is a skill that has to be learned and refined over time. The ability to think abstractly is not one that we are born with. Only after many years, do we have the ability to control and isolate variables, search for relationships, such as proportions, understand probability, and lastly, formulate hypotheses and test them with carefully designed experiments.
- One measure of these cognitive skills is the Classroom Test of Scientific Reasoning ("Lawson Test").

Skills

–Measurement of Reasoning

- Classroom Test of Scientific Reasoning ("Lawson Test") The 24-question, multiple-choice test probes students' understanding of: conservation of weight & volume, proportional thinking, identification and control of variables, probabilistic thinking and hypothetico-deductive reasoning.

5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).



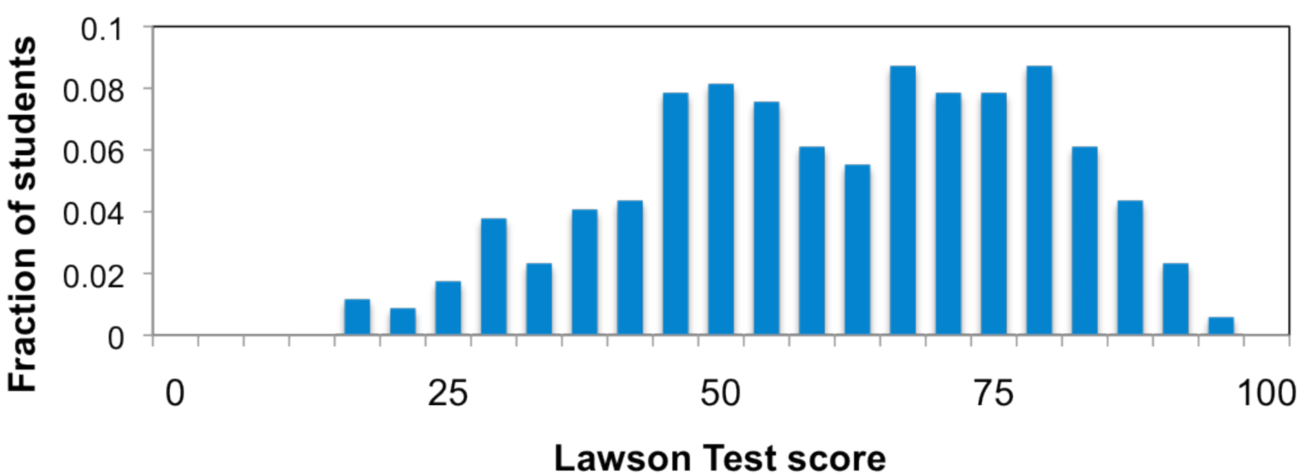
Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. How high would this water rise if it were poured into the empty narrow cylinder?

a. to about 8
b. to about 9
c. to about 10
d. to about 12
e. none of these answers is correct

Skills

–Data on Student Reasoning

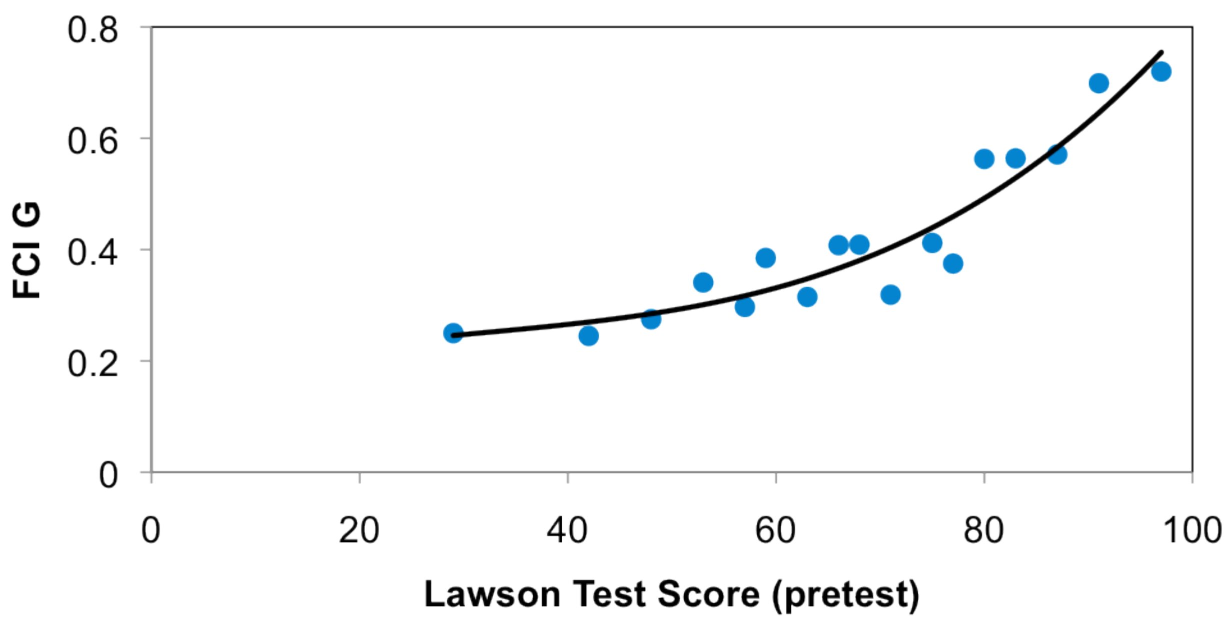
- With the help of the chemistry department we have been able to test freshmen in introductory chemistry. We also have results for sophomore engineering majors in physics 201 and junior biology & natural science majors in physics 253.
- This is a chart below shows the distribution of total Lawson scores among the freshmen.
- Approximately, scores above 75% represent students who have the necessary skills to reason abstractly, and 40- 75% are only possess some of the skills.
- Students who do not have the necessary cognitive skills, will not fully understand abstract concepts such as acceleration and energy.



Skills

–Impact on Conceptual Understanding

- The Lawson Test and FCI were administered to 297 high school and university students who were enrolled in interactive courses. (The teaching methods varied across the sections, but all went behind passive lectures.)
- Similar correlations are seen with the SAT.



Skills

–Metacognitive Skills

- In addition to the cognitive skills, such as scientific reasoning, problem solving, and mathematical, there are metacognitive skills that are equally important. Thinking about thinking, or metacognition, is important in learning.
- Whereas cognitive skills are used to achieve a particular goal (e.g., understand forces), metacognitive skills help to ensure that the goal has been reached (e.g., quizzing oneself to evaluate one's understanding of forces).
- May & Etkina observed a correlation between the amount of metacognitive activity and learning in their courses, in which students were asked to keep weekly journals. Those physics students who showed the greatest and most sophisticated reflection were the students who scored higher on conceptual diagnostic surveys, such as the FCI.
- By employing metacognitive skills, one engages in *self-regulated learning*, which can be divided into several sub-skills: planning, monitoring and adjusting.

Values

- Ultimately, a student must choose to seek out new information or refine their skills. A student's personal epistemology, what an individual believes about the nature of knowledge and how knowledge is formed has a profound impact on how that student will approach learning, develop cognitively, and succeed academically.
- Many students have simplistic epistemologies, and view knowledge as absolute and comprised of many unrelated components. For such students the source of knowledge is often an authority – an instructor or a text. They do not have a constructivist view of knowledge formation.
- More sophisticated students see knowledge as tentative, related, and structured, and believe they can construct knowledge.
- In nearly all contexts, researchers have shown that a student’s personal epistemology correlates with academic success. For example, Ryan showed that the more students believe in simple knowledge, the more likely they are to equate factual recall with comprehension.
- In fact, most physics courses show a degradation of values about learning and science. Using the Maryland Expectations Survey, Redish has found that students' move away from the desired, expert-like values.

TIP Inspiration

– Cognitive Acceleration through Science Education (CASE)

- The CASE program was designed for middle school children. One hour lessons are inserted into the regular science curriculum once every two weeks for two years. These lessons all involve some kind of science content, but their purpose is to teach thinking. Specifically, the program seeks to teach identification and control of variables, proportional reasoning, probability and correlation, and use of abstract models.
- Professor Adey has abundant data demonstrating the dramatic long term success of CASE at dozens of schools in the UK. On average, students who participated in CASE, three years later averaged one full grade higher in science, mathematics, and even English than did students in control classes.

TIP Student Learning Outcomes

- *Develop favorable values about learning*
  - Many of the students initially have poor attitudes and beliefs about learning. For example, many are not very independent in their approach to learning, and many don't appreciate the coherence of scientific knowledge.
- *Develop the necessary reasoning cognitive and metacognitive skills*
  - We often use games and non-physics activities for problem solving practice. In these simple exercises, and throughout the various activities of the course, TIP encourages metacognition, self regulation, and the development of strategic thinking about learning.
- *Understand variables and their relationships*
  - A proper understanding of variables and their relationships is of great importance in science. Many students in the TIP program are deficient in this area. Various TIP activities are designed to develop understanding of the meaning of a variable, how variables can be related and controlled, and the kind of relationships between variables, such as proportional relationships.
- *Develop effective problem solving strategies*
  - TIP promotes the four step method of problem solving first proposed by Polya: 1) formulate the question; 2) plan a solution; 3) execute the plan; 4) review the solution. The specific implementation of each step depends on the problem.

TIP Variations

- Only those students who already show some signs of struggling, such as low SAT scores or low GPA (particularly in STEM courses), are invited to participate. In an effort to determine what course structure would be most beneficial, we set up several different tracks:
  - TIP I is an intense summer course taken by students prior to their introductory mechanics course. Students meet 12 hours per week for two weeks.
  - TIP II is a 12-week course taken concurrently with introductory mechanics . In addition to normal physics class meetings, students meet 2 hours per week.
  - TIP III is a track in which some TIP materials are integrated into a regular section of introductory mechanics.
  - TIP IV is a course that is taken before introductory mechanics. The course satisfies students' critical thinking general education requirement.

TIP Activities

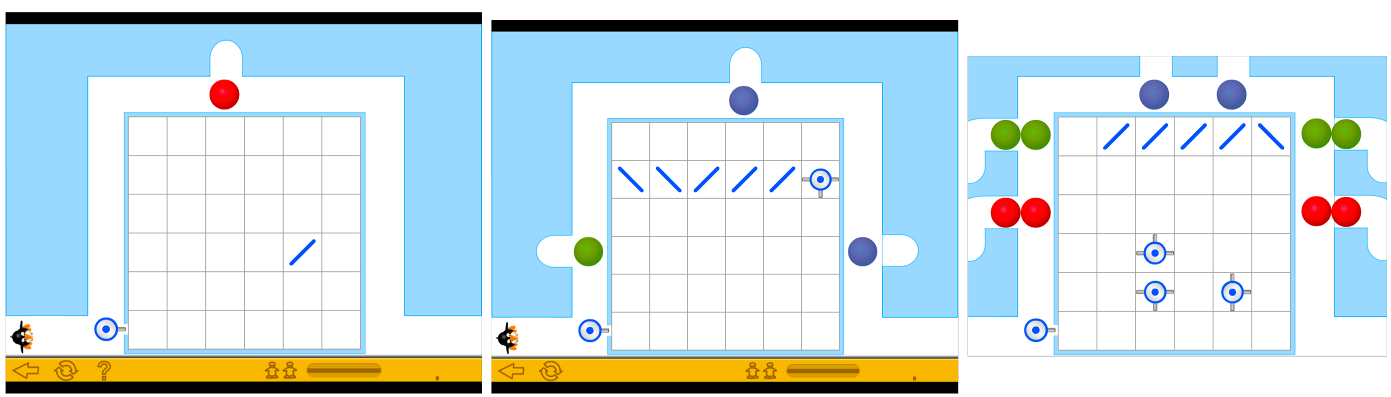
–Scientific Reasoning (especially variables)

- TIP activities often involve student group work, guided by worksheets, including lab experiments.
- Early activities focus on what are variables and the relationships between. Students also develop algebraic and graphic tools to represent the relationships.
- Example activities:
  - One student pulls a cart (sheet of plywood with four low friction, Rollerblade wheels) on which a second student is seated, while maintaining a constant force, which is monitored with a spring scale that is attached to the rope.
  - Groups are given a dozen round, symmetric objects of varying mass, radius, and shape and an inclined plane to investigate what variables affect the time to roll down the plane.

TIP Activities

– Problem Solving & Metacognition

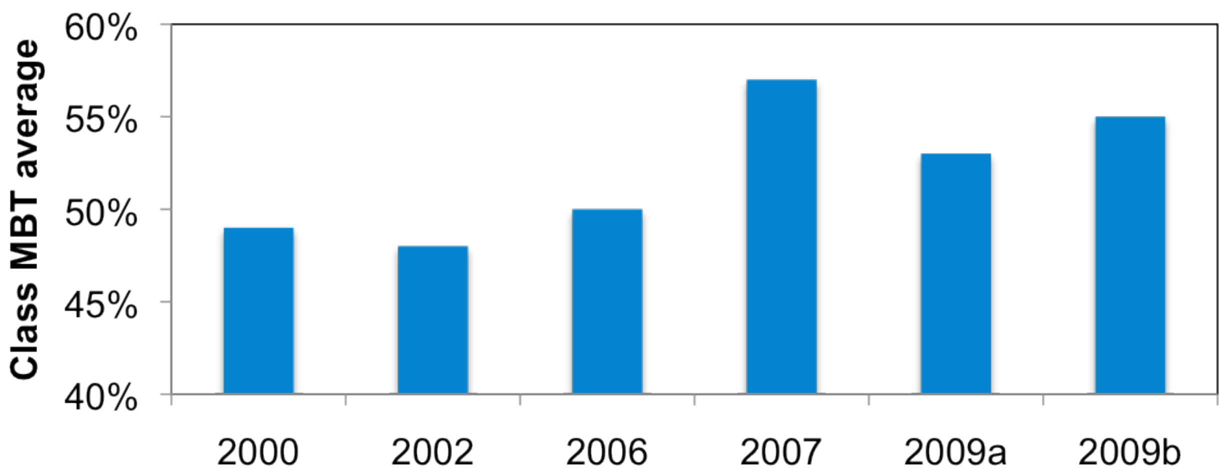
- Students keep journals where they reflect on their progress. They correct tests (including analysis of their mistakes) for additional credit.
- TIP develops students' problem solving skills by modeling effective problem solving strategies.
- The Polya approach is emphasized in different contexts, including everyday problem solving, puzzles, and physics problems.
- One set of games were developed by the MIND Research Institute. These games are completely visual and are even free of any "instructions," which force students to carefully perform step #1 (formulate the question). Students cannot advance without first correcting their mistakes (step #4).



TIP Results

– Reasoning and Problem Solving

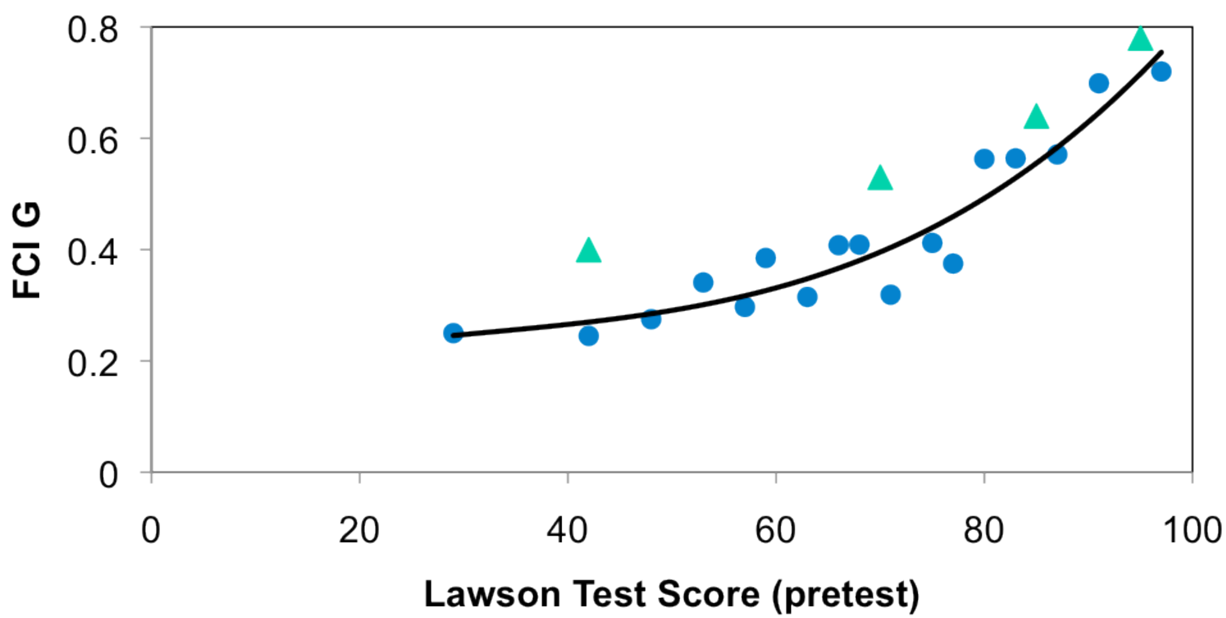
- In four introductory mechanics sections and one pre-physics Thinking in Science course, students were able to improve scores on the Lawson Test. On average, the scores improved from 69% preinstruction to 78% postinstruction, which corresponds to an average normalized Lawson gain of 0.29. The average normalized gains of the five classes varied significantly (0.40, 0.38, 0.26, 0.20, and 0.15).
- The Mechanics Baseline Test (MBT) is a standardized exam sometimes used as a measure of problem solving facility.



TIP Results

– Changes to Conceptual Gains

- The results from one 24-person TIP class are shown below. Students in all quartiles performed better than predicted on the basis of their preinstruction Lawson Test scores, but the lower two quartiles showed the greatest improvement. (Comparison data is the same 297-student dataset that was shown earlier.)



Thanks

- In order to see greater learning, students' previous knowledge must be taken into consideration when designing a curriculum. However, students' skills and values also play a key role in their learning. Most often these are part of the "hidden" or implicit curriculum. Only when they are explicitly addressed is their improvement.
- There are many successful curricula already, but we hope that Thinking in Physics can fill a niche. TIP activities target the needs of the least prepared students. By helping students to understand variables, refine their problem solving skills, develop cognitive and metacognitive skills, we have already seen that students learn more conceptual physics.

- If you would like more information about TIP, or discuss possible connections, please contact Jeff Phillips (jphillips@lmu.edu). You can also visit the LMU PER website **http://myweb.lmu.edu/jphillips/PER**
- For more information on the SoCal AAPT section: **http://www.scaapt.org** Our Spring meeting is May 14 at Pierce College in Los Angeles.