Interactive Lecture Demonstrations

Active Learning in Difficult Settings

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Collaboration

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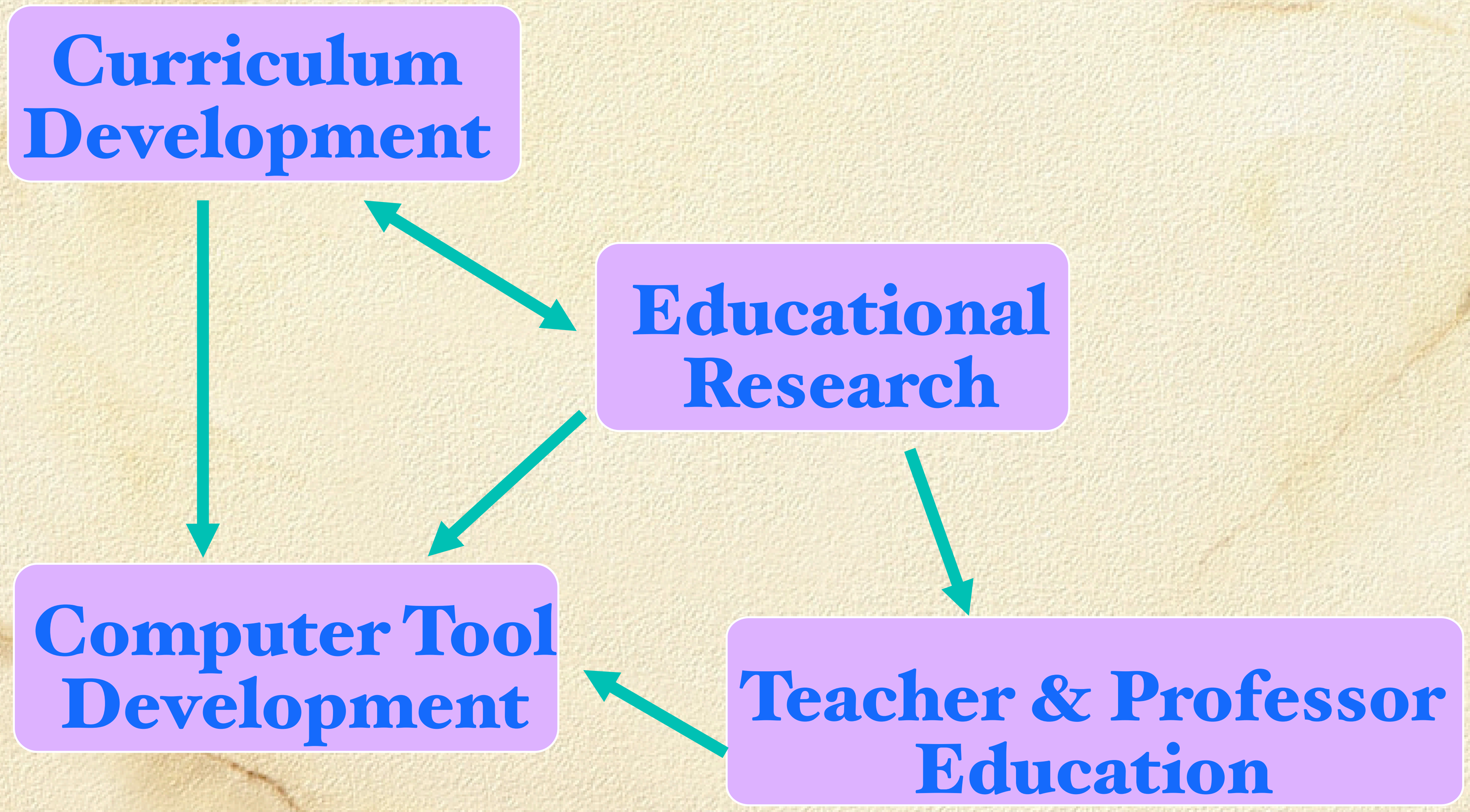


Funding

- ***NSF***
  National Science Foundation
- ***FIPSE***
  Fund for the Improvement of Post Secondary Education
- ***US Department of Education***

Can an active learning environment be created in a large (or small) lecture class?

I obviously think so or I wouldn't have proposed to talk to you about it.

The method I propose is
Interactive Lecture Demonstrations or ***ILDs***

(You will hear two about two other methods for making lectures interactive-Eric Mazur will talk about Peer Instruction and Evelyn Patterson will discuss Just in Time Teaching. You can effectively use all three methods together.)

Let's do an *ILD* to illustrate the method

ILD Prediction Sheet
Motion with Carts-Demo 6

- Please find it in the handouts
- This *ILD* is actually the 6th demo in the Motion with Carts *ILD* sequence which is the second sequence in the *Motion, Force, & Energy* series.
- To show you the procedure, I'll do it with you as if you were my students

Let’s do it

Tools for Scientific Thinking
Interactive Lecture Demonstration
Procedure

1. Describe the demonstration and do it for the class without real-time (MBL) measurements.
2. Ask students to record individual predictions.
3. Have the class engage in small group discussions with nearest neighbors.
4. Ask each student to record final prediction on handout sheet (which will be collected at the end)
5. Elicit predictions & reasoning from students.

ILD Procedure (continued)

6. Carry out the demonstration with real-time (*MBL*) measurements displayed.
7. Ask a few students to describe the result. Then discuss results in the context of the demonstration. (Students fill out a "results sheet" which they keep.)
8. Discuss analogous physical situations with different "surface" features. (That is, a different physical situation that is based on the same concept.)

Reference

- Using Interactive Lecture Demonstrations to Create an Active Learning Environment. (Sokoloff & Thornton)

The Physics Teacher, September, 1997, Vol. 35, pp. 340-347

What effective curricular reform techniques does this example illustrate?

- Begin with the specific and move to the general
- Use peer collaboration
- Keep students actively involved.
- Let the physical world be the authority
- Make appropriate use of technology
- Begin with what students understand
- Emphasize conceptual understanding
- Link abstractions to the concrete
- Find answers from the physical world (Experiment!)

Choosing the Experiments in an Interactive Lecture Demo Sequence

- The sequence of short, understandable experiments was derived from our research in physics learning.
- Experience with students in hands-on, guided discovery laboratories informed our choice of activities.
- Students must understand (or trust) apparatus used (no Mr. Wizard stuff).

Tested MBL *ILD* Sequences

- Walking Sequence- Intro kinematics
- Kinematics-uses carts and fans
- Dynamics- 1st and 2nd Laws
- Third Law
- Energy of Cart on Ramp
- Simple Harmonic Motion (with modeling and Vector Visualization)
- Gravity
- Projectile Motion (using the Visualizer)
- Heat and Temperature
- Simple DC Circuits, RC Circuits
- Lenses and Image Formation

Tested MBL ILD Sequences (continued)

- Introduction to Vectors (ILD with Dynamic Tutorial assigned as homework)-uses *Vector Visualizer*

Motion, Force, and Energy Interactive Lecture Demo Sequences

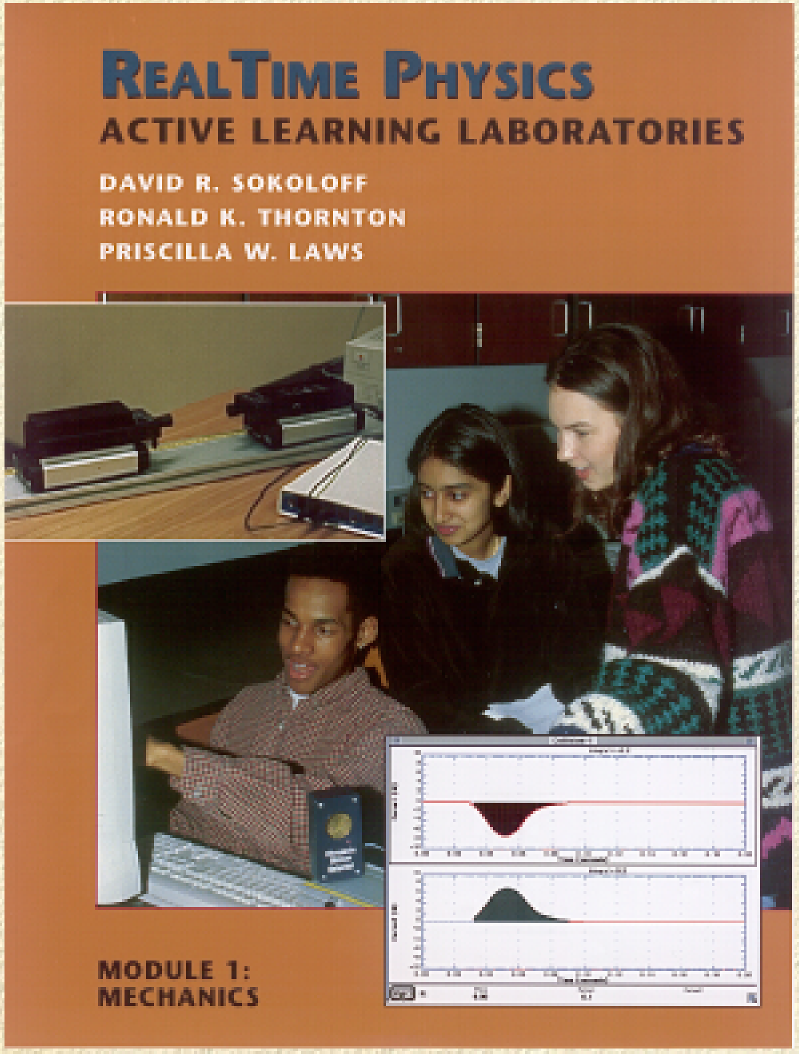
- Published by Vernier Software & Technology
- Includes
  - Teachers' Guide
  - Presentation Guide
  - Student Prediction and Results Sheets
  - *TST* and *LoggerPro* Versions of Experiment Setups (Mac, DOS, Windows)
  - Actual Backup Results in Experimental Setups
  - Paper showing actual learning results
  - Videos of actual *ILD's*

ILDs are part of the *Physics Suite* being developed by the Activity-based Physics Group

- Centerpiece of the Suite is *Understanding Physics* by Cummings, Laws, Redish, and Cooney-- a new book based on Halliday, Resnik, and Walker and the results of physics education research.
- The Suite includes coordinated Labs, *Interactive Lecture Demos*, Tutorials
- Published by Wiley

RealTime Physics: Mechanics

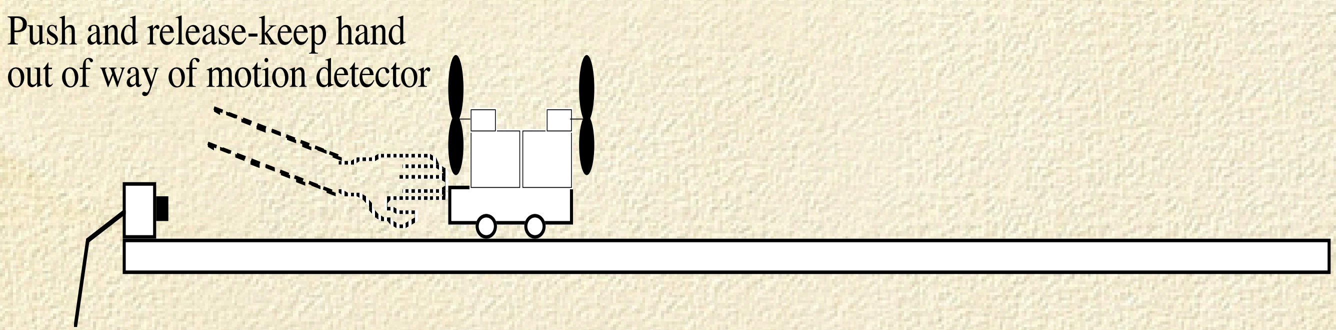
Published by John Wiley & Sons is also part of the Suite



How do students react to *ILDs*?

Let’s watch a Ist Law Demo from the Dynamics Sequence

Demonstration 3: Show that cart accelerates in either direction when only one fan unit is on (as seen in previous demonstrations). With both fans on (balanced) the cart does not move. Now push and release and observe velocity and acceleration.



Prediction begins just after cart leaves hand and ends just before the cart is stopped. Discuss in context of previous demonstration--constant velocity motion with net force equal to zero. Discuss in context of bicycle and/or car moving down road at constant velocity--why is it necessary to pedal or step on the accelerator?

Make your prediction first

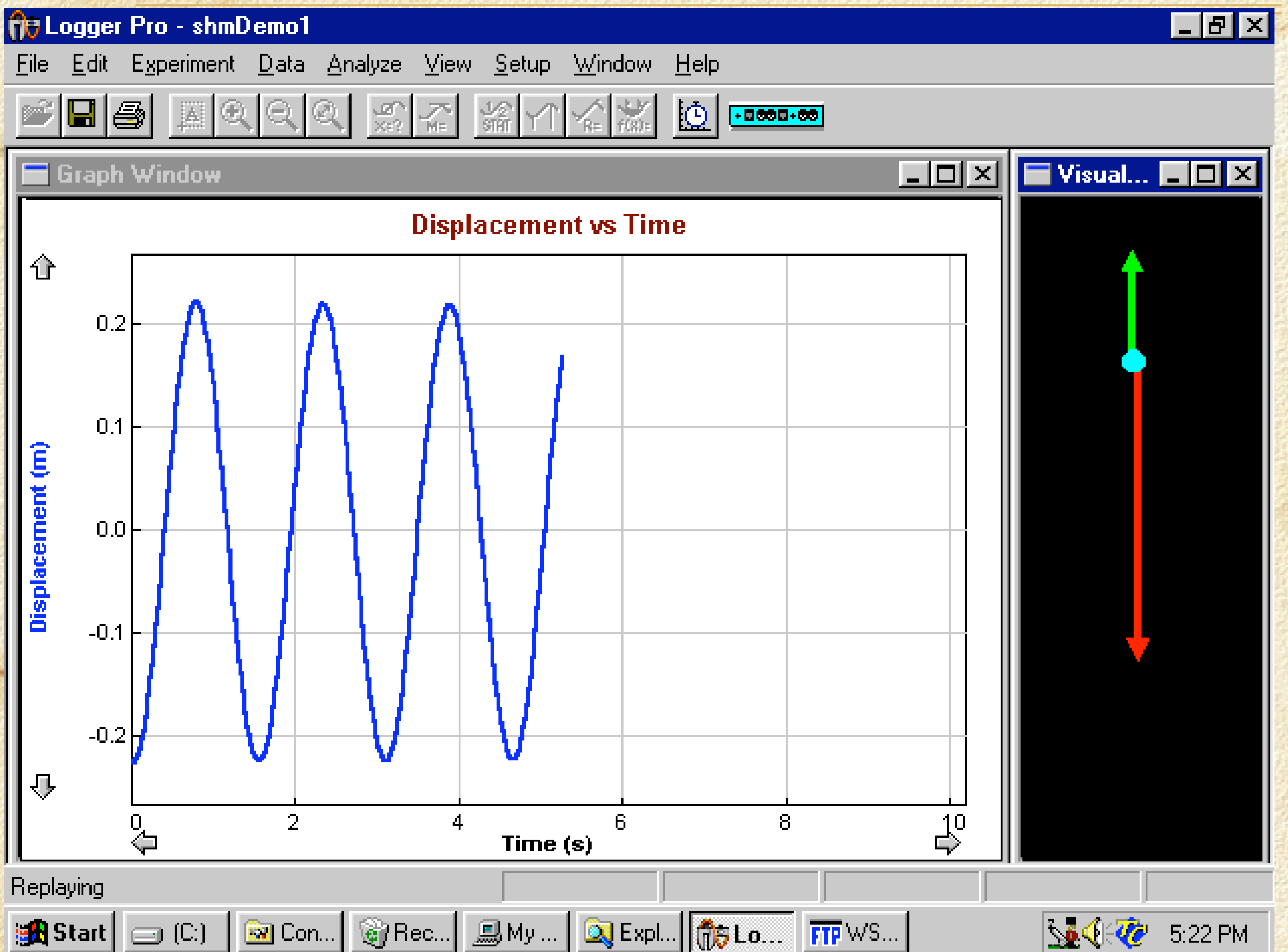
Video of a Newton's 1st Law Interactive Demo

- Tufts Physics 1- non-calculus introductory physics (approximately 170 students) Fall 98

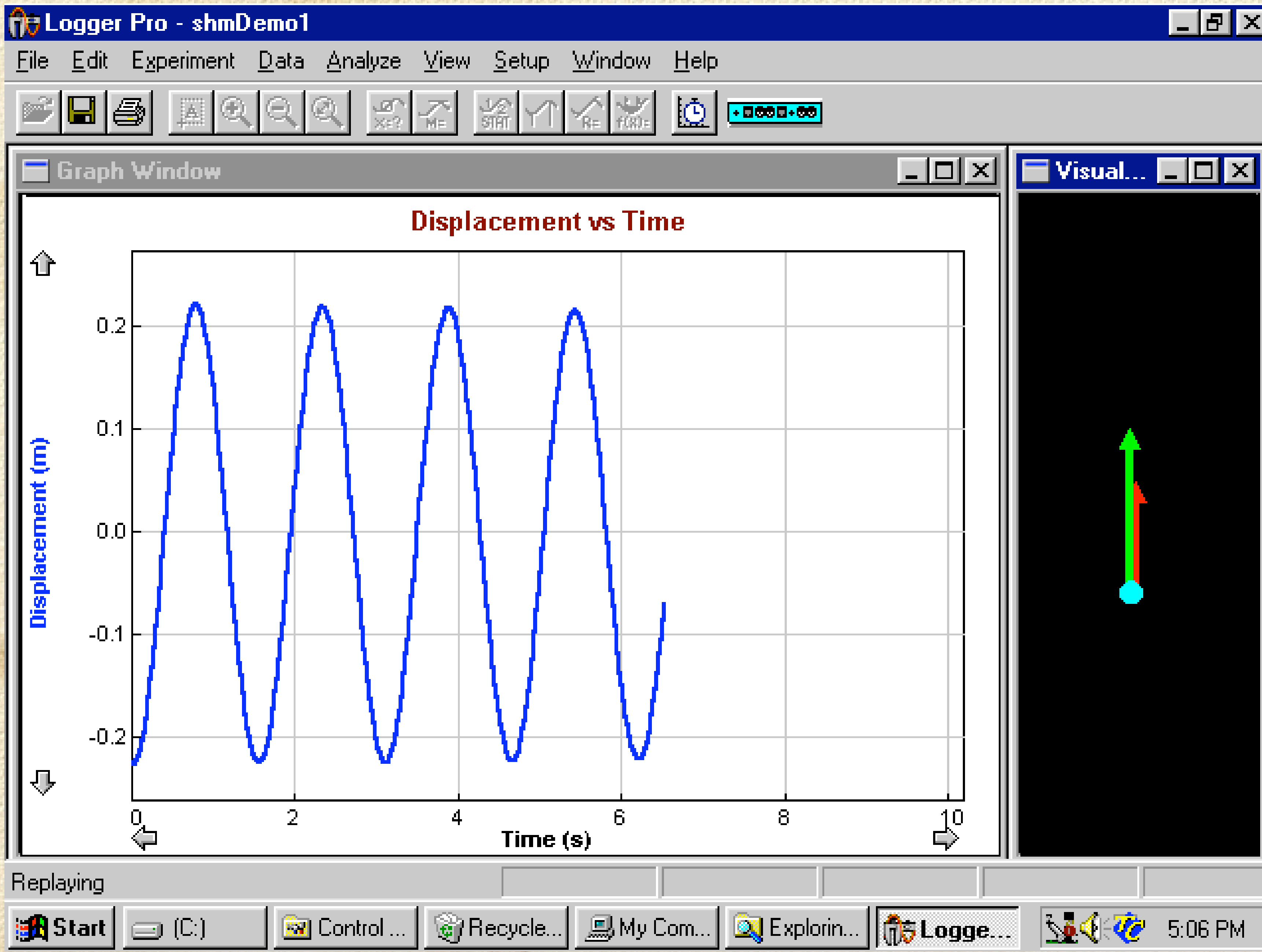
Video of “The Energy of a Cart on a Ramp” Interactive Demo

- Tufts Physics 1- non-calculus introductory physics (approximately 170 students) Fall 98

Active X Visualizer in LoggerPro

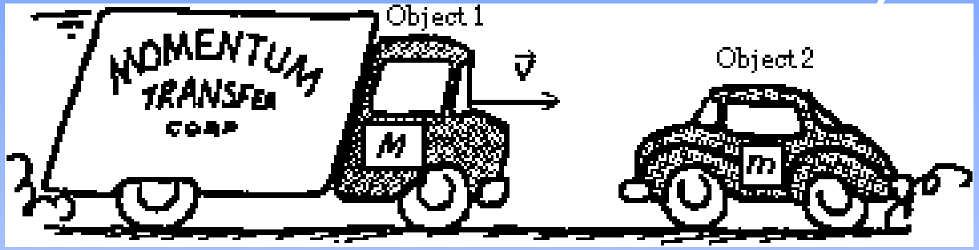


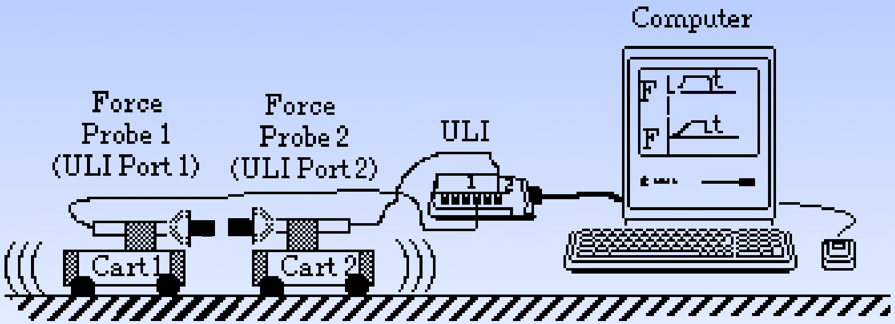
Active X Visualizer in LoggerPro



Example of a 3rd Law Interactive Lecture Demonstration

Forces of Interaction in a Collision Between Two Objects

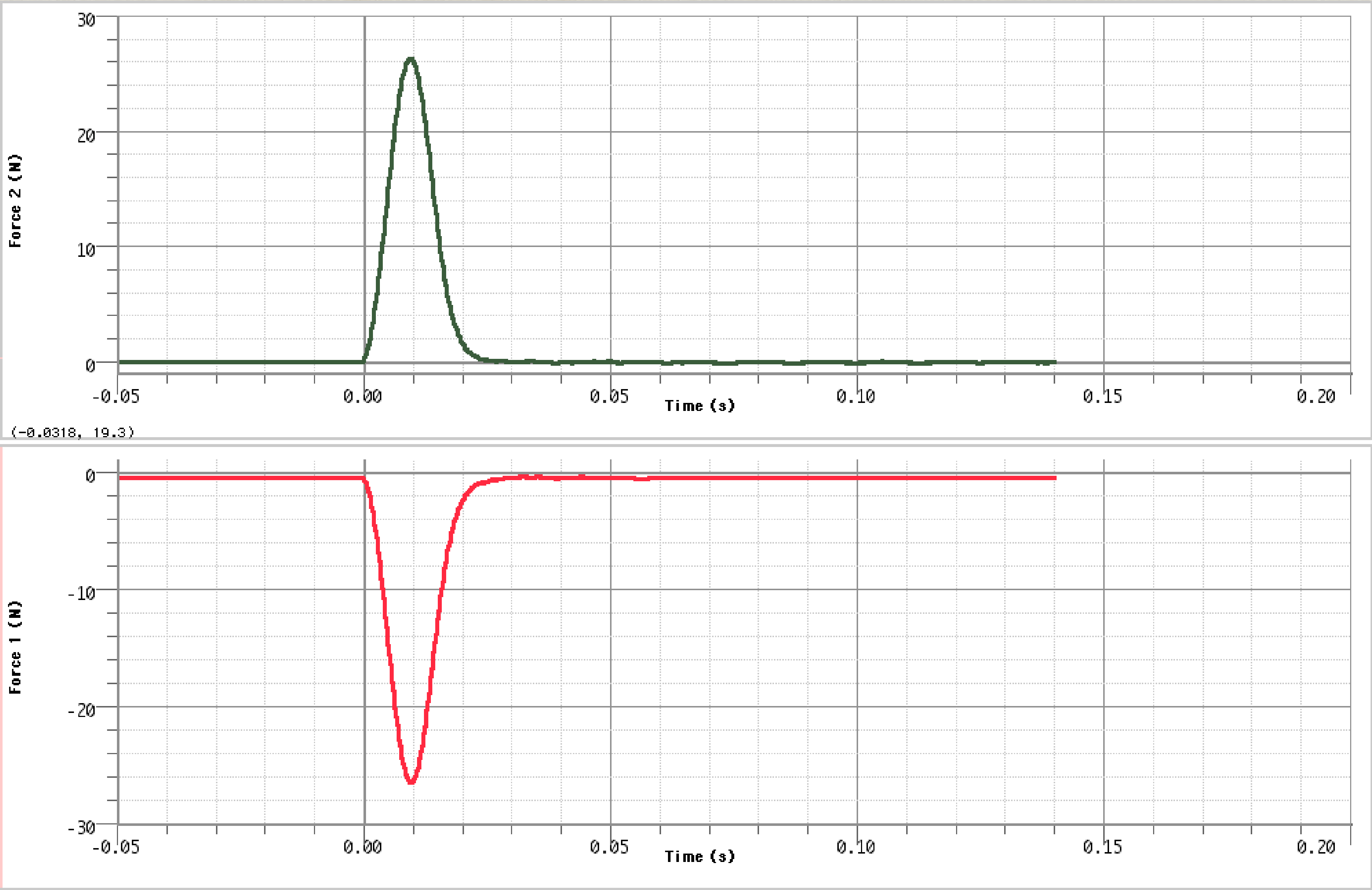




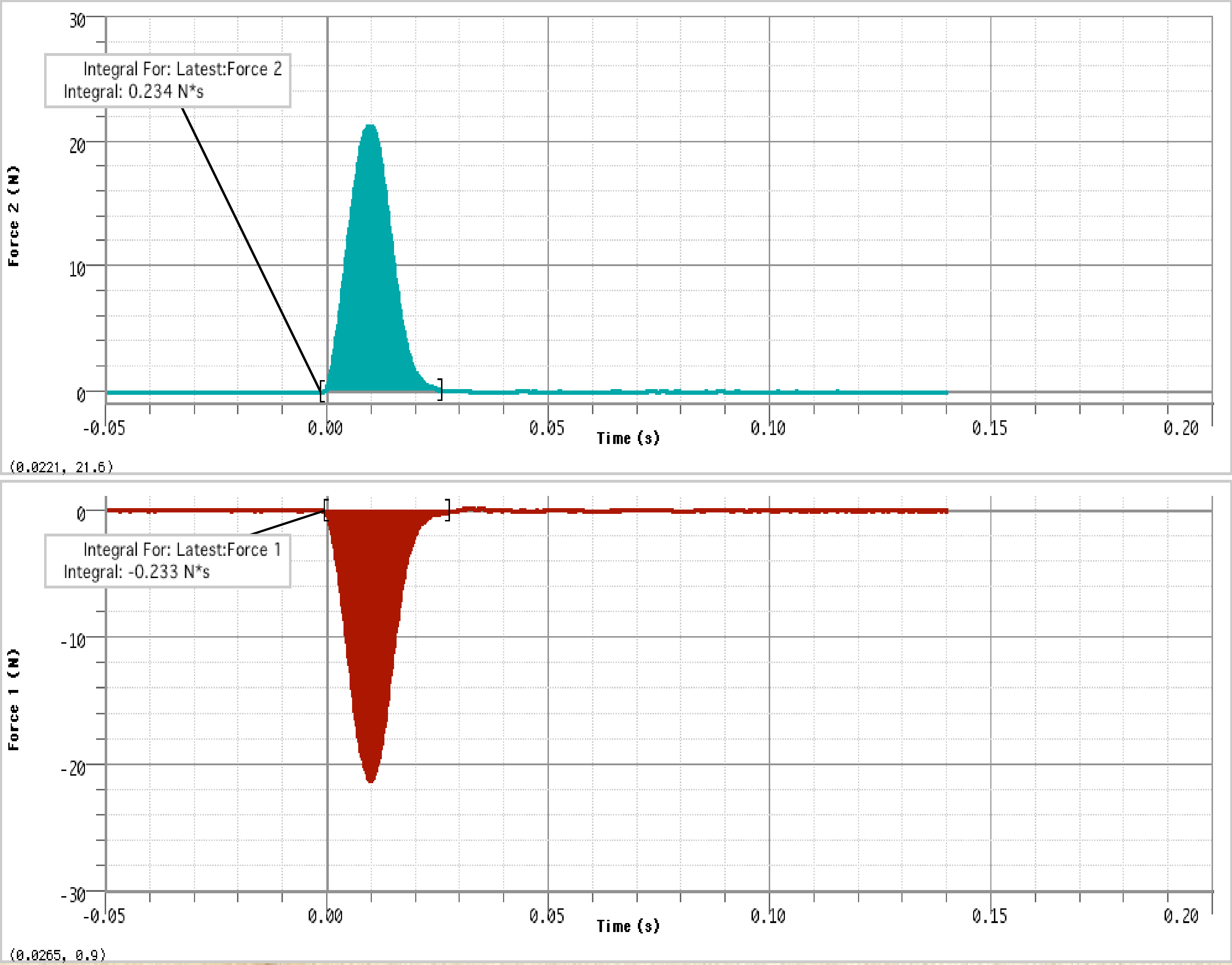
Let's do it

- Look at Demo 4-Sample Forces in Collisions Demo
- (part of Newton's 3rd Law Sequence)

Newton' Third-Collision



Collision-Impulse



So what do students learn?

We have spent years

- Creating effective learning environments for introductory science(physics) courses (curricula, tools, pedagogical methods, group structures)
- And developing methods of conceptual evaluation to measure student learning and guide our progress.
- For large scale and frequent evaluation we have settled on conceptual multiple-choice assessment.

Multiple Choice Conceptual Evaluation

- Conceptual evaluation for
  - kinematics (description of motion) and
  - dynamics (force and motion which is well characterized by Newton's Laws).
- Force & Motion Conceptual Evaluation (FMCE)

developed by the Center for Science and Math Teaching at Tufts (Thornton & Sokoloff)

Assessing Student Learning of Newton's Laws:

The Force and Motion Conceptual Evaluation of Active Learning Laboratory and Lecture Curricula

(Thornton & Sokoloff), *Am. J. Phys*, **66**, pp. 338-352 (1998)

Why Multiple Choice?

- More easily administered to large numbers of students.
- Evaluation takes less time.
- Student responses can be reliably evaluated even by the inexperienced.
- Can be designed to guide instruction.
- With proper construction, student views can be evaluated from the pattern of answers, changes over time can be seen, frequency of student views can be measured.
- Multiple choice combined with open response can help the teacher/researcher explicate the students response.

Using the FMCE

- Student answers correlate well (above 90%) with written short answers in which students explain the reason for their choices
- Almost all students pick choices that we can associate with a relatively small number of student models.
- Testing with smaller student samples shows that those who can pick the correct graph under these circumstances are almost equally successful at drawing the graph correctly without being presented with choices.

FMCE

- Because we are able to identify statistically most student views from the pattern of answers (and because there are very few random answers), we are also able to identify students with less common beliefs about motion and follow up with opportunities for interviews or open-ended responses to help us understand student thinking.
- The use of an easily administered and robust multiple choice test has also allowed us and others to track changes in student views of dynamics and to separate the effects of various curricular changes on student learning.

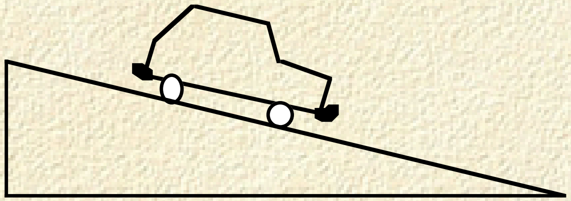
FMCE

- Use multiple representations
  - The Force Graph questions require explicit knowledge of coordinate systems and graphs but require little reading.
  - The Force Sled questions use natural language and make no explicit reference to a coordinate system or graphs.

Comparison with short answer

- As with all the questions on the test students who answered correctly were also able to describe in words why they picked the answers they did.
- Statistically one of the last questions to be answered in a Newtonian manner is the force on a cart rolling up a ramp as it reverses direction at the top (question 9).

Questions 8-10 refer to a toy car which is given a quick push so that it rolls up an inclined ramp. After it is released, it rolls up, reaches its highest point and rolls back down again. *Friction is so small it can be ignored.*



Use one of the following choices (**A** through **G**) to indicate the **net force** acting on the car for each of the cases described below. Answer choice **J** if you think that none is correct.

A Net **constant** force **down** ramp

B Net **increasing** force **down** ramp

C Net **decreasing** force **down** ramp

D Net force zero

E Net **constant** force **up** ramp

F Net **increasing** force **up** ramp

G Net **decreasing** force **up** ramp

______8. The car is moving up the ramp after it is released.

______9. The car is at its highest point.

______10. The car is moving down the ramp.

Cart on Ramp

- The following are typical explanations from students who answered this question from a Newtonian point of view:
  - "After the car is released the only net force acting on it is the x-component of its weight which has a net force down the ramp in the positive direction."
  - "When the car is at the top of the ramp, its velocity is 0 for just an instant, but in the next instant it is moving down the ramp, v2-v1 = a pos number so it is accel. down. Also, gravity is always pulling down on the car no matter which way it is moving."

Cart on Ramp

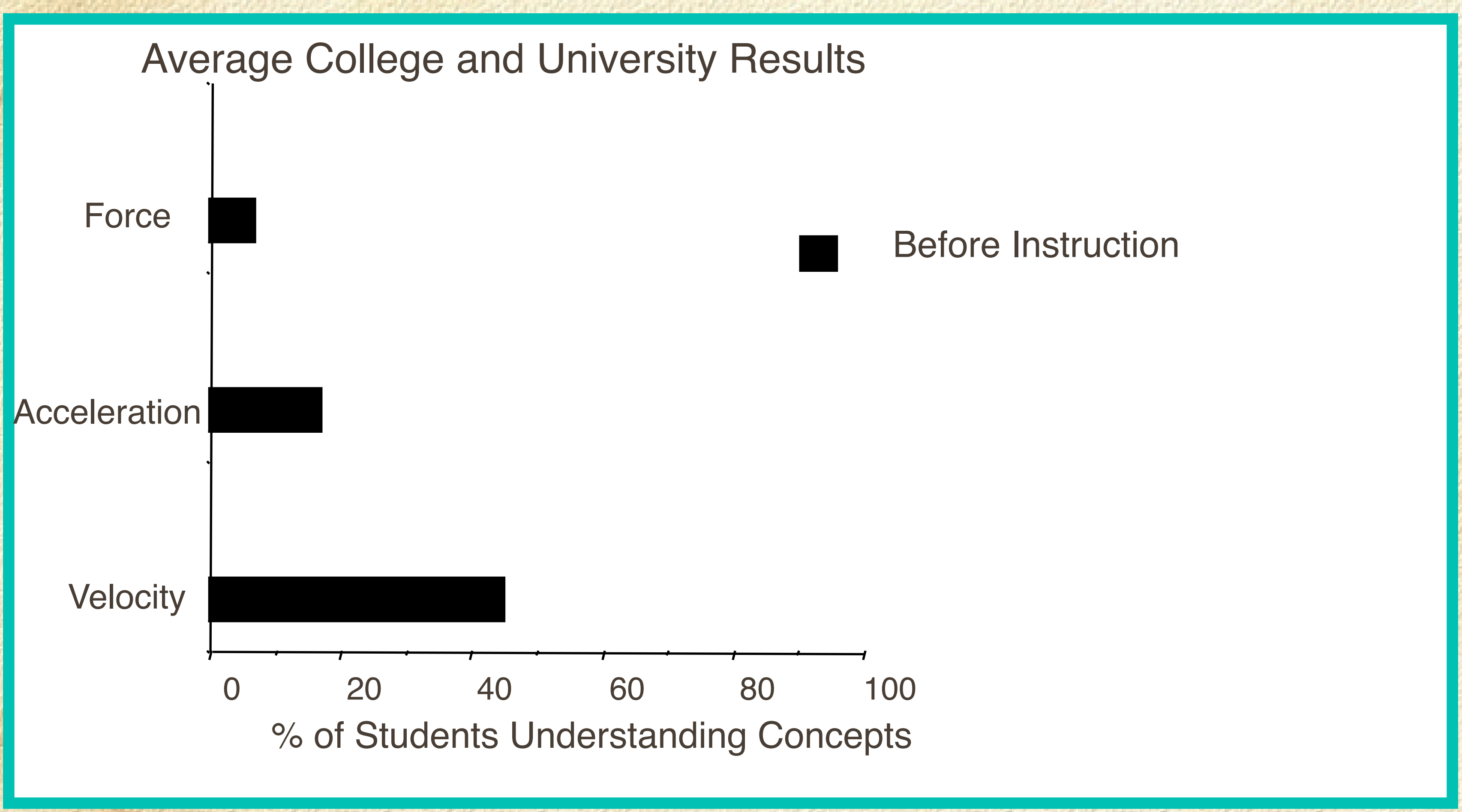
- Typical student answers for those who answered as if motion implies force were:
  - "At the highest point, the toy car's force is switching from one direction to another and there are no net forces acting upon it, so it is zero."
  - "Because at the one instant the car is at its highest point it is no longer moving so the force is zero for that one instant it is at rest = net force = 0"
- The agreement between the multiple choice and open answer responses is almost 100%.

Physics Courses Using New Methods

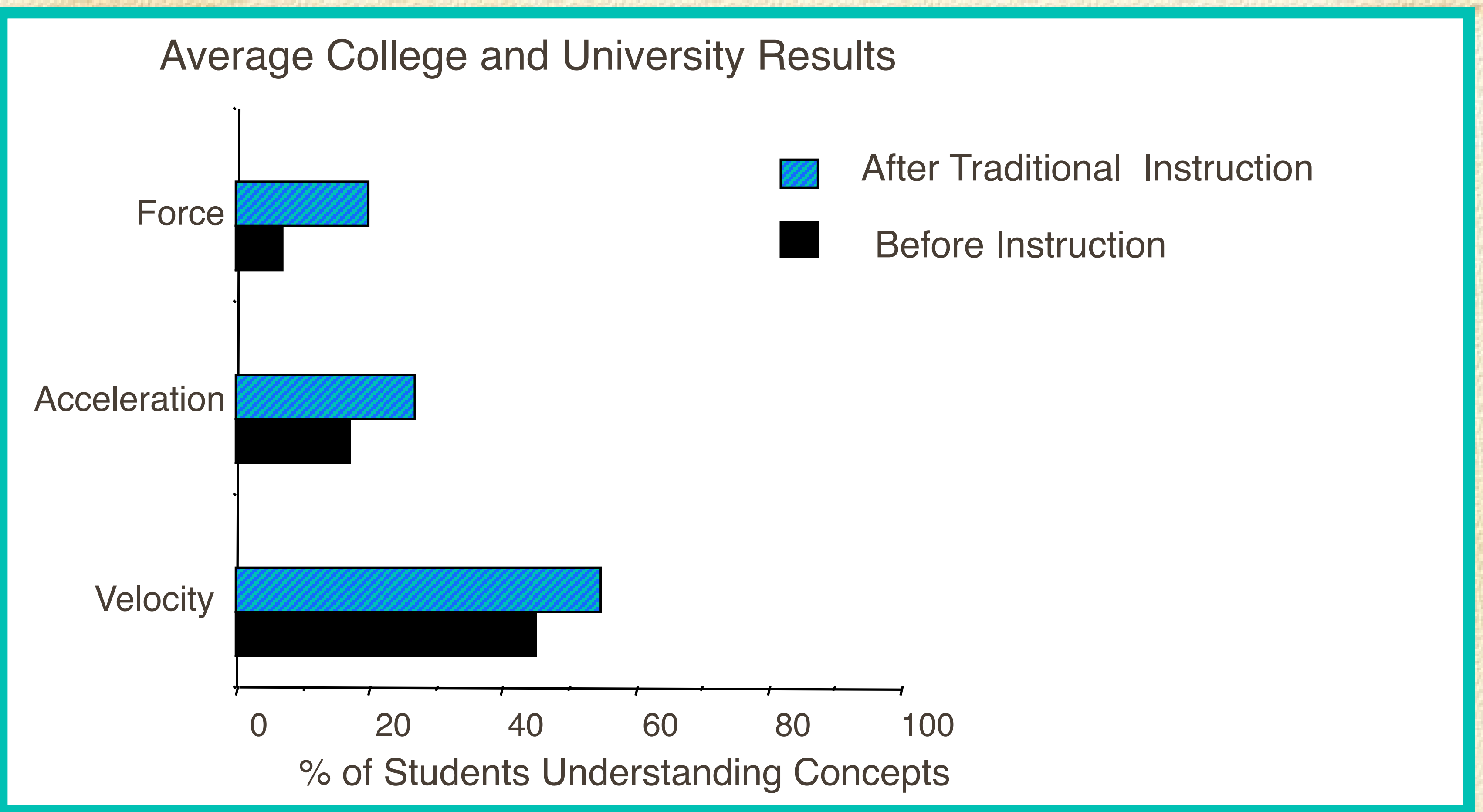
We have evidence of substantial, persistent learning of such physical concepts by a large number of students in varied contexts in courses and laboratories that use methods I am about to describe.

Such methods also work for students who have traditionally had less success in physics and science courses: women and girls, minority students, and those who are badly prepared.

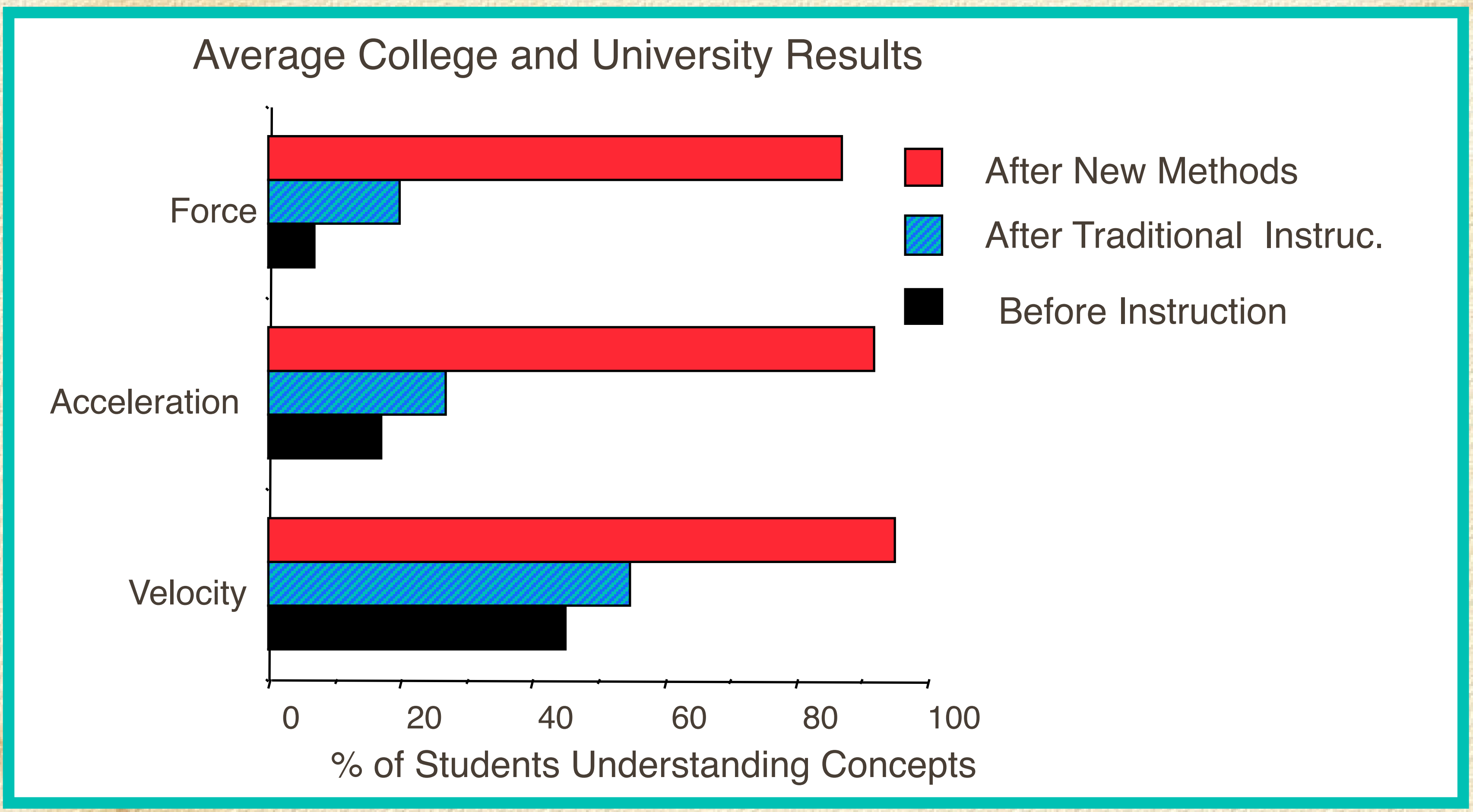
University Physics Courses Before Instruction



University Physics Courses After Normal Instruction



University Physics Courses After New Methods



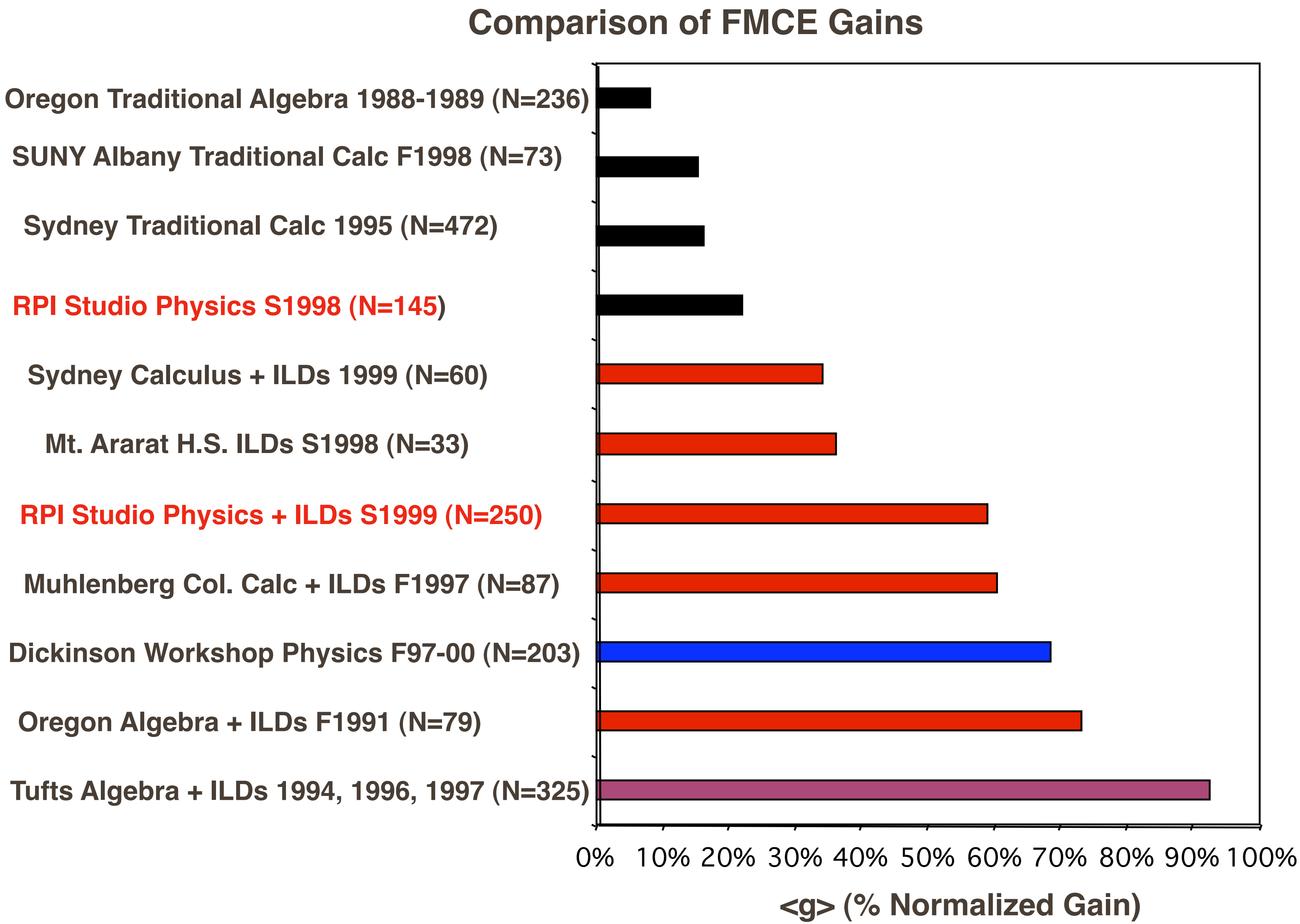
What about 1 number results

- Not my favorite, but useful in some situations
- If we wish to compare a large number of learning circumstances.

Let's compare *ILD's* to standard instruction using the FMCE

Example Data

- Conceptual evaluation for kinematics and dynamics uses the Motion and Force Conceptual Evaluation (FMCE) developed at the Center for Science and Math Teaching at Tufts
- Gains (% of possible improvement) shown are pre-instruction, post-instruction gains on the single # score of the FMCE. (correlates at 0.8 to the FCI)
- Examples for different student populations, different professors. All *ILD* scores are far above the results of traditional instruction.


Comparison of FMCE Gains
Oregon Traditional Algebra 1988-1989 (N=236)
SUNY Albany Traditional Calc F1998 (N=73)
Sydney Traditional Calc 1995 (N=472)
RPI Studio Physics S1998 (N=145)
Sydney Calculus + ILDs 1999 (N=60)
Mt. Ararat H.S. ILDs S1998 (N=33)
RPI Studio Physics + ILDs S1999 (N=250)
Muhlenberg Col. Calc + ILDs F1997 (N=87)
Dickinson Workshop Physics F97-00 (N=203)
Oregon Algebra + ILDs F1991 (N=79)
Tufts Algebra + ILDs 1994, 1996, 1997 (N=325)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
<g> (% Normalized Gain)

Let me tell you a story about engineers

New Methods at RPI (Structural Changes)

- RPI adapted some elements of Workshop Physics to produce Studio Physics. Students spent less total time in class but more time doing computer-based activities.
- The result? Students happier. Conceptual learning in mechanics somewhat better than traditional. (22% vs 15% normalized gain on the FMCE)

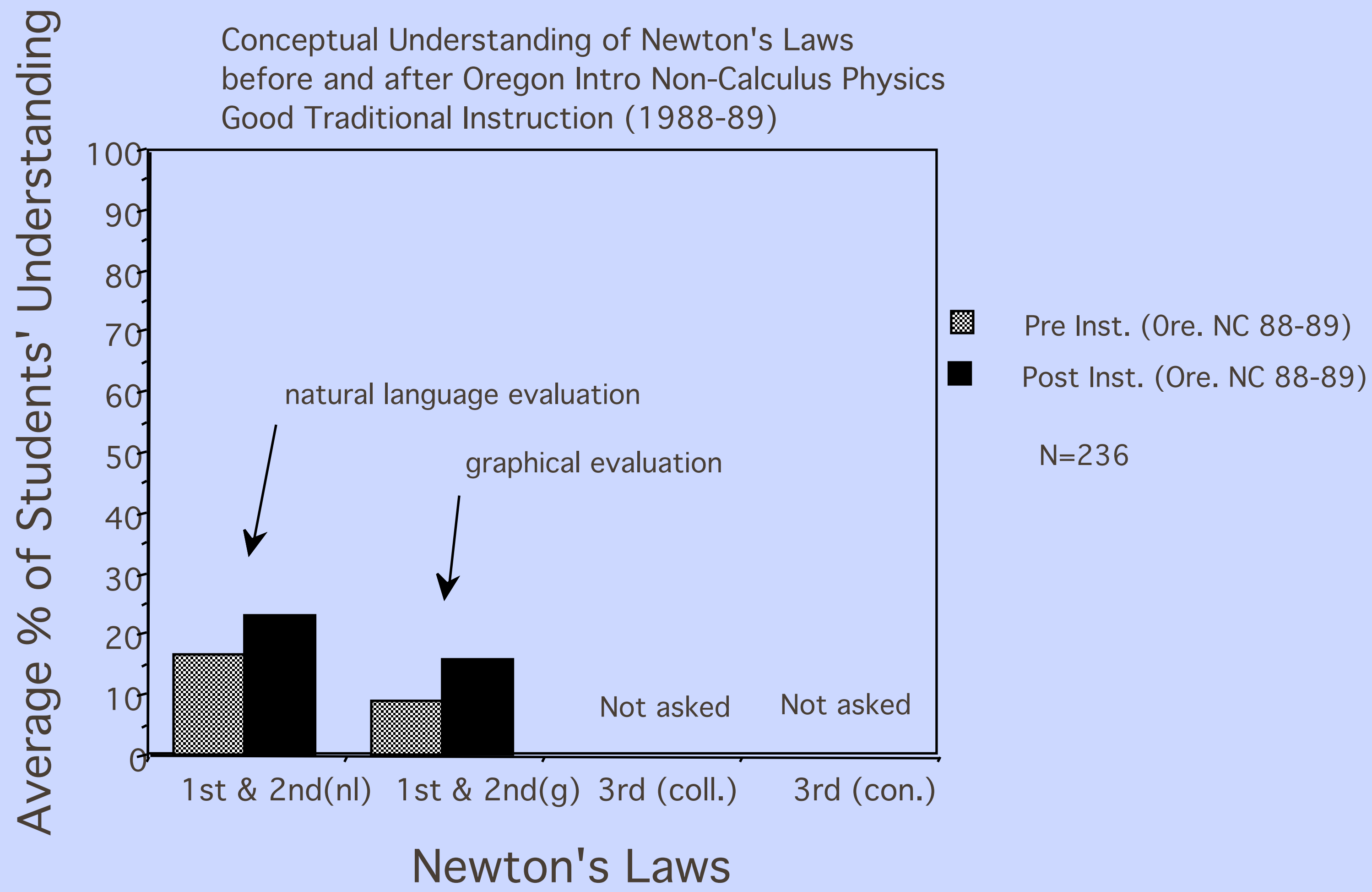
Research-based Curricular Change

- In the spring of 1998 and 1999 Karen Cummings of the RPI physics department introduced a series of research-based Interactive Lecture Demonstrations (ILD's) on Mechanics (four 40-minute segments some of which you have here) into Studio Physics
- Result? In 1999, normalized gain for the FMCE was about 60% instead of 22%.

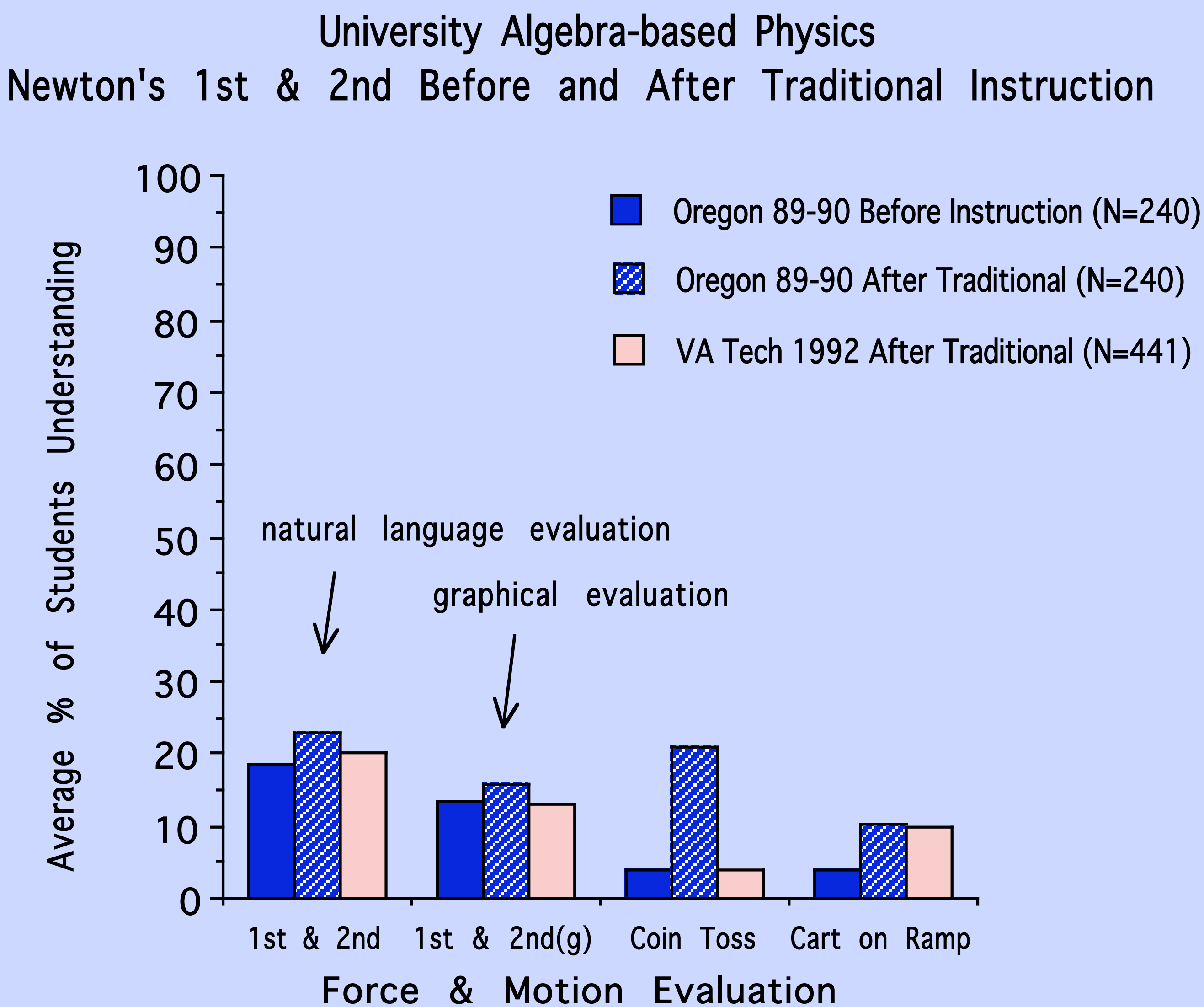
Summary Results

- Newton's 1st and 2nd Laws (natural language)
- Newton's 1st and 2nd Laws (graphical)
- Newton's 3rd Law (collision)
- Newton's 3rd Law (contact)

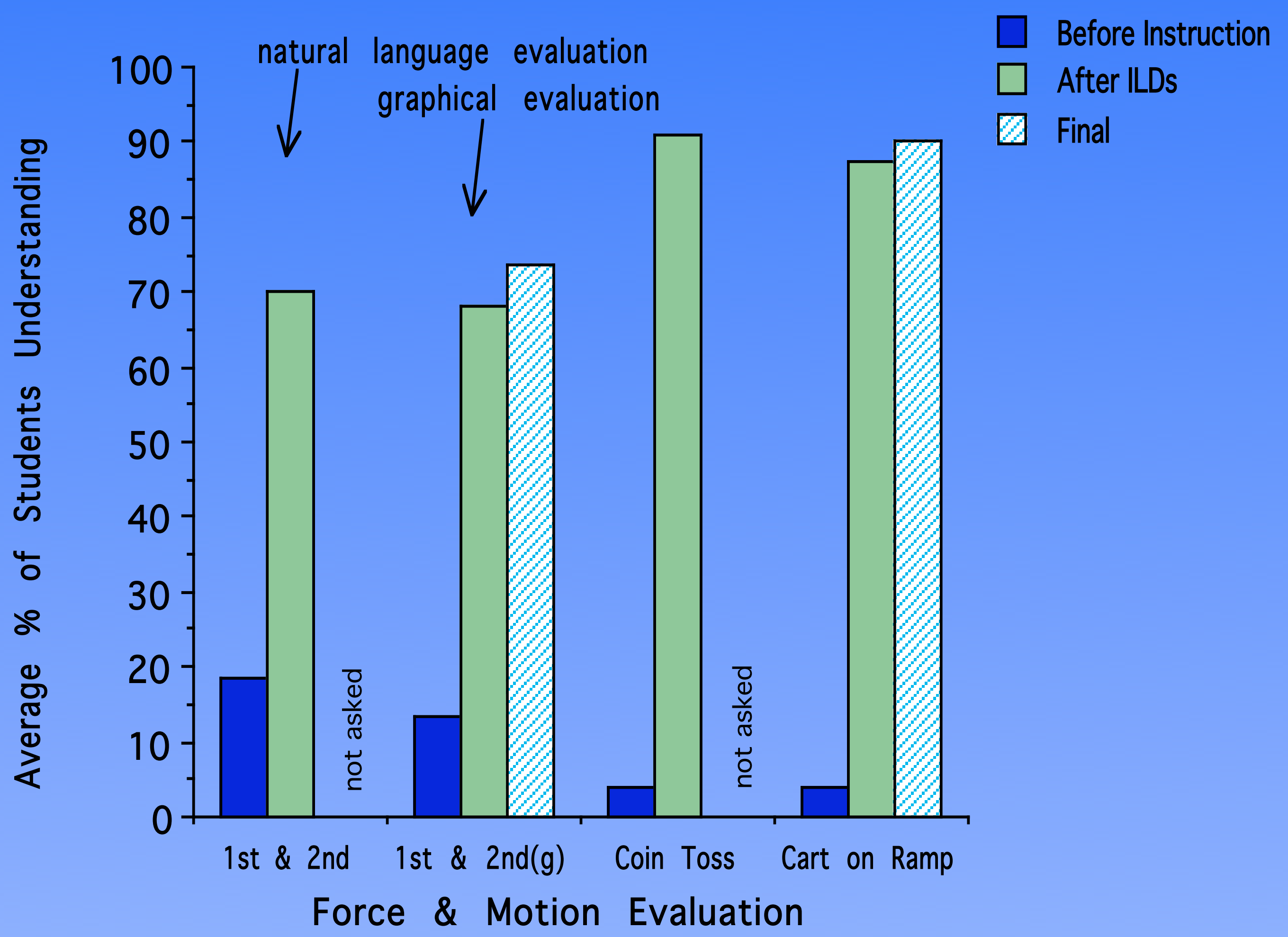
Typical Gains from Good Traditional Instruction



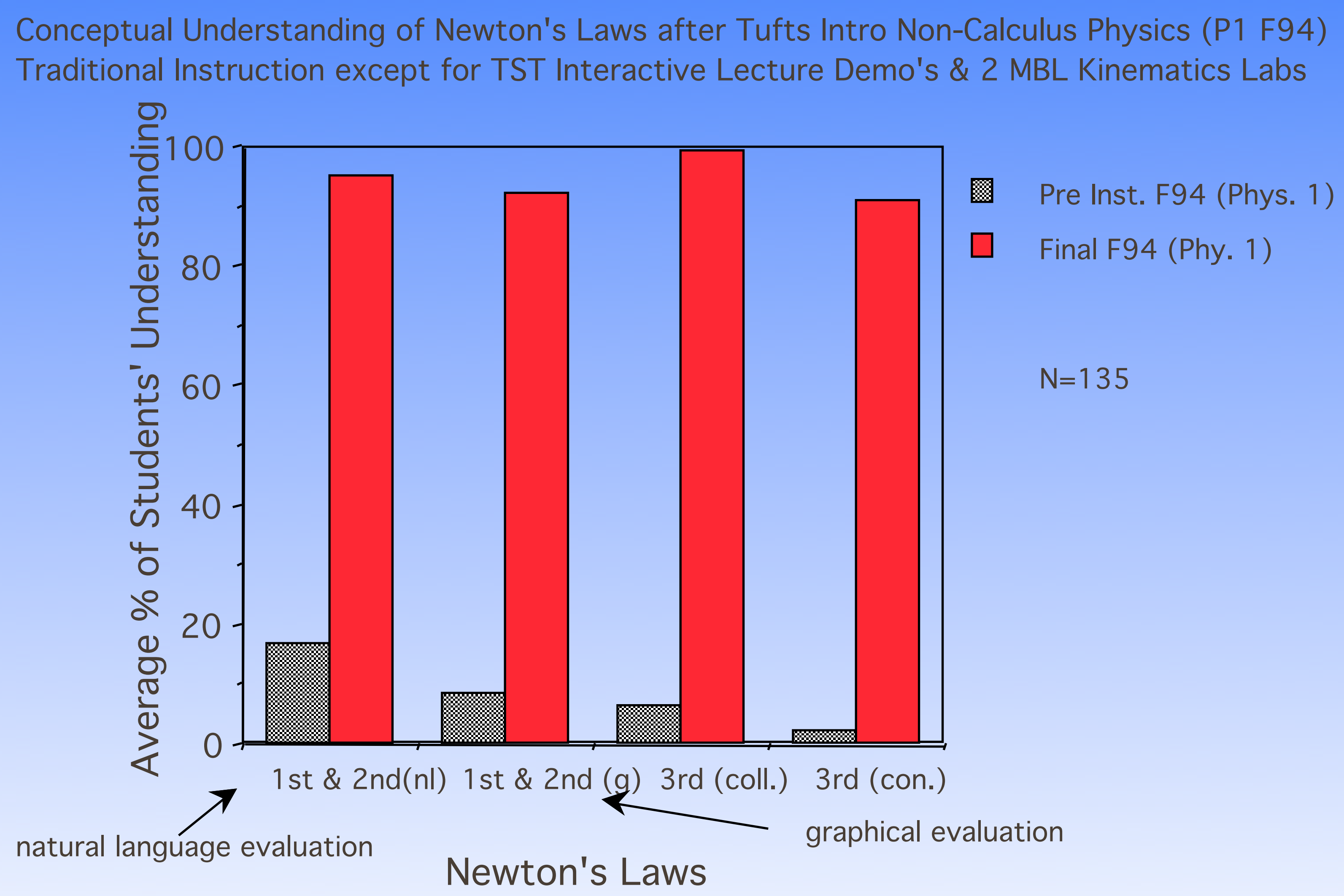
University Algebra-based Physics
Traditional Instruction



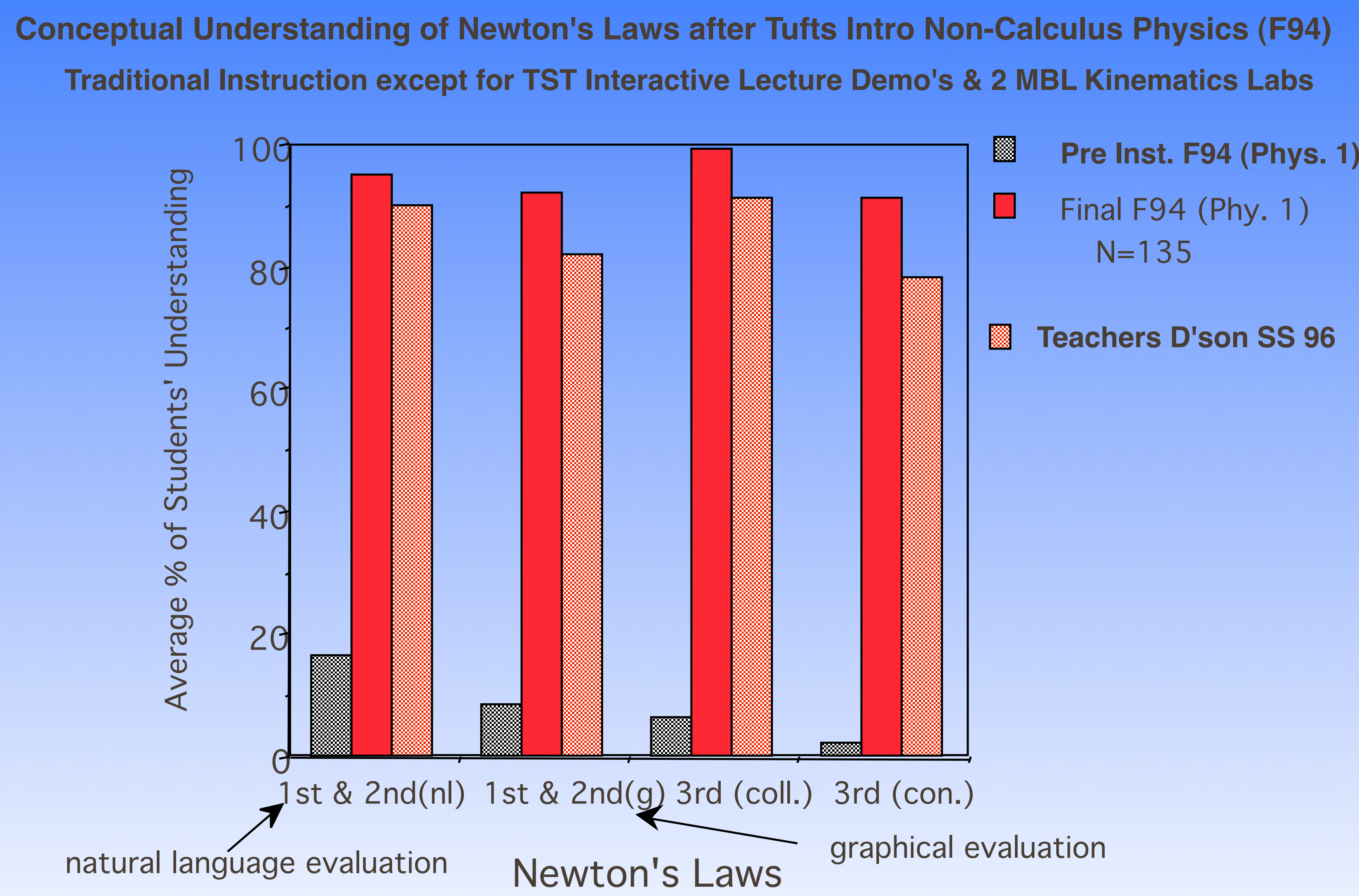
Oregon after ILD’s



Summary Results for Interactive Lecture Demo's at Tufts



Comparison of Teacher Results to Student Results



Our Instructional and Assessment Philosophy

"I still don't have all of the answers, but I'm beginning to ask the right questions."