Understanding Understanding

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- Interactions with many colleagues in PER
- Interactions with many, many students
  - to whom I owe the greatest debt.

Some history since 1969…

- High school physics and physical science, 9th grade physical science teacher
  - East Tech HS, Cleveland, OH
  - Middletown Jr-Sr HS, Middletown, MD
- University
  - U TX-Austin
  - Okla State Univ.
  - Boise State Univ.
- Research
  - Westinghouse HS, Pittsburgh, PA
  - Capitol HS, Boise, ID
  - Carnegie-Mellon University
  - Boise State University
  - Basin School, Idaho City, ID
  - Cynthia Mann Elementary, Boise, ID

Understanding?

- "If, when the circumstances of testing are slightly altered, the sought-after competence can no longer be documented, then understanding—in any reasonable sense of the term—has simply not been achieved."
  - P. 6, *The unschooled mind: how children think and how schools should teach* Howard Gardner, 1991, Basic Books

Let’s look at some video

- Excerpts from the Private Universe Project
  - Harvard-Smithsonian Astrophysical Observatory

From published literature…

Kinematics-velocity

“Our research also has provided evidence that for some students certain preconceptions may be remarkably persistent. … The belief that a position criterion may be used to compare relative velocities seemed to remain intact in some students even after several weeks of instruction.” (Trowbridge & McDermott, 1980, AJP)

Kinematics-acceleration

“The conceptual difficulties with acceleration that were encountered by the students in our study appeared to be very persistent. … Even with assistance in making the necessary observations, these students were unable to combine this information in a manner that permitted successful comparison of two accelerations.” (Trowbridge & McDermott, 1981, AJP)

From published literature…

Electric circuits

“We found that many students were unable to interpret the circuit correctly. … Even more disturbing is the fact that the misconception persisted in some students who had been through a calculus-based course in electricity which included five experiments on electric circuits.” (Fredette & Clement, 1981, JCST)

Real image formation

“The discussion above demonstrates that, although they might have been able to give correct verbal responses to these questions, the students who participated in our study were frequently unable to relate their knowledge to simple, but real, optical systems.” (Goldberg & McDermott, 1987, AJP)

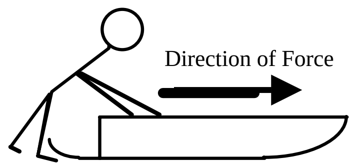
A closer look…

- Force and Motion Conceptual Evaluation
  - FMCE

- Thornton, R. & Sokoloff, D. (1998) “Assessing student learning of Newton’s laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula,” *American Journal of Physics* **66**(4): 338 – 352.

- The following is from the FMCE…

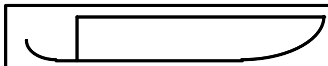
Typical calc-level intro physics performance



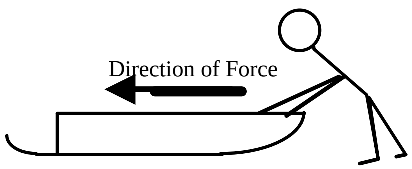
A. The force is toward the **right** and is **increasing** in strength (magnitude).

B. The force is toward the **right** and is of **constant** strength (magnitude).

C. The force is toward the **right** and is **decreasing** in strength (magnitude).



D. No applied force is needed



E. The force is toward the **left** and is **decreasing** in strength (magnitude).

F. The force is toward the **left** and is of **constant** strength (magnitude).

G. The force is toward the **left** and is **increasing** in strength (magnitude).

"Pre"-instruction

	1	2	3	4	5	7
A	63	5	4	5	5	12
B	9	55	0	3	37	18
C	1	1	37	1	0	7
D	0	11	4	0	27	4
E	1	2	7	2	0	31
F	1	2	19	13	5	2
G	1	0	5	52	2	2

Post-instruction

	1	2	3	4	5	7
A	59	4	4	4	6	10
B	16	50	0	0	25	27
C	1	1	33	0	0	3
D	0	21	2	0	43	1
E	0	0	3	2	0	33
F	0	0	24	18	2	2
G	0	0	10	51	0	0

Why "pre"?

*(*sled on ice, friction to be ignored*)*

1. Which force would keep the sled moving toward the right and speeding up at a steady rate (constant acceleration)?
2. Which force would keep the sled moving toward the right at a steady (constant) velocity?
3. The sled is moving toward the right. Which force would slow it down at a steady rate (constant acceleration)?
4. Which force would keep the sled moving toward the left and speeding up at a steady rate (constant acceleration)?
5. The sled was started from rest and pushed until it reached a steady (constant) velocity toward the right. Which force would keep the sled moving at this velocity?
7. The sled is moving toward the left. Which force would slow it down at a steady rate (constant acceleration)?

Two Views

- Person-on-the-street: *pots*
  - The velocity goes as the force
- Newtonian: *New*
  - The acceleration goes as the net force
- Two scoring keys: *pots* & *New*

Content-driven

Table 1: Pre–Post Data, Measures of change in normal instruction, science and engineering majors

Algebra-Trig Level Intro Physics

Whole class scores			Average Scores				Effect Size		Normalized	
			Pre (0 - 15)		Post (0 -15)		(st dev)		Loss	Gain
Year	Term	N	pots*	New**	pots*	New**	pots*	New**	<L>	<g>
West Coast Public Univ. A										
1990		99	10.1	1.5	8.5	3.3	-0.47	0.59	-0.16	0.13
"Prairie State" Public Univ.										
2002	SP	112	10.3	0.9	9.0	2.7	-0.40	0.66	-0.13	0.13
Calculus Level Intro Physics										
North East State Public Univ.										
1998		72	9.6	1.7	8.5	3.5	-0.30	0.47	-0.11	0.14
West Coast Public Univ. B										
1999	Wint.	87	9.3	2.6	6.5	5.4	-0.62	0.60	-0.30	0.23
1999	SP	73	9.1	2.3	7.6	4.0	-0.36	0.38	-0.17	0.13
2000	SP	115	9.2	2.4	7.2	4.8	-0.50	0.59	-0.22	0.19
West Coast Private Univ.										
2000	SP	38	9.8	0.6	9.6	1.9	-0.08	0.54	-0.03	0.09

Student understanding-driven

Table 2: Pre–Post Data, Measures of change in alternative instruction, non-science, non-engineering majors

Conceptual Physics, College Level

Whole class scores			Scatter Plot Averages				Effect Size		Normalized	
			Pre (0 - 15)		Post (0 -15)		(st dev)		Loss	Gain
Year	Term	N	pots	New	pots	New	pots	New	<L>	<g>
Intermountain State University										
2000	FL	90	9.3	0.8	2.5	9.2	-2.20	2.50	-0.66	0.59
2001	SP	87	9.8	0.8	2.2	9.6	-2.40	2.40	-0.74	0.62
2002	FL	66	9.4	0.8	2.2	8.8	-2.19	2.26	-0.72	0.57
2004	SP	69	7.9	2.2	1.8	10.8	-1.85	2.31	-0.78	0.67
2005	SP	53	9.9	0.8	1.5	11.1	-3.08	3.38	-0.85	0.73
High School Level										
North Central State High School										
2001	FLa	23	11.3	0.6	0.6	13.3	-5.40	6.30	-0.95	0.89
2001	FLb	24	10.6	0.9	0.8	13.1	-3.70	6.10	-0.93	0.86

The results of physics teaching

- The most common outcome of physics teaching is that students leave with the *same understanding* of the phenomena they had when they came.
  - Students come to class with person-on-the-street conceptions
- The understanding that changes is that most students come expecting to understand physics, but they leave believing they are not good at physics.

No change in understanding about the phenomena

- Irregardless of…
  - Year in school
  - Gender
  - Qualifications of instructor
  - When during the last century

No change in understanding

- Still need more evidence?
- *Students' and Teachers' Conceptions in Science* -- a bibliography with 6,995 entries
  - All sciences, all ages, many countries, back to 1903 (most since late 70's)
  - url: http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html

Queries

- Shouldn’t the result of physics teaching be that students leave having advanced their understanding of the phenomena studied?
- Doesn’t the evidence from student understanding-driven physics instruction indicate that it is not a matter of some can, but most cannot?

- “…a physics major has to be trained to used today’s physics whereas a physics teacher has to be trained to see development of physical theories in…students minds…”
  - Hans Niedderer in "International Conference on Physics Teachers' Education Proceedings” Dortmund: University of Dortmund, p. 151, 1992.

Query

- If we are not producing physics teachers who have developed physical theory in their own minds, then how will they be able to detect this development in the minds of their students?
- What are we doing to the rest of the students in our classes in the meantime?