Are We There Yet?

The Assessment Conundrum

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25 year continuing project to improve undergraduate education with contributions by:
Many faculty and graduate students of U of M Physics Department
In collaboration with U of M Physics Education Research (PER) Group

Current PER group: Bijaya Aryal, Evan Frodermann, Ken Heller, Leon Hsu, Jia-Ling Lin, Eugene Park, Jie Yang

Details at http://groups.physics.umn.edu/physed/

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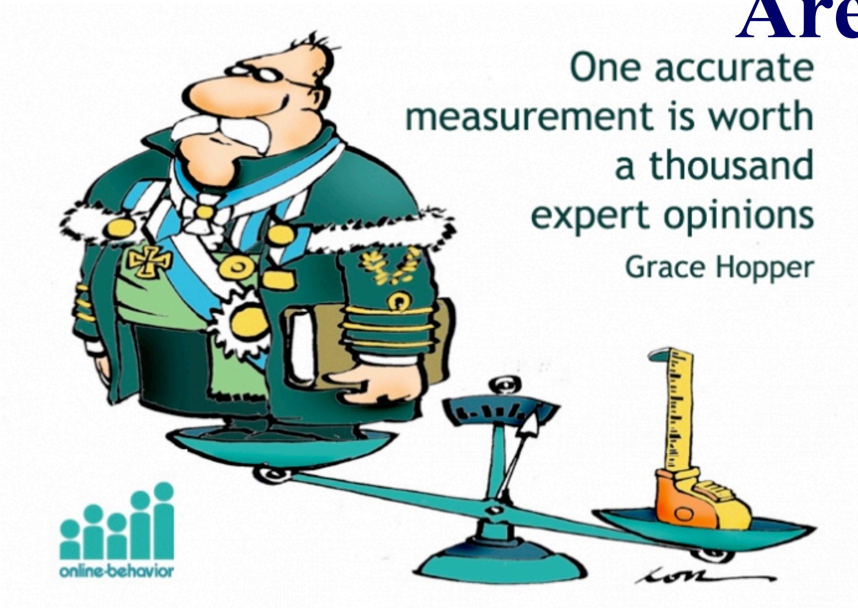
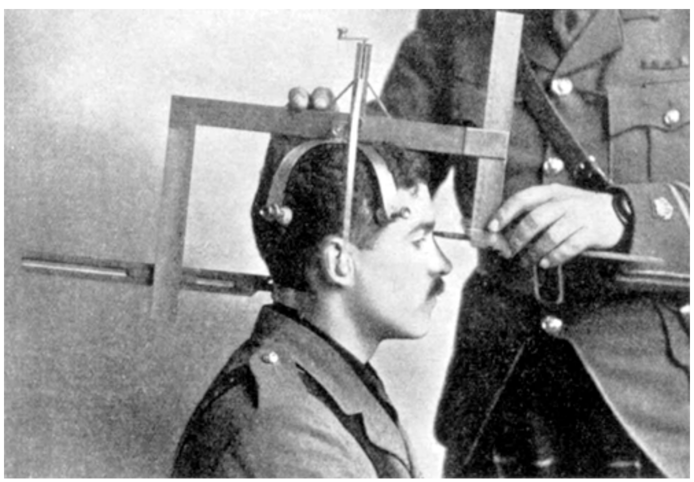
Are We There Yet?



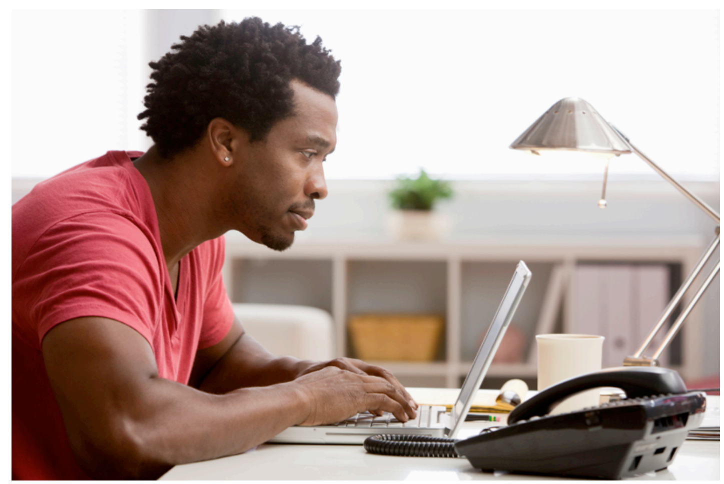
Assessment is the answer

Grace Hopper – invented the first computer compiler, coined the term "debugging".
BA math & physics (1928),
PhD math (1934),
Admiral US Navy (1985)

Quantities easy to measure are usually not important.
Important quantities are usually not easy to measure.

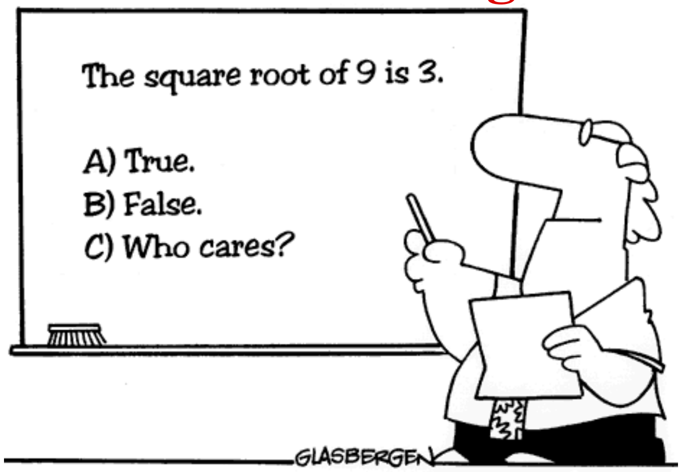


Learning is a good example



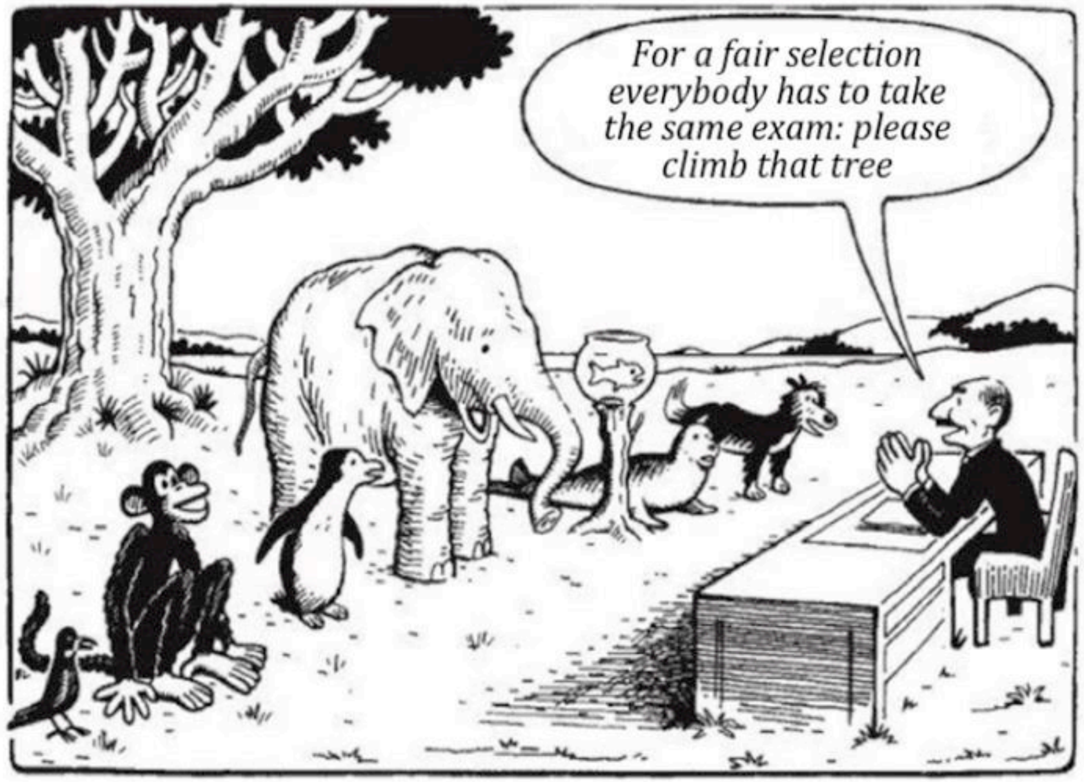
Assessment traps

machine scoring



Many students actually look forward to Mr. Atwadder's math tests.

fairness



measuring can influence the measurement

Meaningful assessment combines many different measurements.

Where are we going?

Where are we starting from?

Are we on the right path?

Are we getting closer?

How do we know when we have arrived?

Goal setting

Initial conditions

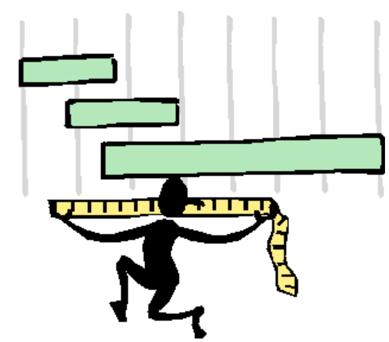
Formative assessment

Summative assessment

Diving into Assessment

1. Fix this course.
2. What needs doing?
3. How do we know? (Assessment)

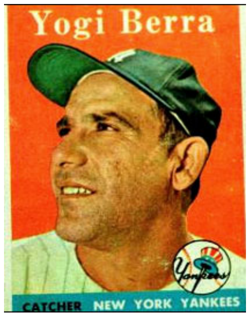
- What should be the goal?
- What should be the content?
- Who are the students?
- What will instructors do?



4. How do we stay fixed? (Quality Assurance)
5. Some Data

Initial Assessment

"You can observe a lot by watching"

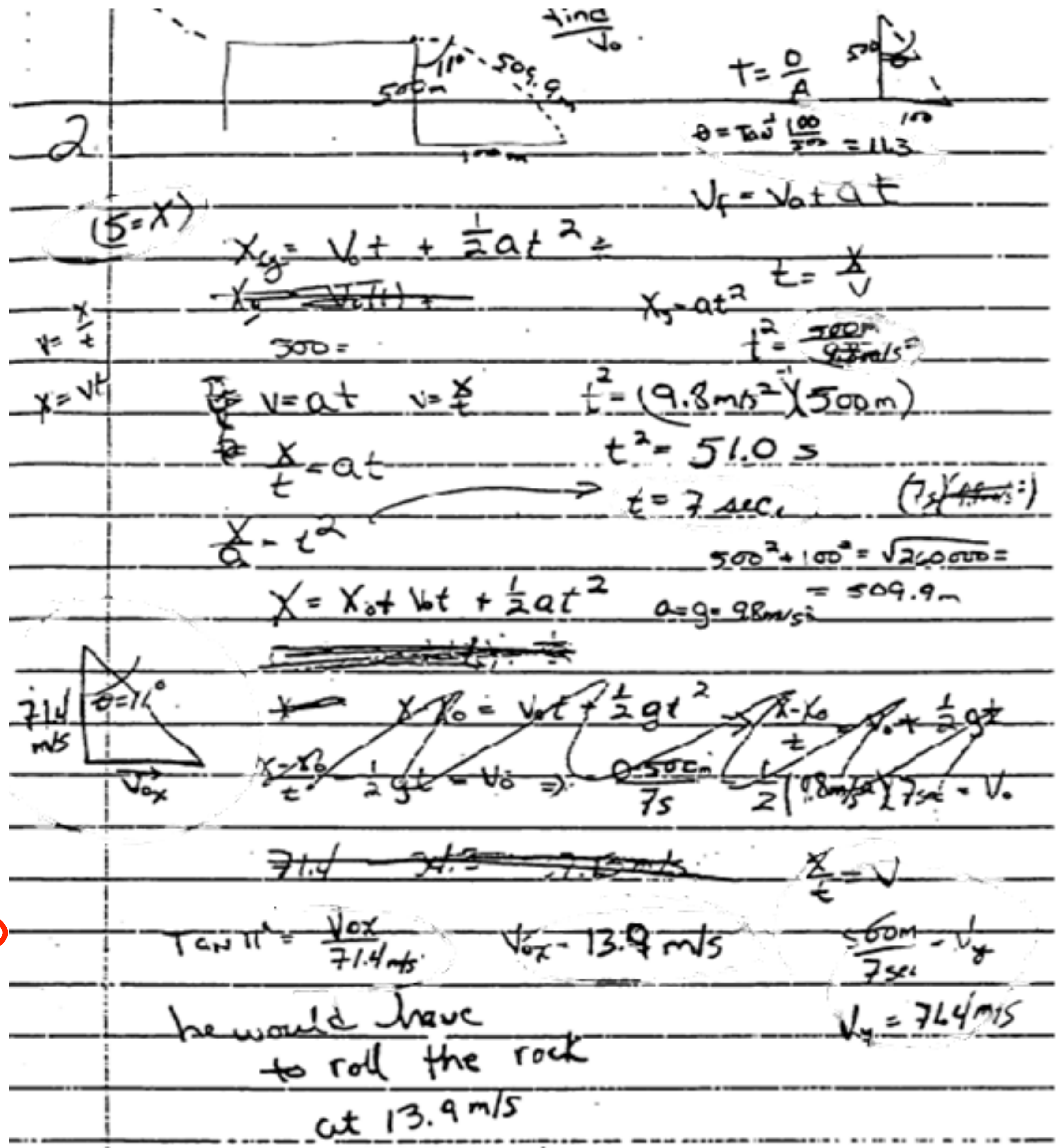


**We are not happy.
Neither are our students.**

Solution

- Get better students
- Get better teachers
- Do things differently

What Students Show Us After Instruction



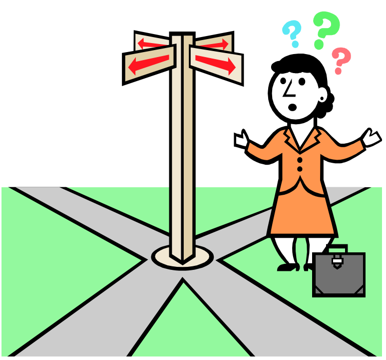
To Do Assessment You Need a Goal

puck

University of Minnesota Women's Hockey Team National Champions 2012, 2013, 2015

There are several possible goals of any course.

You cannot accomplish them all



- Process ↔ Content
- Qualitative ↔ Quantitative
- Concepts ↔ Problem Solving
- Breath ↔ Depth
- Applied ↔ Abstract
- Topic 1 ↔ Topic 2

Decisions are necessary

Define the Goals

Who are we trying to satisfy?

What do they want?

- The country.
- Faculty who require their students to take the class.
- The discipline.
- Our department.
- Students who take the class.

Design a questionnaire for faculty in other departments

Overall Goals

Free response

List (17 possible) with rating scale (1 to 5)

Content

Forced selection of chapters from a standard text.

Type of Labs

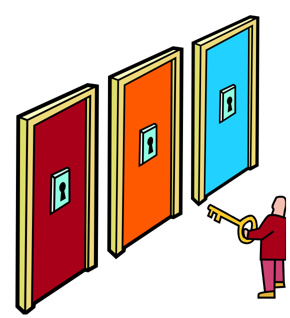
Free response

List with rating scale

Type of Discussion Section

Free response

List with rating scale



Questionnaire for Faculty Requiring Algebra-based Physics

Many different goals could be addressed through this course. Would you please rate each of the following possibl goals in relation to its importance for your students on a scale of 1 to 5?

1=unimportant	2=slightly important	3=somewhat important	4=important	5=very important

Know the basic principles behind all physics (e.g. forces, conservation of energy, ...)	1	2	3	4	5
Know the range of applicability of the principles of physics (e.g. conservation of energy applied to fluid flow, heat transfer, plasmas, ...)	1	2	3	4	5
Be familiar with a wide range of physics topics (e.g. specific heat, AC circuits, rotational motion, geometrical optics,...)	1	2	3	4	5
Solve problems using general quantitative problem solving skills within the context of physics	1	2	3	4	5
Solve problems using general qualitative logical reasoning within the context of physics	1	2	3	4	5
Solve many problems to gain familiarity with solving physics problems	1	2	3	4	5
Formulate and carry out experiments	1	2	3	4	5
Analyze data from physical measurements	1	2	3	4	5
Use modern measurement tools for physical measurements (e.g.. oscilloscopes, computer data acquisition, timing techniques,...)	1	2	3	4	5
Program computers to solve problems within the context of physics.	1	2	3	4	5
Overcome misconceptions about the behavior of the physical world	1	2	3	4	5

Questionnaire for Faculty Requiring Algebra-based Physics (continued)

Understand and appreciate 'modern physics' (e.g. solid state, quantum optics, cosmology, quantum mechanics, nuclei, particles,...)	1	2	3	4	5
Understand and appreciate the historical development and intellectual organization of physics.	1	2	3	4	5
Express, verbally and in writing, logical, qualitative thought in the context of physics.	1	2	3	4	5
Learn to work in teams to solve problems within the context of physics.	1	2	3	4	5
Use with confidence the physics topics covered.	1	2	3	4	5
Apply the physics topics covered to new situations not explicitly taught by the course.	1	2	3	4	5
Other goal. Please specify here	1	2	3	4	5

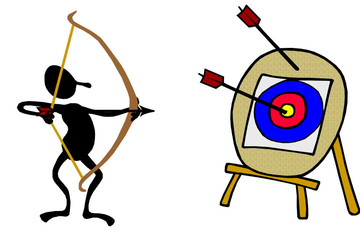
Forced choice

★ **Please place a star (*) next to the TWO goals listed above that you consider to be the MOST IMPORTANT for your students.**

Free response

If this course is required, what is the primary reason (in your opinion) your department requires students to take this physics course?

Faculty Goals



Many different goals could be addressed through this course. Would you please rate each of the following possible goals in relation to its importance for your students on a scale of 1 to 5?

Algebra-based Course (24 different majors) 1987

- **4.7** Basic principles behind all physics
- **4.2** General qualitative problem solving skills
- **4.2** Overcome misconceptions about physical world
- **4.0** General quantitative problem solving skills
- **4.0** Apply physics topics covered to new situations

Problem Solving is Important

1. Know the basic principles behind all physics (e.g. forces, conservation of energy, ...)
2. Know the range of applicability of the principles of physics (e.g. conservation of energy applied to fluid flow, heat transfer, plasmas, ...)
3. Be familiar with a wide range of physics topics (e.g. specific heat, AC circuits, rotational motion, geometrical optics,...)

coverage

4. Solve problems using general quantitative problem solving skills within the context of physics
5. Solve problems using general qualitative logical reasoning within the context of physics
6. Formulate and carry out experiments
7. Analyze data from physical measurements

lab skills

8. Use modern measurement tools for physical measurements (e.g.. oscilloscopes, computer data acquisition, timing techniques,...)
9. Program computers to solve problems within the context of physics.

technology

10. Overcome misconceptions about the behavior of the physical world
11. Understand and appreciate 'modern physics' (e.g. solid state, quantum optics, cosmology, quantum mechanics, nuclei, particles,...)
12. Understand and appreciate the historical development and intellectual organization of physics.

intellectual growth

13. Express, verbally and in writing, logical, qualitative thought in the context of physics.

communication

14. Use with confidence the physics topics covered.

positive attitude

15. Apply the physics topics covered to new situations not explicitly taught by the course.
16. Other goal. Please specify here

What Do Other Faculty Want? (5 pt scale)

Goals: Calculus-based Course (88% engineering majors) 1993

- 4.5 Basic principles behind all physics
- 4.5 General qualitative problem solving skills
- 4.4 General quantitative problem solving skills
- 4.2 Apply physics topics covered to new situations
- 4.2 Use with confidence

Goals: Algebra-based Course (24 different majors) 1987

- 4.7 Basic principles behind all physics
- 4.2 General qualitative problem solving skills
- 4.2 Overcome misconceptions about physical world
- 4.0 General quantitative problem solving skills
- 4.0 Apply physics topics covered to new situations

Goals: Biology Majors Course 2003

- 4.9 Basic principles behind all physics
- 4.4 General qualitative problem solving skills
- 4.3 Use biological examples of physical principles
- 4.2 Overcome misconceptions about physical world
- 4.1 General quantitative problem solving skills
- 4.0 Apply physics topics covered to real world situations
- 4.0 Know range of applicability of physics principles

Topics - Physics for Biology Majors

%T	✓	%*	Topic
90	✓	15	Potential energy and conservation of energy
85	✓	15	Kinetic energy and work
85	✓	20	Entropy and the second law of thermodynamics
85	✓	15	Electric charge and force
85	✓	13	Electric potential
80	✓	0	Linear motion
80	✓	0	Forces and Newton's Laws
75	✓	15	Units, dimensions and vectors
75	✓	5	Temperature and ideal gas
75	✓	0	Electric field
75		5	Molecules and gases (e.g. probability distributions of velocity)
75	✓	9	Mirrors and lenses
70		0	Momentum and collisions
70	✓	9	Nuclear physics and radioactive decay
65	✓	0	Two dimensional motion
65		0	Gravitation
65		4	Currents in materials (e.g. resistance, insulator, semiconductors)
65	✓	15	Heat flow and the first law of thermodynamics
65	✓	0	Magnetic forces and fields
60	✓	4	Geometrical optics (e.g. reflection and refraction)
60	✓	0	Diffraction
55	✓	0	Oscillatory motion
55	✓	4	Currents and DC circuits

Making Hard Choices

No more than 1 week/chapter

* 4 most important

19/23 Chapters

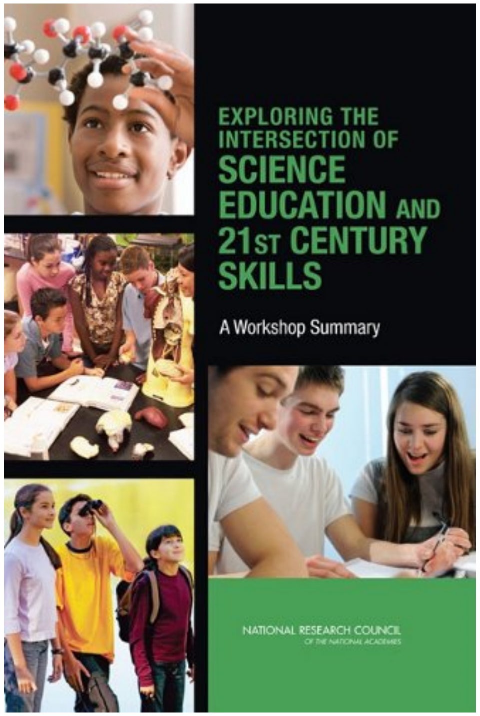
Topics - Physics for Biology Majors

%T		%*	
50	✓	0	~~Rotations and~~ torque
45	✓	5	Applications of Newton's laws
45		0	Angular momentum
45		0	Gauss' law
45	✓	4	Currents and magnetic fields (e.g. Ampere's law, ~~Biot-Savart law)~~
45	✓	0	Interference
40	✓	5	Fluid mechanics
40		5	Properties of solids (e.g. stress, strain, thermal expansion)
40	✓	0	Capacitors ~~and dielectrics~~
40		4	Maxwell's equations and electromagnetic waves
40		0	Relativity
35	✓	4	Faraday's law
35	✓	0	Superposition and interference of waves
30		0	Mechanical waves
30	✓	0	Statics
30		0	Magnetism and matter (e.g. ferromagnetism, diamagnetism)
30		9	AC circuits
30		0	Atomic physics
20		0	Quantum physics
15		0	Magnetic Inductance
15		0	Particle physics
0		0	Other. Please specify.

9/21 Chapters

2 semesters (28 wks) = 28 Chapters

Other Stakeholders -The Country Needs An Educated Workforce



NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES (2010)

21st Century Skills

- Adaptability:
- Complex communication/social skills:
- Self-management/self-development:
- Systems thinking:
- Non-routine problem solving:
- Diagnose the problem.
- Link information.
- Reflect on solution strategy.
- Switch strategy if necessary.
- Generate new solutions.
- Integrate seemingly unrelated information.

University of Minnesota Strategic Planning - 2007

At the time of receiving a bachelor's degree, students will demonstrate the following qualities:

1. the ability to identify, define, and solve problems
2. the ability to locate and evaluate information
3. mastery of a body of knowledge and mode of inquiry
4. an understanding of diverse philosophies and cultures in a global society
5. the ability to communicate effectively
6. an understanding of the role of creativity, innovation, discovery, and expression in the arts and humanities and in the natural and social sciences
7. skills for effective citizenship and life-long learning.

The syllabus for every course must say which of these 7 it addresses

Intro Physics Contributes to 1, 2, 3, 5, 7

UNIVERSITY OF ALBERTA

Graduate Attributes (2014)

1 Ethical responsibility

2 Scholarship

3 Critical thinking

4 Communication

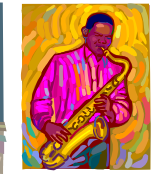
5 Collaboration

6 Creativity

7 Confidence

Problem-solving Framework
Used by experts in all fields





G. Polya, 1945

Chi, M., Glaser, R., & Rees, E. (1982)

STEP 1 Recognize the Problem

What's going on and what do I want?

Not a linear sequence.
Requires continuous
reflection and iteration.

STEP 2 Describe the problem in terms of the field

What does this have to do with ...... ?

Observations to determine
student difficulties.

STEP 3 Plan a solution

How do I get what I want?

Modified Polya's 4 steps.

STEP 4 Execute the plan

Let's get the answer.

Designed problems to:

1. Obviously require a framework
2. Impede student naïve practice.

STEP 5 Evaluate the solution

Can this be true?

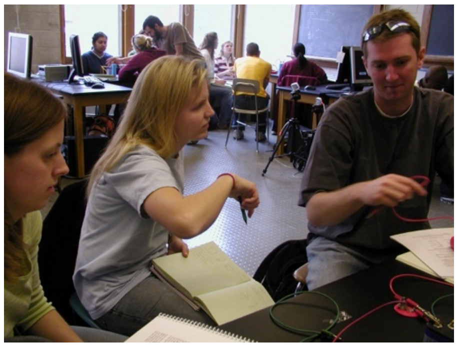
Instituted Cooperative Groups
for peer coaching

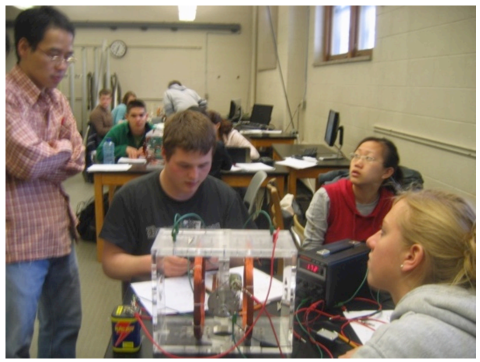
Johnson & Johnson, 1978

Cooperative Groups Benefits Other Than:

Provide peer coaching and facilitates expert coaching

Allow success solving complex problems by practicing an expert-like problem solving framework from the beginning of the course.





Allows better formative assessment of student thought process

Observation, Audio & video recording

Email 8/24/05

"Another good reason for cooperative group methods: this is how we solve all kinds of problems in the real world - the real academic world and the real business world. I wish they'd had this when I was in school. Keep up the great work."

Vice President,
Handhelds Hewlett Packard

Assessments That Subvert Course Goals

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

Answer the following questions.

1. **What is traxoline?**
2. **Where is traxoline montilled?**
3. **How is traxoline quasselled?**
4. **Why is it important to know about traxoline?**

(attributed to Judy Lanier)

A Problem that Requires Problem-solving

You have a summer job with the CSI unit helping to investigate a tragic incident. At the scene, you see a road running straight down hill at 10° to the horizontal. At the bottom of the hill, the road widens into a small, level parking lot overlooking a cliff. The cliff has a vertical drop of 400 feet to the ground below where a car is wrecked 30 feet from the base of the cliff. When you drop a stone from the edge of the cliff it takes 5.0 seconds to hit the bottom. For the investigation, you need to calculate the car's average acceleration coming down the hill. A witness claims the car was parked on the hill and began coasting down the road, taking about 3 seconds to get down the hill.

Decisions must be made

Built from

A block starts from rest and accelerates for 3.0 seconds. It then goes 30 ft. in 5.0 seconds at a constant velocity.

a. What was the final velocity of the block?
b. What was the acceleration of the block?

A Course is a System

All resources need to be directed coherently to achieve the few goals of the course

Coherence allows minimizing effort while increasing student performance

All the resources work together

Assessment shows content and pedagogy are not enough

Incorporate Teaching Assistants more closely

- **Education about pedagogy**
- **Communication with faculty**
- **Restructure duties.**

Incorporate laboratory with same goals & pedagogy as the course.

Testing & grading to reinforce course goals

- **Absolute grading system**
- **Both individual & group tests**
- **Fully explained problem solutions**

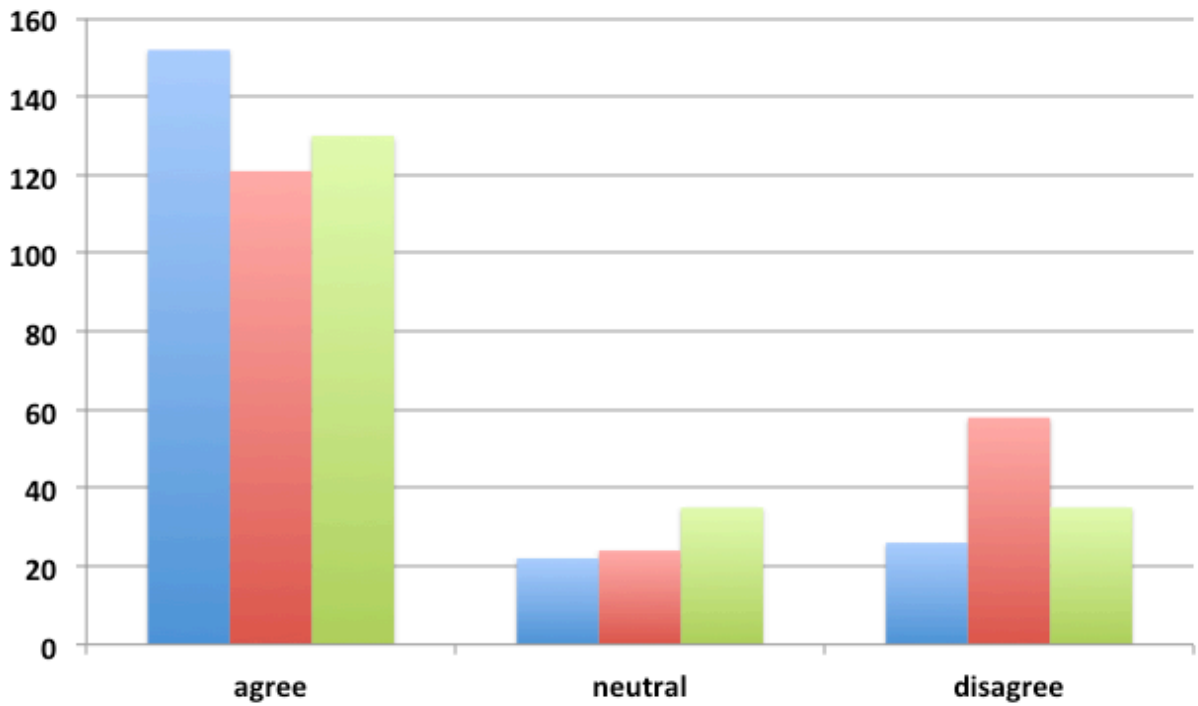
Course Structure @ Minnesota

LECTURES	**Three hours each week, sometimes with informal cooperative groups, peer coaching. Model constructing knowledge, model using the problem solving framework.**
DISCUSSION SECTION	**One hour each Thursday -- groups practice using problem-solving framework to solve context-rich problems. Peer coaching, TA coaching.**
LABORATORY	**Two hours each week -- *same* groups practice using framework to solve concrete experimental problems. *Same* TA. Peer coaching, TA coaching.**
TESTS	**Friday -- problem-solving quiz & conceptual questions (usually multiple choice) every three weeks. Fading**

Scaffolding – computer reading tests, clickers, JITT, limit formula usage, sample quizzes, problem solving manual, context rich problems

Student Opinion

	SA	A	N	D	SD
1991 class (n = 99) 1992 class (n = 135)					
1. The recitations sessions were well coordinated with the lecture.	7 *8*	75 *62*	11 *11*	5 *12*	2 *7*
2. The discussion with my group helped me to understand the course material.	13 *8*	53 *47*	13 *9*	17 *28*	4 *8*
3. My group worked well together to to complete problem solving activities.	14 *4*	59 *53*	18 *17*	7 *21*	2 *5*



Question 1
Question 2
Question 3

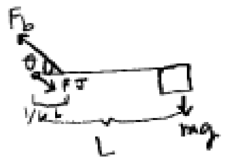
Student Opinion Data: Algebra-based Physics 1998

Rate the usefulness of the following components of the course.
Use a scale from 1 to 10 with 10 being extremely useful and 1 being completely useless in helping you learn physics in this course.

	Ave. All Sections (N = 393)	Rank
108. Textbook	6.6 ± 0.13	1
106. Discussion Sessions (CGPS)	6.5 ± 0.13	1
101. Homework (not graded)	6.4 ± 0.14	1
105. Quizzes and Exams	6.1 ± 0.12	4
103. Lectures	6.1 ± 0.13	4
102. Laboratory	5.5 ± 0.12	6
109. Material on Class Web Pages	5.3 ± 0.14	6
107. TA's in tutoring room	4.6 ± 0.14	8
110. University tutors in Lind Hall	4.2 ± 0.14	8
104. Lecturer Office Hours	3.9 ± 0.12	10

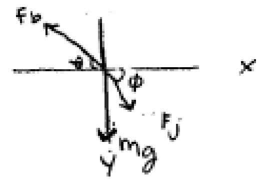
Problem Solving After Instruction

Solving a problem by making logically connected decisions.



Knowns
$\theta = 80°$
$V_m = 3.76\ L = 3760\ mL$

Force Diagram



Target: F_j = Force of joint

Approach: Use Forces
$\Sigma F_x = 0$
$\Sigma F_y = 0$
Use Torque
$\Sigma \tau = 0$

$\rho = \frac{m}{V}$

$\rho V_m = m$

assume density of milk is similar to water. = $1\ g/cm^3 = 1\ g/mL = .001\ kg/mL$

$\Sigma F_x = 0$
$F_{jx} - F_{bx} = 0$

$\Sigma F_y = 0$
$F_{by} - mg - F_{jy} = 0$

$\Sigma \tau = 0$ (joint is pivot point)
$F_{by}(1/6 L) - mgL = 0$

$F_b \cos\theta = F_{bx}$
$F_b \sin\theta = F_{by}$
$F_{jy} = F_j \sin\phi$
$F_{jx} = F_j \cos\phi$
$F_j^2 = F_{jx}^2 + F_{jy}^2$

equation		unknown
$F_j^2 = F_{jx}^2 + F_{jy}^2$	1	F_{jx}, F_{jy} [1, 2]
$F_{by} - mg - F_{jy} = 0$	2	F_{by} [3]
$F_{jx} - F_{bx} = 0$	3	F_{bx} [4]
$F_{by}(1/6 L) - mgL = 0$	4	
$F_{bx} = F_b \cos\theta$	5	F_b [5]
$F_{by} = F_b \sin\theta$	6	

$F_b = \frac{F_{by}}{\sin\theta}$

$\frac{F_{by}}{\sin\theta} \cos\theta = F_{bx}$

$6mg = F_{by}$

$F_{jx} = \frac{6mg}{\sin\theta} \cos\theta$

$F_{jy} = F_{by} - mg = 6mg - mg$

$F_j = \sqrt{\left(\frac{6mg}{\sin\theta}\cos\theta\right)^2 + (6mg - mg)^2}$

Plug in ρV for m

$F_j = \sqrt{\left(\frac{6 g\rho V_g}{\sin\theta}\cos\theta\right)^2 + (5\rho V g)^2}$

$= \sqrt{\left(\frac{6(.001)3760 g}{\sin 80}\cos 80\right)^2 + (5(.001)(3760 g))^2} =$

$\boxed{43.3\ N}$

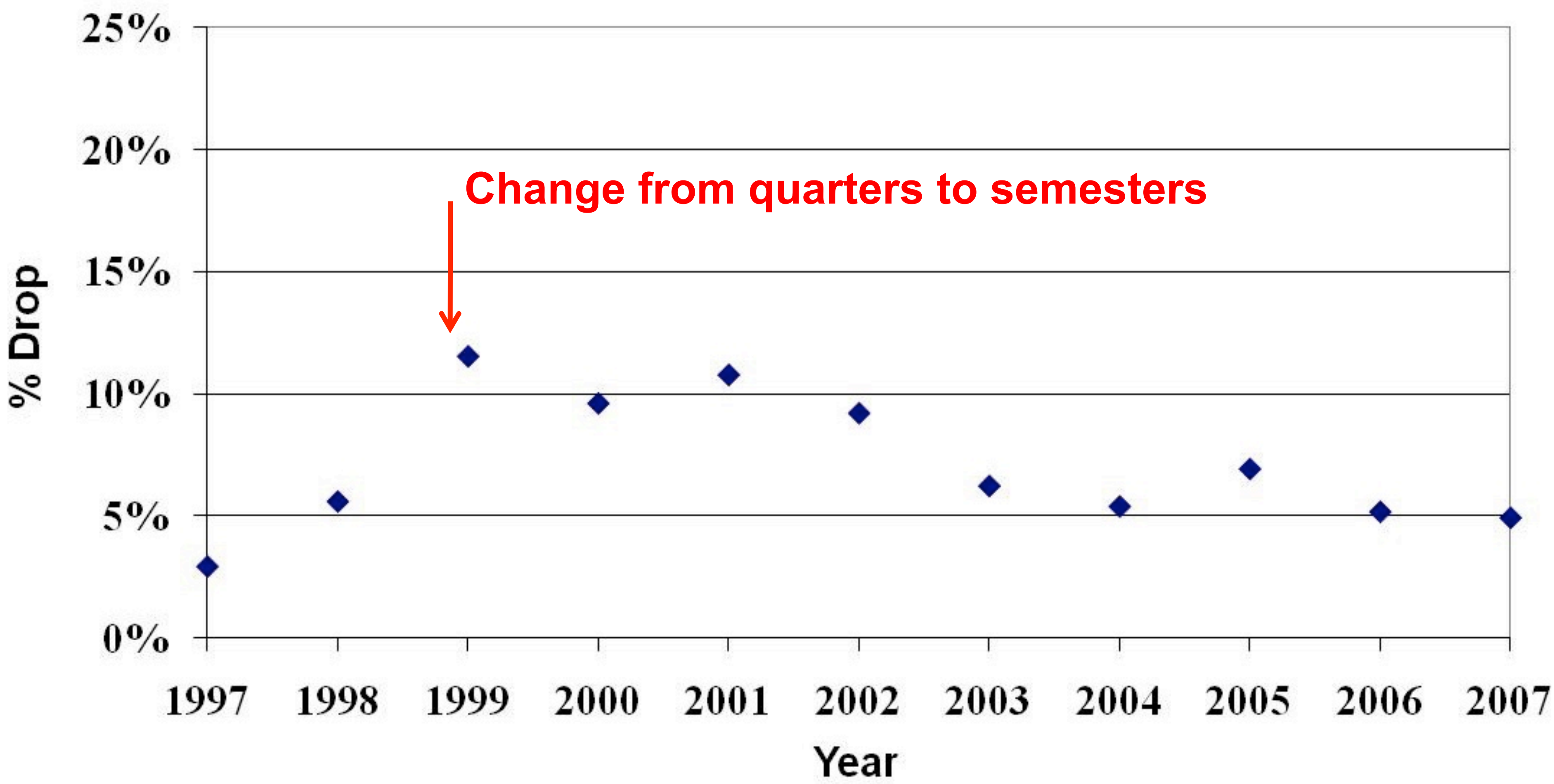
units $\left(\frac{kg}{mL} \cdot mL \frac{m}{s^2}\right)^2 + \left(\frac{kg}{mL} \cdot m \cdot \frac{m}{s^2}\right)^2 = \sqrt{\frac{kg^2 m^2}{s^4}} = kg\,m/s^2 = N$ ✓

43.3 N is the amount needed to lift an ≈ 4.3 kg object straight off the ground; this is reasonable

Intro Physics for Biology Majors and Pre-Meds (Final Exam, Fall 2005)

Retention after Implementation – Physics

Previous dropout + F/D rate was ~ 30%



Dropout rate ~ 6%, F/D rate ~ 3% in all classes

Develop a Rubric to Characterize & Quantify Expert-like Problem Solving

Almost Independent Dimensions

- **Useful Description**
  - organize information from the problem statement symbolically, visually, and/or in writing.
- **Physics Approach**
  - select appropriate physics concepts and principles
- **Specific Application of Physics**
  - apply physics approach to the specific conditions in problem
- **Mathematical Procedures**
  - follow appropriate & correct math rules/procedures
- **Logical Progression**
  - overall the solution progresses logically; it is coherent, focused toward a goal, and consistent (not necessarily linear)

J. Docktor (2009): tested for validity & reliability - based on previous work by:

J. Blue (1997); T. Foster (2000); T. Thaden-Koch (2005);

P. Heller, R. Keith, S. Anderson (1992)

Problem solving rubric at a glance

CATEGORY:
(based on literature)

SCORE ←

	5	4	3	2	1	0	NA (P)	NA (S)
Useful Description								
Physics Approach								
Specific Application								
Math Procedures								
Logical Progression								

Want

- **Minimum** number of categories with relevant aspects of problem solving
- **Minimum** number of scores with enough information to improve instruction

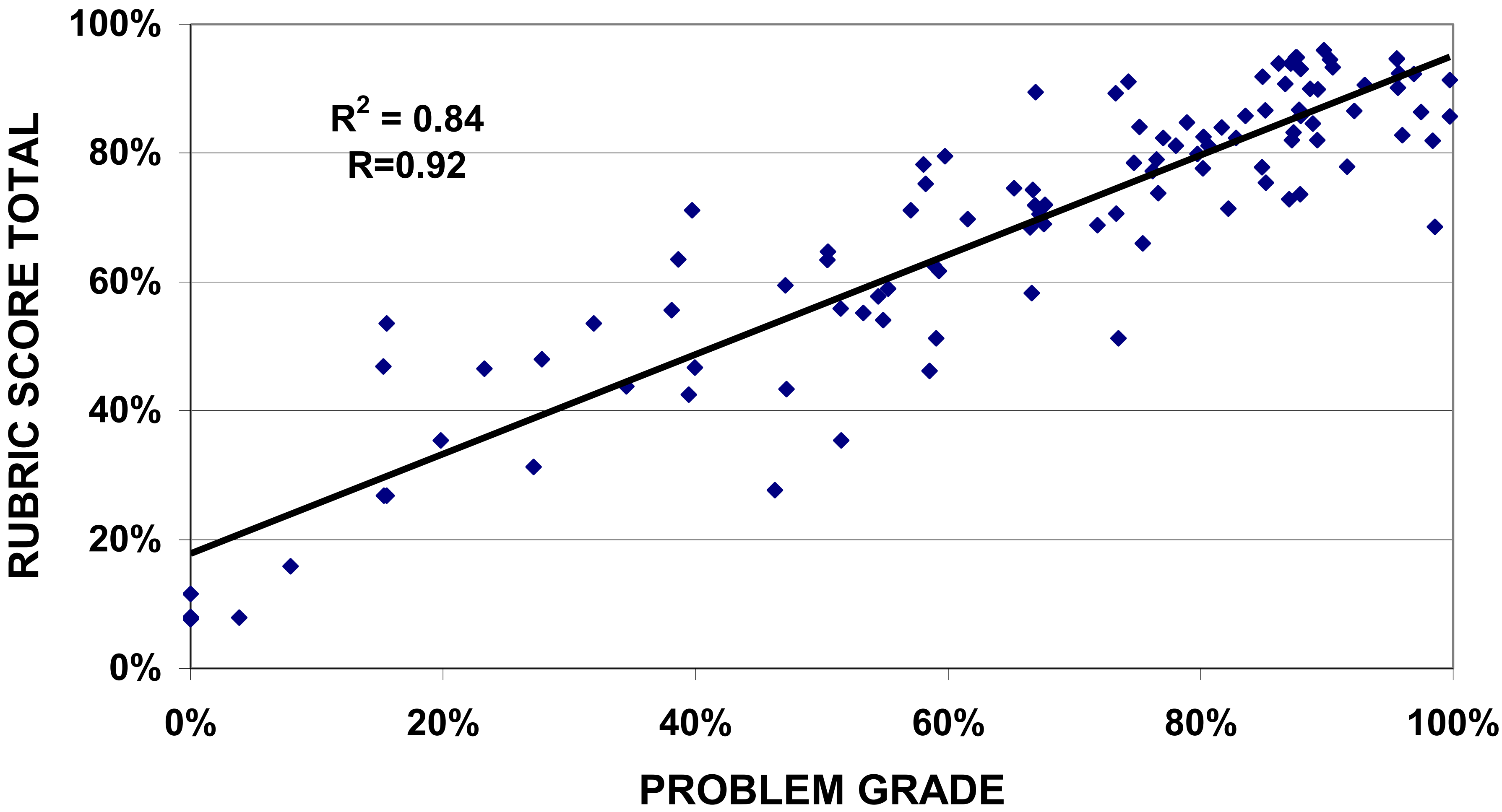
Rubric Scores (in general)

5	4	3	2	1	0
Complete & appro-priate	Minor omission or errors	Parts missing and/or contain errors	Most missing and/or contain errors	All inappro-priate	No evidence of category

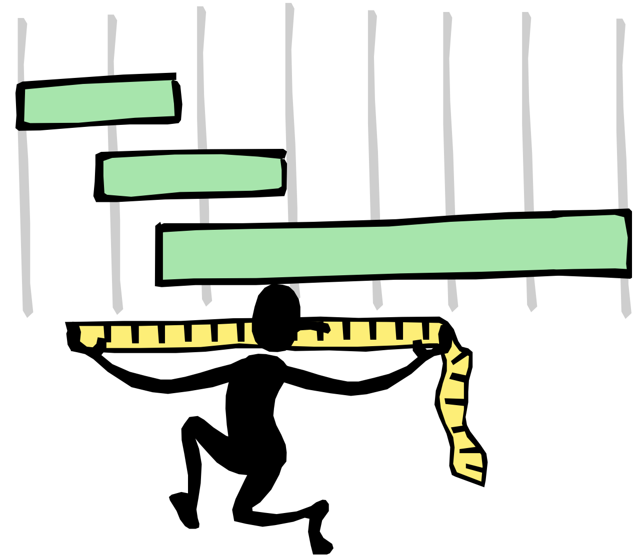
NOT APPLICABLE (NA):

NA - Problem	NA - Solver
Not necessary for this problem *(i.e. visualization or physics principles given)*	Not necessary for this solver *(i.e. able to solve without explicit statement)*

RUBRIC SCORE VS. PROBLEM GRADE
TEST 1 PROBLEM 2 (SECTION 2, N=110)

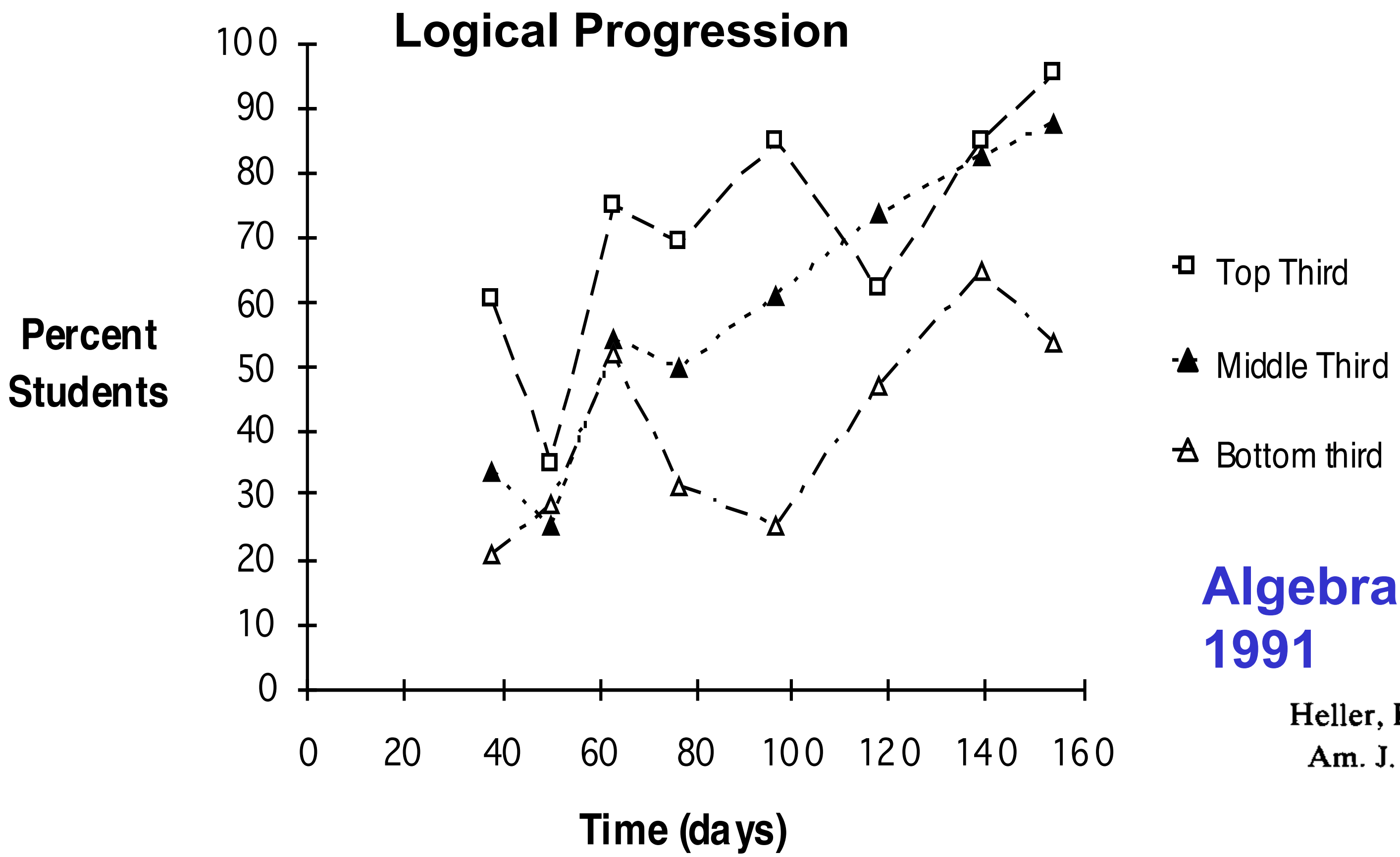


Assessment



- Problem Solving Skill
- Drop out rate
- Failure rate
- National concept tests (FCI, BEMA)
- National attitude survey (CLASS)
- Math skills test
- What students value in the course
- Engineering student longitudinal study
- Faculty use
- Adoption by other institutions and other disciplines

Improvement in Problem Solving



Algebra based physics 1991

Heller, Keith, and Anderson
Am. J. Phys., Vol. 60, No. 7, July 1992

General Approach - does the student understand the physics

Specific Application of the Physics - starting from the physics they used, how did the student apply this knowledge?

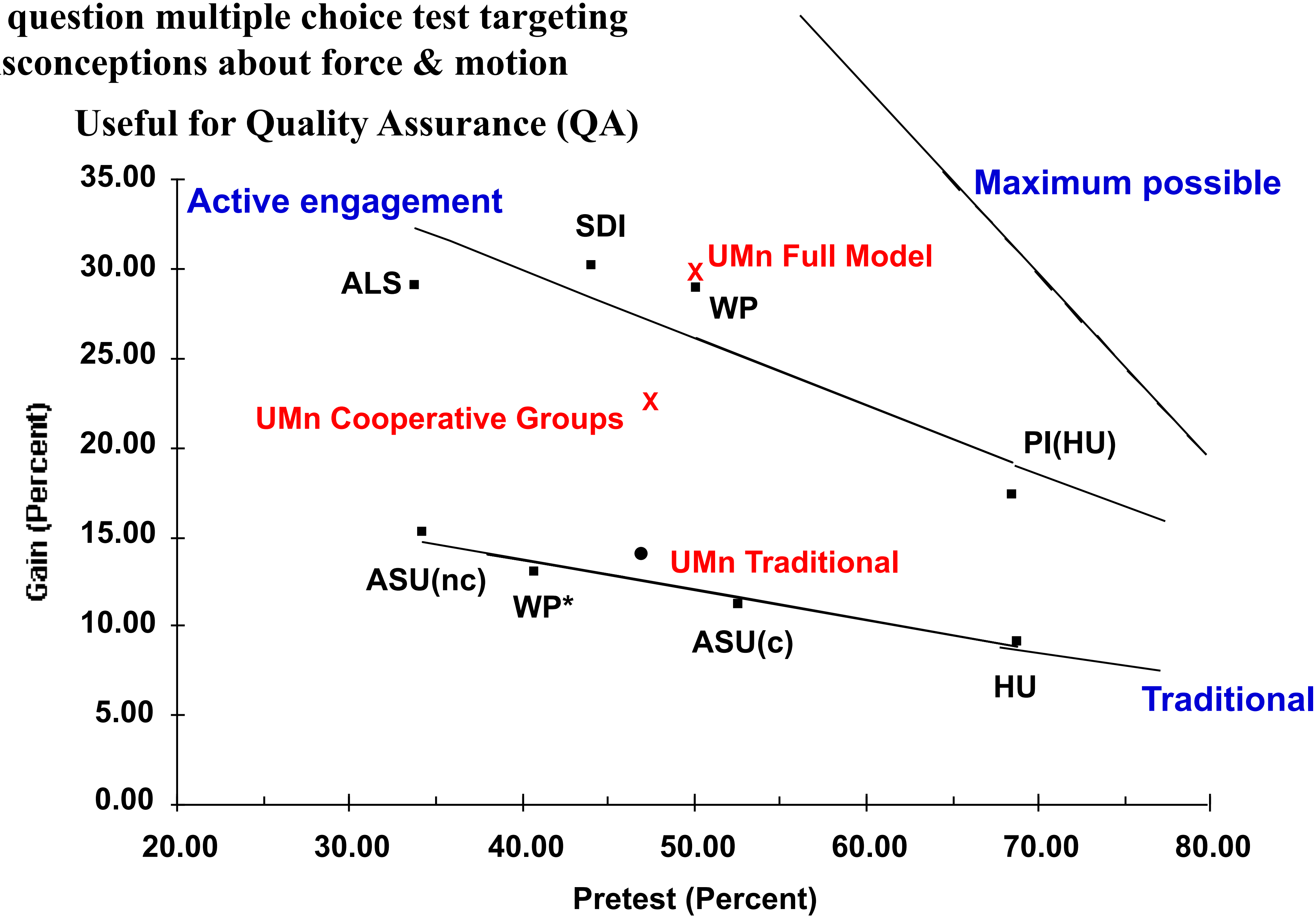
Logical Progression - is the solution logically presented?

Appropriate Mathematics - is the math correct and useful?

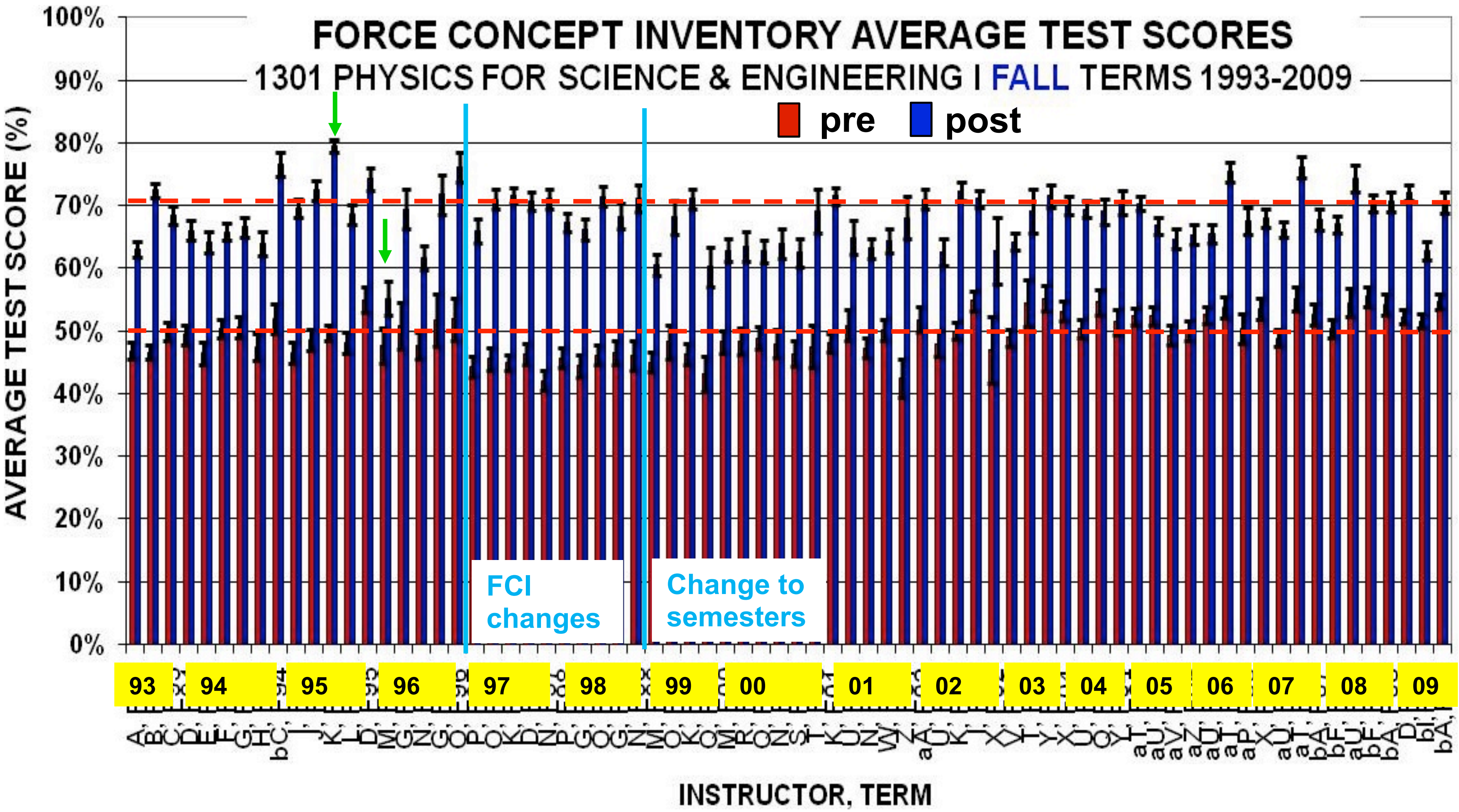
Gain on Force Concept Inventory (Hake plot)

30 question multiple choice test targeting misconceptions about force & motion

Useful for Quality Assurance (QA)



Hake, Am. J. Phys. 66 (1), January 1998



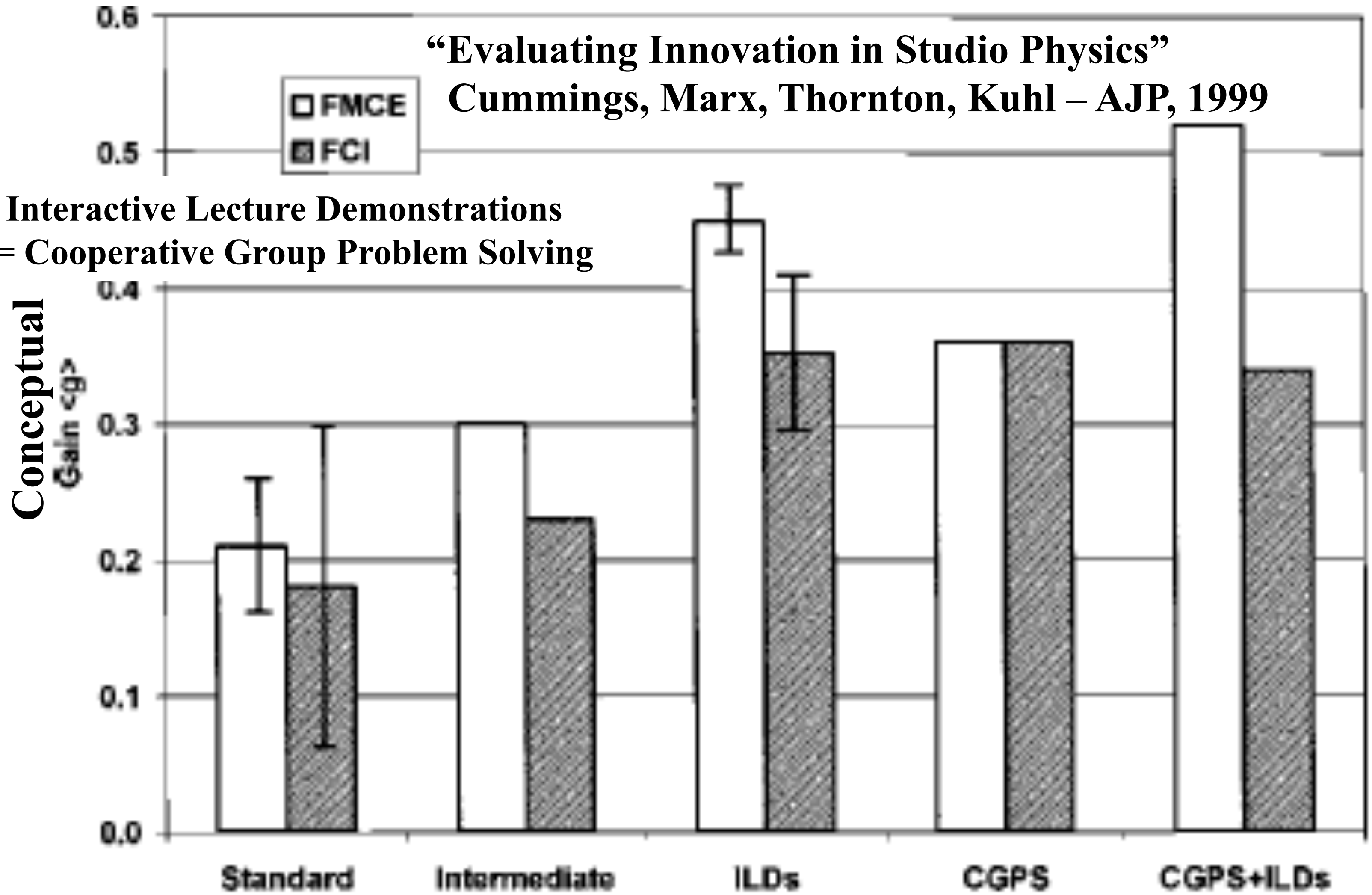
Each letter represents a different professor (41 different ones)

- **Incoming student scores are slowly rising (better high school preparation)**
- **Our standard course (CGPS) achieves average FCI ~70%**
- **Our "best practices" course achieves average FCI ~80%**
- **Not executing any cooperative group procedures achieves no gain (~50%)**

Assessment not connected to Minnesota: Performed @ Rensselaer

"Evaluating Innovation in Studio Physics"
Cummings, Marx, Thornton, Kuhl – AJP, 1999

ILDs = Interactive Lecture Demonstrations
CGPS = Cooperative Group Problem Solving



"Students in Cooperative Group Problem Solving sections not only had significant gains on the Force and Motion Conceptual Evaluation (FMCE) and Force Concept Inventory (FCI) but also performed better on the problem-solving section of the last course exam."

Cooperative Group Problem Solving Propagates Slowly Through the Department

"You can observe
a lot by watching"

Introductory Physics

Algebra-based Course for Pre Professionals (24 different majors) 1987

Calculus-based Course for Engineering and Physical Science Students (88% engineering majors) 1993

Calculus based Course for Biology Majors (1/3 premeds) 2003

Upper Division Physics Major Courses 2002

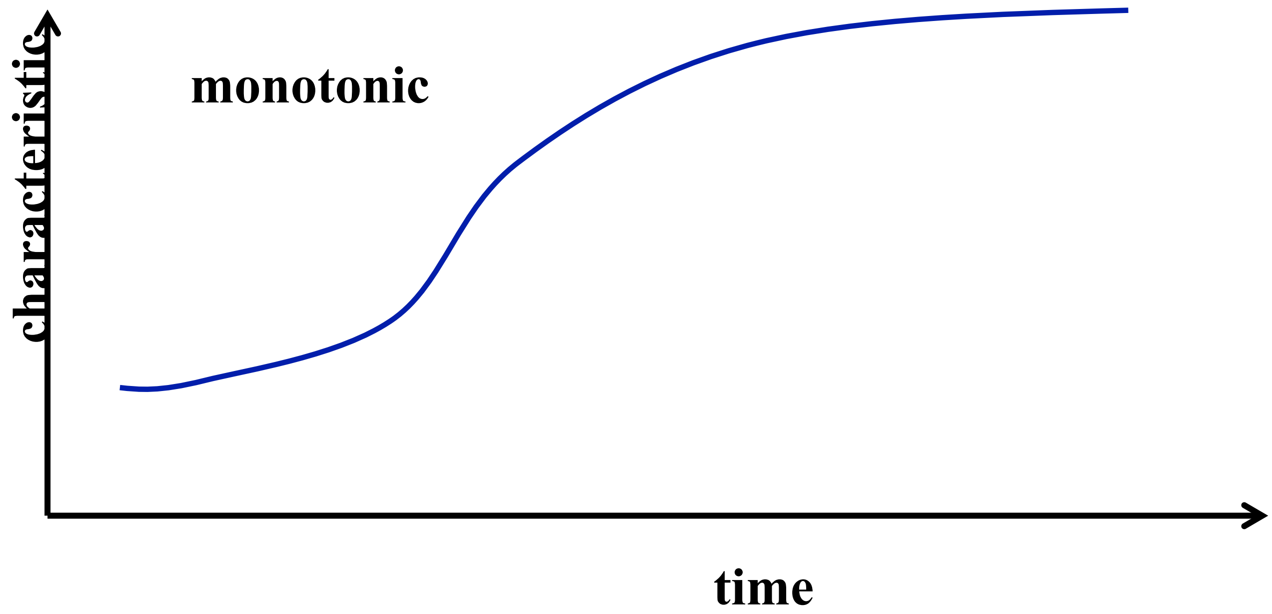
Analytic Mechanics
Electricity & Magnetism
Quantum Mechanics

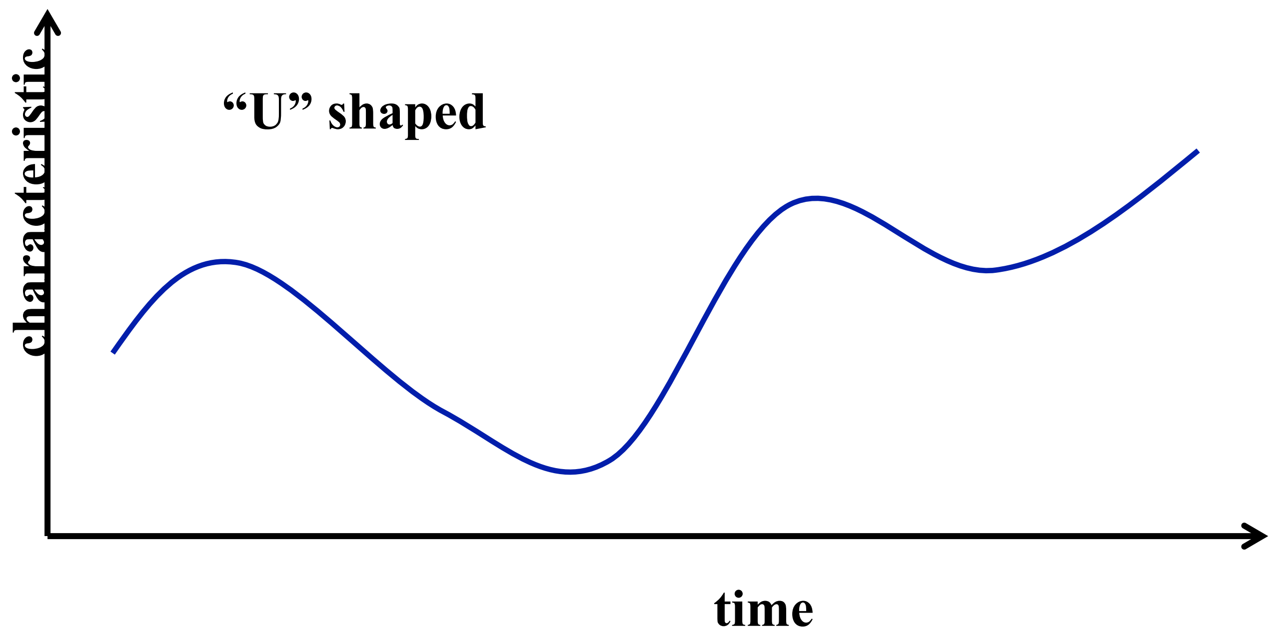
Graduate Courses 2007

Quantum Mechanics

Budget constraints have prevented additional requested expansion into other courses

Learning Progress is Not Monotonic



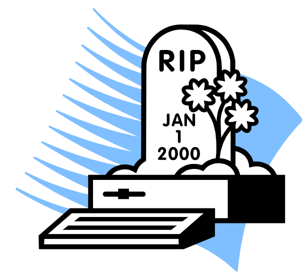


Different students progress differently in learning. Support, both intellectual and emotional are needed.

Caution: Learning is Difficult

Changing a deeply held way of thinking is traumatic

That trauma is the death of successful ideas and practices.



Response to emotional trauma

Death of a loved-one (Elisabeth Kubler-Ross)

- **denial**
- **anger**
- **bargaining**
- **depression**
- **acceptance**

5 stages of reacting to a traumatic event : Learning Expert-like Problem Solving!

DENIAL --- "I don't really have to do all that. I'll try it again my own way! I'll just have to be more careful. I've missed something so I'll read the book or ask someone and then try again."

ANGER --- "%$@^##& professor!", "I shouldn't have to take this course. I should wait until someone else teaches it. It's such a weird way of teaching. This has nothing to do with what I need. These problems are tricky and unclear."

BARGAINING --- "I'll work harder. Can I do something for extra credit? Just make the problems clearer and give us enough time to solve them."

DEPRESSION --- "What am I going to do. I'm going to fail. I give up. I'll never be able to pass the course with this rotten professor. What's the use".

ACCEPTANCE --- "Ok. I really need to make decisions in an organized way to solve problems. These problems really are the kind of thing I need to be able to solve. I actually use this in my other classes and my internship."

Adapted from Counseling For Loss & Life Changes (1997)
http://www.counselingforloss.com/article8.htm

Email after Introductory Physics for Biology & Pre-Medical Students May, 2013

I am one of your former students in PHYS 1201. I would like to thank you for your efforts in teaching us physics and guiding us through many difficult problems. I am currently studying for the MCAT and realized that your course, even though I hated it in the beginning, has helped me think critically and work through problems in an organized manner.

Have a great summer and best wishes,

Modern Pedagogy Slogan:

A teacher should be
“The Guide on the Side not
The Sage on the Stage.”

Is not really modern

The superior leader (teacher) gets things done with very little motion. He imparts instruction not through many words but through a few deeds. He keeps informed about everything but interferes hardly at all. He is a catalyst, and though things would not get done well if he weren't there, when they succeed he takes no credit. And because he takes no credit, credit never leaves him.

A leader (teacher) is best when people barely know he exists, not so good when people obey and acclaim him, worst when they despise him. But of a good leader (teacher), who talks little, when his work is done, his aim fulfilled, they (students) will say, 'We did this ourselves.'

Lao Tse, *Tao Te Ching (580-500 B.C.)*

Lao-Tse is considered the first philosopher of the Taoist school. The Te-Tao Ching, attributed to Lao-Tse, is one of the most sacred texts of Taoism.

The End

Please visit our website for more information:

http://groups.physics.umn.edu/physed/

PER group &
18 years of alumni who contributed to this research.

The best is the enemy of the good.

"le mieux est l'ennemi du bien"

Voltaire