Research on how school is nurturing the anti-scientific mind and how this can be changed

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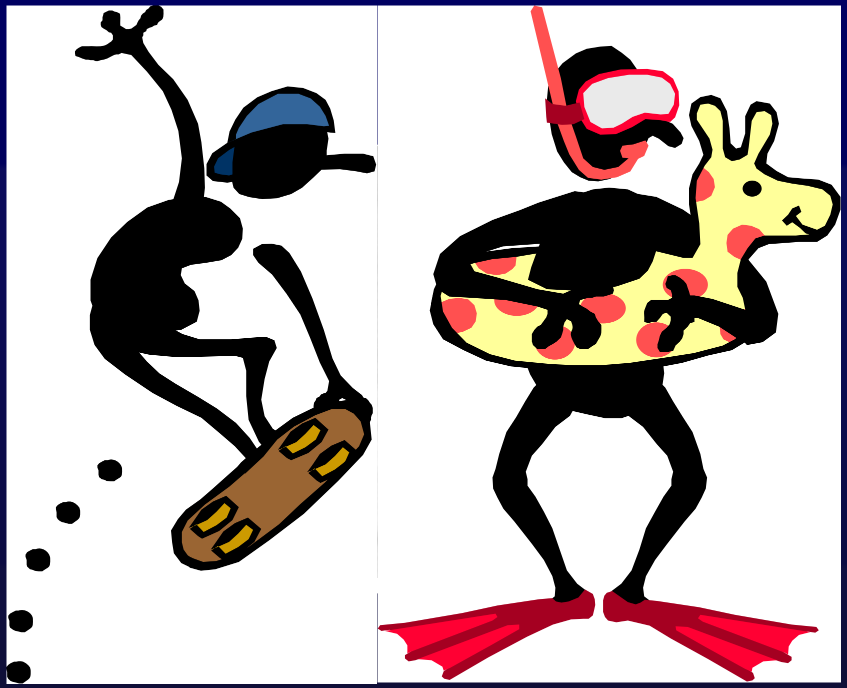
What is “scientific mind?”

Narrow pragmatic view

$\Longrightarrow$ practical research on it, how to develop

What do I mean by scienfic mind?

Think about and use science like a scientist.



Educational goal =Transform how think ⇒ scientist-like

competencies and beliefs

I. Components of expert competence

Expert competence =

•factual knowledge

•**Organizational structure**⇒ effective retrieval and use of facts

or ?

•**Ability to monitor own thinking** *(metacognitive skills)*
("Do I understand this? How can I check?")

•New ways of thinking--require extended focused mental effort to "construct".
•Built on prior thinking.
•Traditional instruction- facts & memorization, deficient.

Classroom evidence of failure--

Extensive physics Ed. research on mastery of concepts
(expert organization and application of ideas)

traditional instruction $\Rightarrow$ < 30% gain,
independent of instructor, class size, institution, …

II. Beliefs about physics, learning, and problem solving

Novice

Content: isolated pieces of information to be memorized.

Handed down by an authority. Unrelated to world.

Problem solving: pattern matching to memorized recipes.

Expert

Content: coherent structure of concepts.

Describes nature, established by experiment.

Prob. Solving: Systematic concept-based strategies. Widely applicable.

*adapted from D. Hammer

Novice

Content: isolated pieces of information to be memorized.

Handed down by an authority. Unrelated to world.

Problem solving: pattern matching to memorized recipes.

$\Rightarrow$ underlie "anti-science" beliefs

- any authority equally valid
- "truth" not grounded in experiment
- no connections (drug resistant TB and evolution, etc.)

U. of Colorado research on novice-expert beliefs about science.

How vary across populations.
How develop.
How impacted by teaching.

Kathy Perkins, Wendy Adams, Jack Barbera,
Kara Gray, Mindy Gratny, CEW

Measuring beliefs- CLASS Survey

(Colorado Learning Attitudes about Science Survey)

Measures students' beliefs about physics & learning physics

(Builds on prior work – MPEX[1] & VASS[2]).

42 statements:

Strongly Disagree 1 2 3 4 5 Strongly Agree

I think about the physics I experience in everyday life.

It is possible to explain physics ideas without mathematical formulas.

Score % Favorable : % of statements agrees with experts.

Blunt but useful instrument

Newer- chemistry version, others in development

1. Redish, E., Saul, J. M. Steinberg, R. N., (1998). *Amer. Journal of Phys*.
2. Halloun, I. E., (1996). *Proceedings of the ICUPE.*

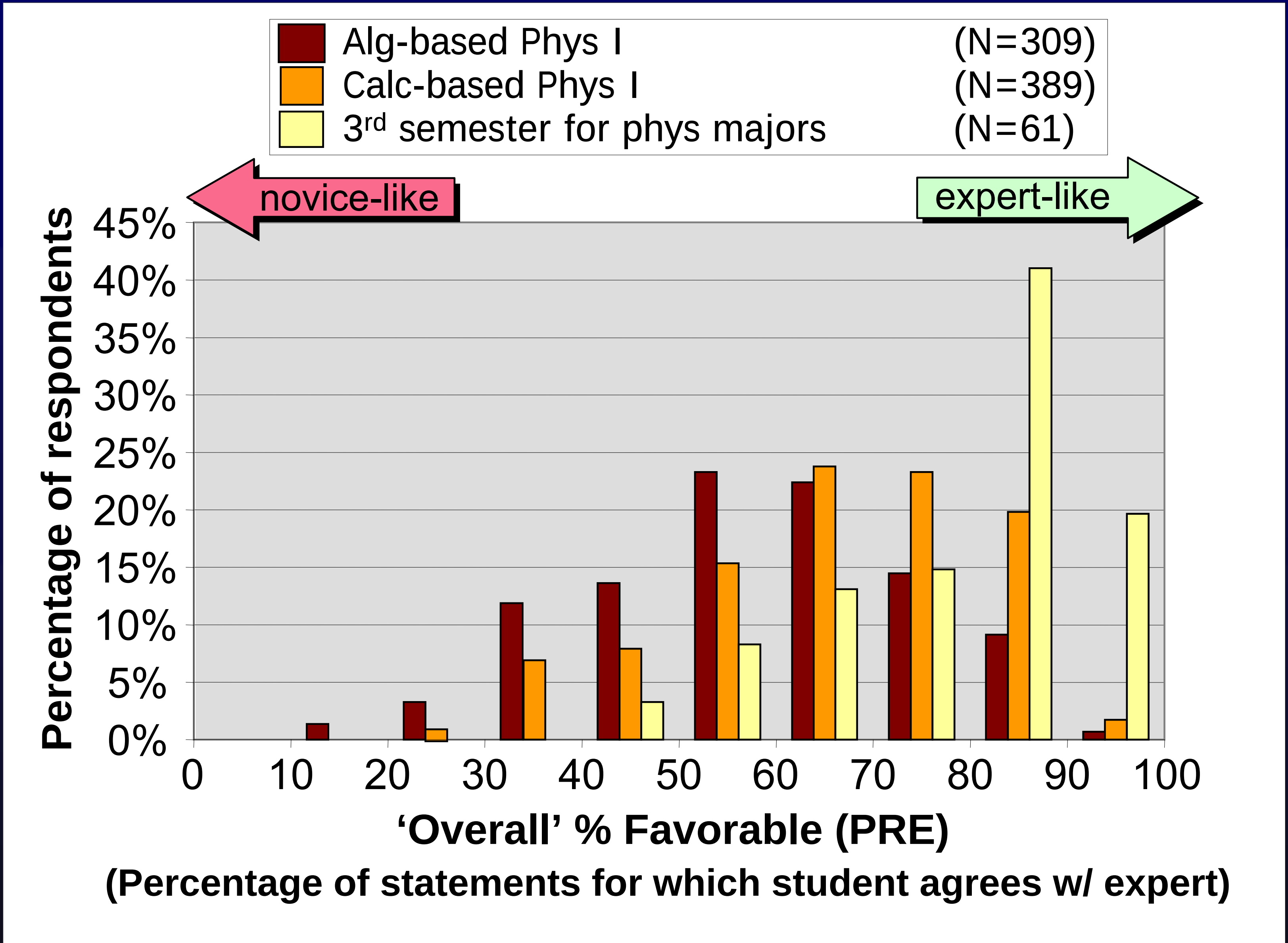
CLASS Phys Categories- statements where responses correlate

"Personal Interest"
"Real World Connections"
"Problem Solving-General"
"Problem Solving-Confidence"
"Problem Solving-Sophistication"
"Sense Making/Effort"
"Conceptual Connections"
"Applied Conceptual Understanding"

Use-- give before ("pre") and at end ("post") of courses.

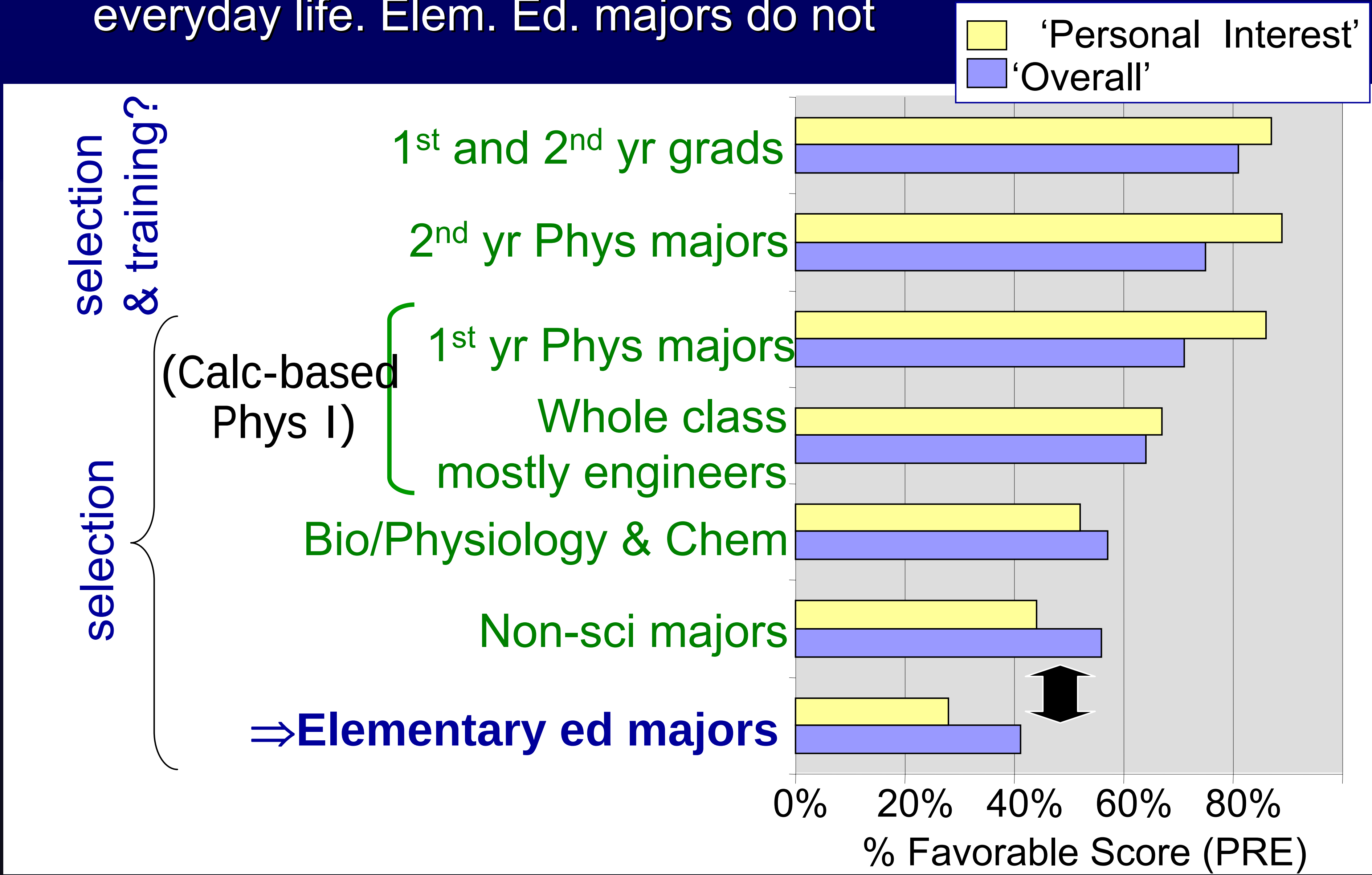
- Look at differences in beliefs across different majors.
- How correlate with learning & major.
- How impacted by teaching practices.

Distribution of Beliefs



Surveyed beliefs and choice of major

Physics majors see physics as highly relevant and useful in everyday life. Elem. Ed. majors do not



Gender differences-varies with major

- Alg-based Phys I, Fa04: 116 men, 193 women (mostly premed)

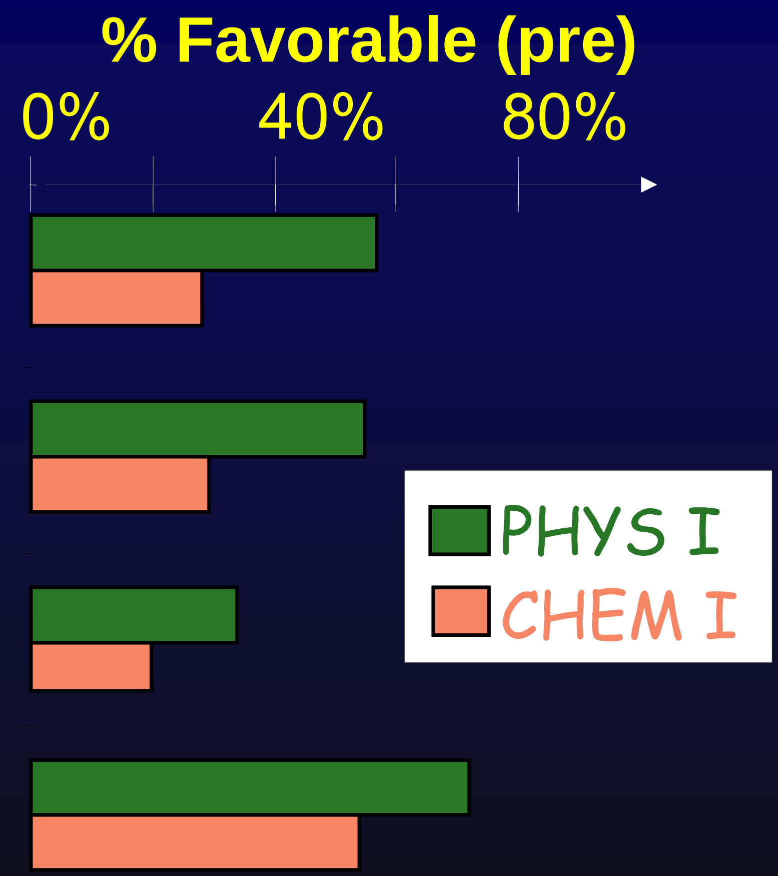
	Overall	Personal Interest
	Pre-	Pre-
Men	61%	65%
Women	54%	45%

→ Largest gender gap in 'Personal Interest'

- Calculus based course- engineers & physics majors little if any gender differences

Student beliefs not about "science" overall. Specific to discipline.

First university science courses for premeds
-- chem-phys differences.



38. It is possible to explain [ ] ideas without mathematical formulas.

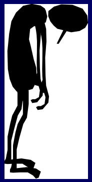
37. To understand [ ], I sometimes think about my personal experiences and relate them to the topic being analyzed.

1. A significant problem in learning [ ] is being able to memorize all the information I need to know.

6. Knowledge in [ ] consists of many disconnected topics.

How teaching impacts beliefs

novice



expert

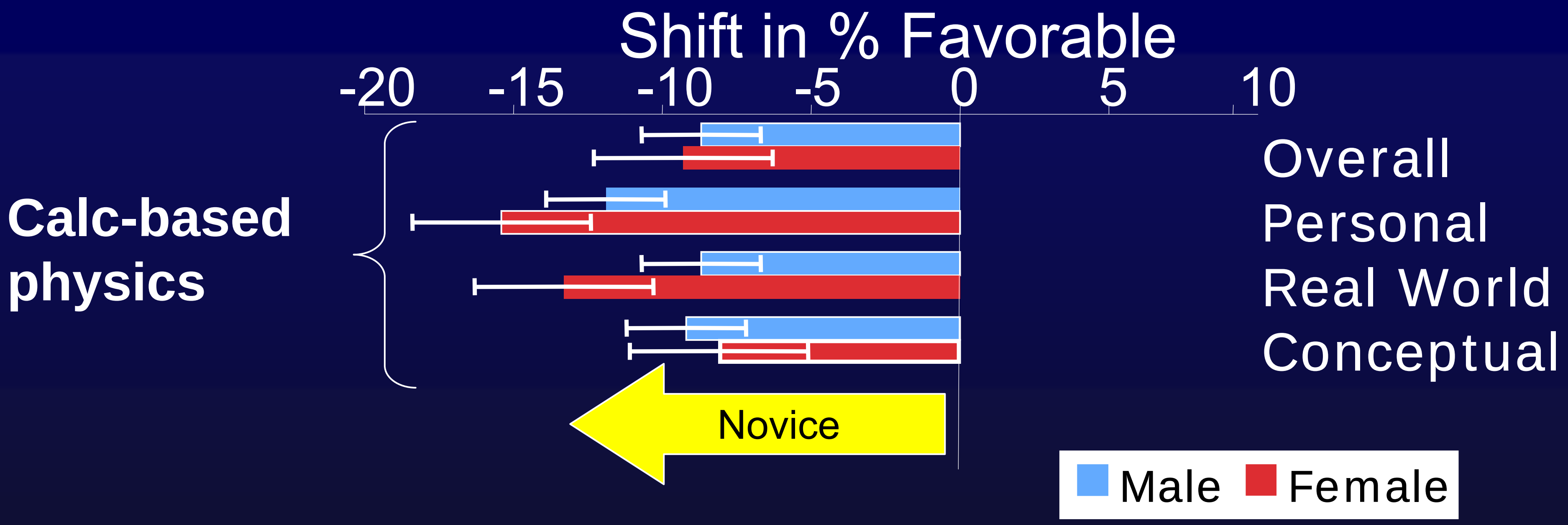
Nearly all introductory physics and chemistry courses negatively impact students' beliefs.

(CU and Maryland results).

Even when good conceptual learning gains.

How teaching impacts beliefs

- typical shift in intro physics course.



Less data on chemistry but ~ same or worse.

makes perfect sense--

Typical introductory chem and physics course (from student perspective)

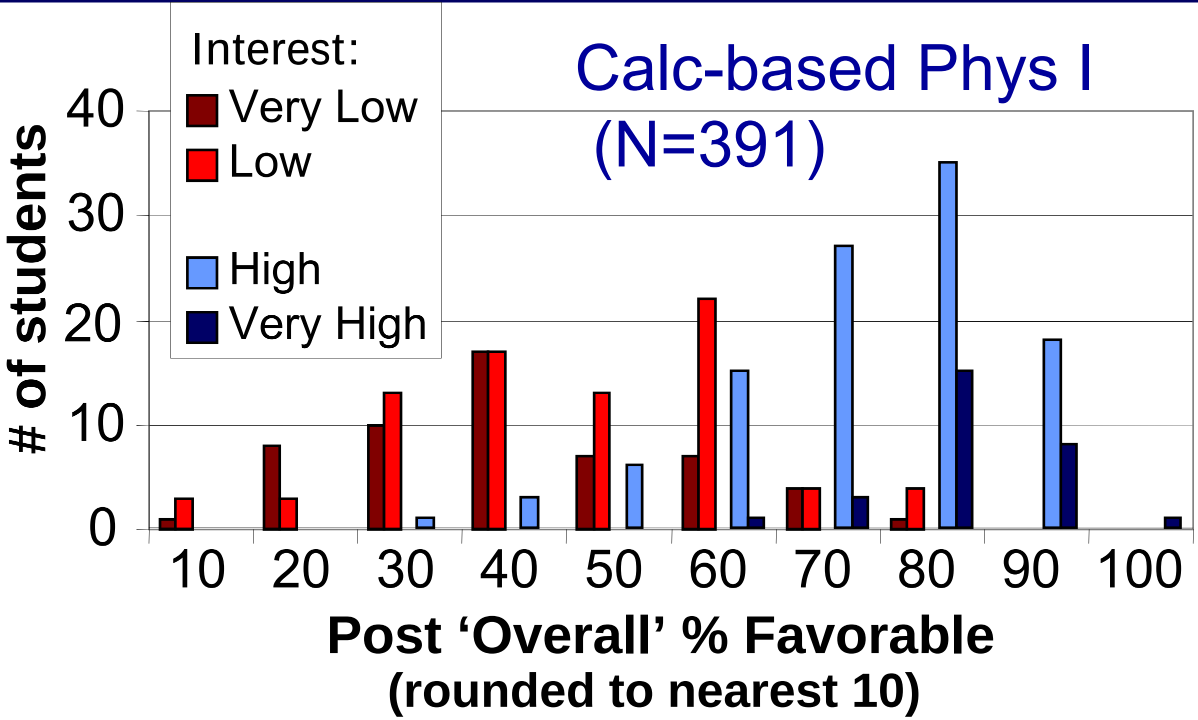
•Large number of topics presented as facts by authority. Coverage too rapid and shallow to understand, or see deeper connections.

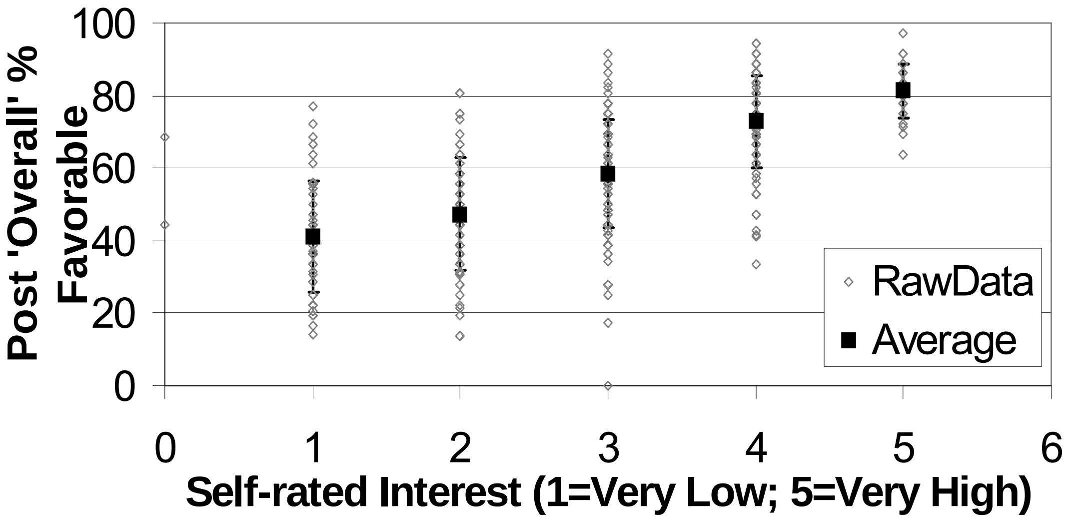
•Emphasis on memorization of isolated facts, particularly in exams/grading.

•Highly abstract presentation, not connect to real world or prior knowledge.

$\Rightarrow$ teaching novice beliefs!

Surveyed Beliefs correlate with Self-reported Interest





Higher self-reported interest, more expert-like beliefs overall.

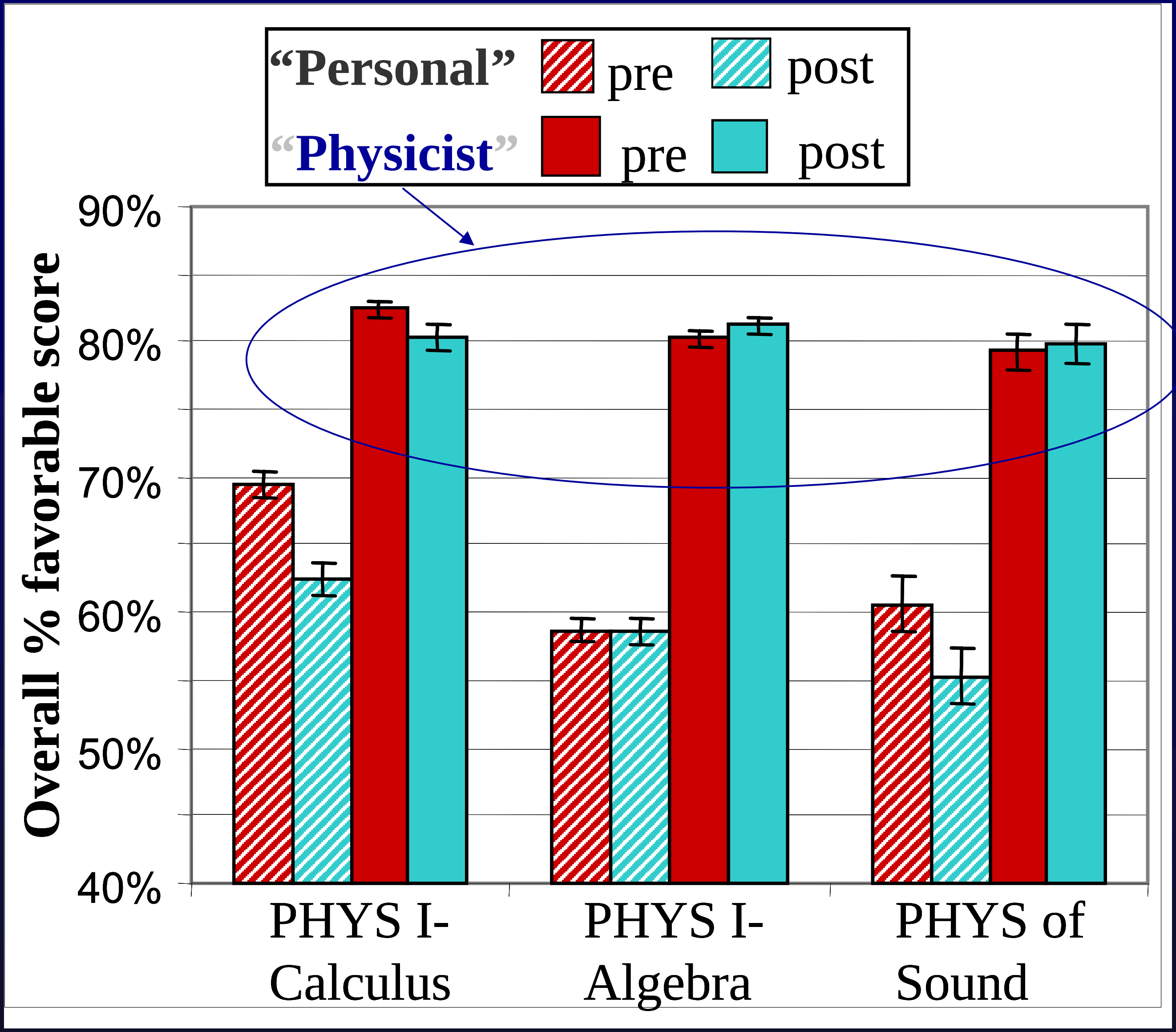
Things research has revealed about expert beliefs relevant to instruction.

Students know what experts belief- but do not think are valid/apply to them.

Asked survey in modified form.
For each statement had two responses

Answer as you personally believe.
strongly disagree strongly agree

Answer as you think a physicist would answer.
strongly disagree strongly agree



All student populations know what physicists believe.
Also ~ independent of physics in high school. None to AP.

Implications for teaching of scientific beliefs

Finding 1. Need to convince students, not inform them about expert beliefs about science and problem solving.

Finding 2. Modest efforts that explicitly address beliefs have clear impact.

Intervention--Make explicit ongoing part of instruction:
Why is this worth learning?
How does it connect to real world?
Why does this make sense?
How connects to things student already knows?

$\Rightarrow$ consistently no decline, sometimes slight improvement.

in progress--better understanding how to improve.

Summary:

- Number of key components of “scientific mind” can be measured. Expert competencies & beliefs.
- Traditional science teaching gives little gain in competencies, negative gain in beliefs.
- Research is showing how to improve for all students.

Some final concerns:

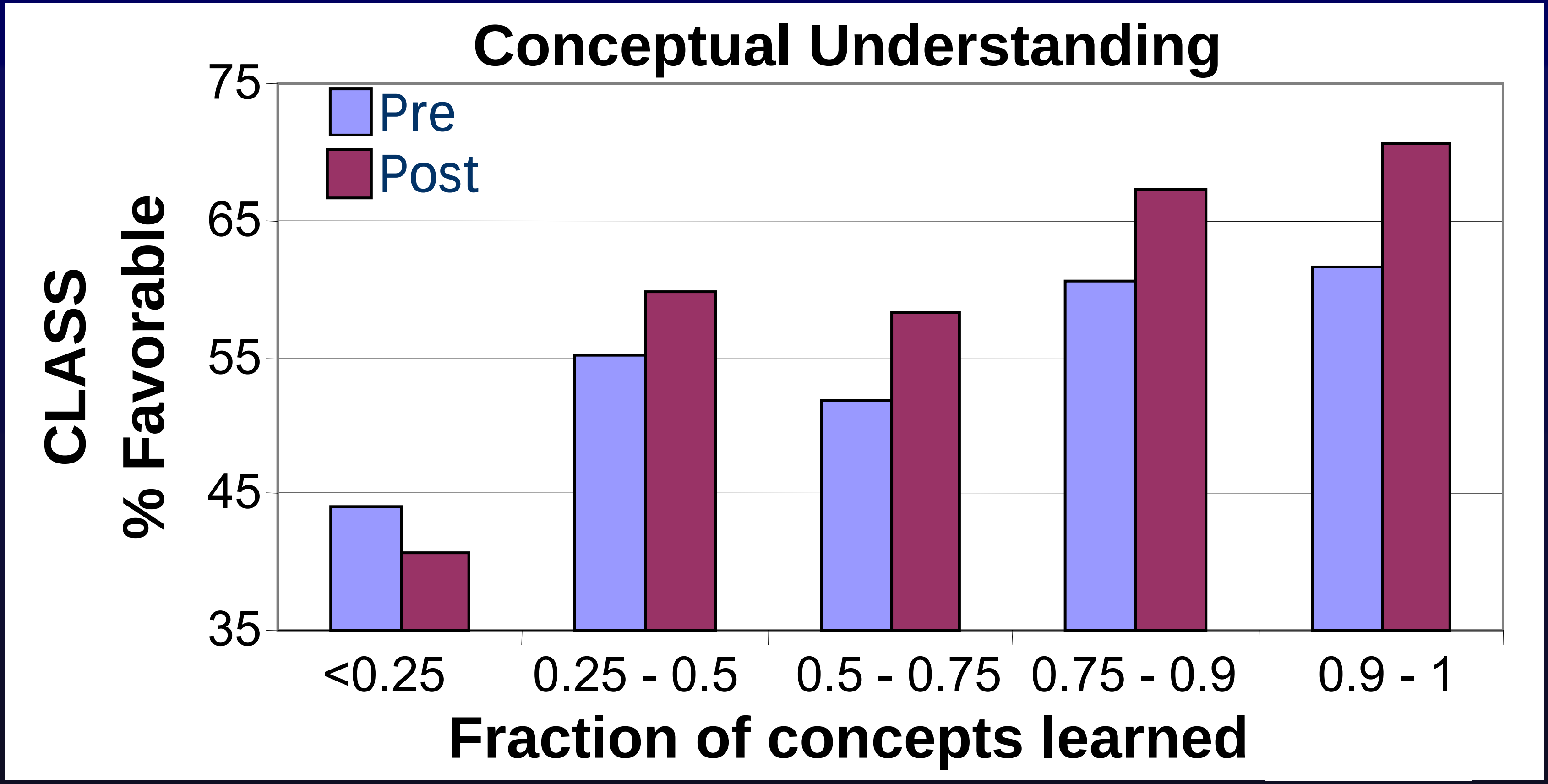
- Exceptionally novice-like beliefs about science for elementary education majors/teachers.
- Conflicting/confusing views of “skepticism”
    social interactions--negative and undesirable trait
    scientific settings-- positive and essential trait

extra slides below

Surveyed beliefs and content learning

- Calc-based Phys I: 416 students

Content Learning: Force & Motion Conceptual Eval.



Conclusions

The emerging story: Surveyed students' beliefs about physics and learning physics:

- show a correlation with content learning
- show a correlation with choice of major
- and show an influence on their interest in and pursuit of physics

Has important implications for teaching, and for recruitment and retention in physics.

Surveyed Beliefs and Self-reported Interest

- Students' beliefs as measured by CLASS, and
- Self-rated interest
  - supplemental questions on post-survey

"Currently, what is your level of interest in physics? "
(very low, low, moderate, high, very high)

"During the semester, my interest in physics…"
(increased, decreased, stayed the same)

"Why?" (Open response)

How and 'Why' students' interest in physics changes

- Same course (Calc-based Phys I course; N=391)

- Change in Interest :

Increased	No change	Decreased
19%	37%	45%

- Change in Beliefs :

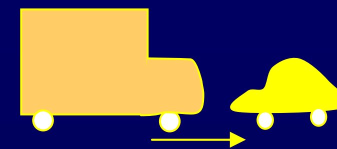
% Favorable on CLASS shifted toward novice (-7%)

- Reasons given for 'Why' interest changed:

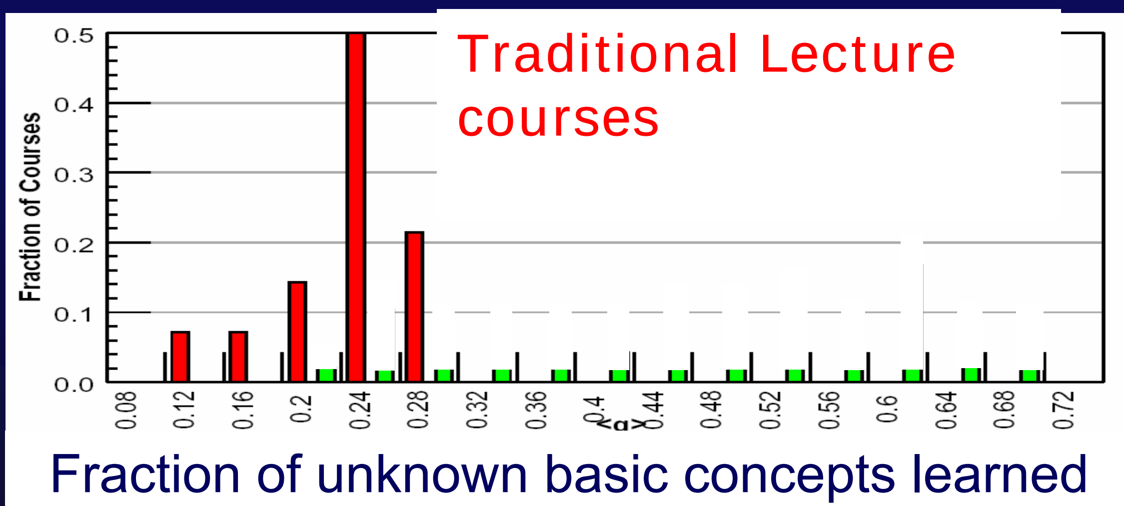
  Coded into 5 types of reasons
  - Beliefs (as probed by CLASS)
  - Specific Aspects of Instruction
  - Personal Success in Course
  - Comparison with Prior Experience (HS)
  - Relation to Career Path

Conceptual understanding in traditional course.

- Force Concept Inventory- basic concepts of force and motion 1st semester physics



Ask at start and end of semester-- 100's of courses



What % learned?

On average learn <30% of concepts did not already know.
Lecturer quality, class size, institution,...doesn't matter!
Similar data on higher level courses.

R. Hake, "…A six-thousand-student survey…" AJP 66, 64-74 ('98).