Studying Student Beliefs About Science:
their importance and what affects them

We have developed and validated surveys that probe students' beliefs about physics and chemistry and about how these subjects are learned. These surveys then provide a measure of students' beliefs on a novice-to-expert scale that can be used to investigate the impact of teaching or relationships between beliefs and other educational outcomes of interest. These surveys are being used in courses across North America. At the University of Colorado, we have administered these surveys to more than 15,000 students in over 50 courses. I will discuss how to develop and validate such surveys, and what we have learned from them. We see how beliefs correlate with learning of content, choice of major, and interest, and how different teaching practices impact beliefs in positive and negative ways. We have also seen surprising results with regard to the beliefs students have when they enter the university, particularly in how beliefs about chemistry and physics differ.

- To do:

- Bring copy of chemistry and physics statements.

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their importance and what affects them

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Outline

- What do we mean by beliefs?
- Measuring beliefs:
  The CLASS-Phys and CLASS-Chem Survey
- Importance of studying students' beliefs:
  - Characterizing beliefs – Chemistry and Physics
  - Correlations between beliefs and … :
    - Choice of major & pursuit of study
    - Changes in self-reported interest
    - (Content learning)
- Can we impact students' beliefs?
- Developing belief surveys

Beliefs about science

Novice		**Expert**
Isolated pieces of information	**content and structure**	Coherent framework of concepts
Handed down by authority. No connection to real world	**source**	Describes nature. Established by experiment
Pattern matching to memorized recipes.	**problem solving**	Systematic concept-based strategies. Widely applicable.
(boring, useless)		*(relevant, useful, interesting)*

Think about science like a scientist.

Adapted from David Hammer (Cognition and Instruction)

The CLASS Survey

(Colorado Learning Attitudes about Science Survey)

- Builds on previous work in physics by (MPEX[1] & VASS[2])
- Main Goals:
  - Change focus from "expectations for learning in course" to "beliefs about the discipline and learning the discipline"
  - Valid/Reliable across university populations (non-sci to majors)
  - Probe additional facets of beliefs (problem solving, chem specific)
- CLASS-Phys (42 statements) & CLASS-Chem (50 statements) (39 common 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.

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

CLASS: Scoring

Strongly Disagree 1 2 3 4 5 Strongly Agree

I think about the physics I experience in everyday life.

- Score 'Overall' % Favorable : (%Unfavorable, %Neutral)

percentage of statements for which the student <u>agrees</u> with the expert

- Score % Favorable on individual statements:

percentage of students <u>agreeing</u> with expert

- Score % Favorable on categories (4-10 statements):

percentage of statements for which student agree with expert

- Personal Interest
- Real World Connection
- Problem Solving (PS) General
- PS Confidence
- PS Sophistication
- Sense Making / Effort
- Conceptual Connections
- Conceptual Learning
- Atomic-Molecular Perspective of Chemistry

CLASS-Phys: Adams et al., Physical Review ST - PER
CLASS-Chem: Barbera et al., (Submitted to JCE)

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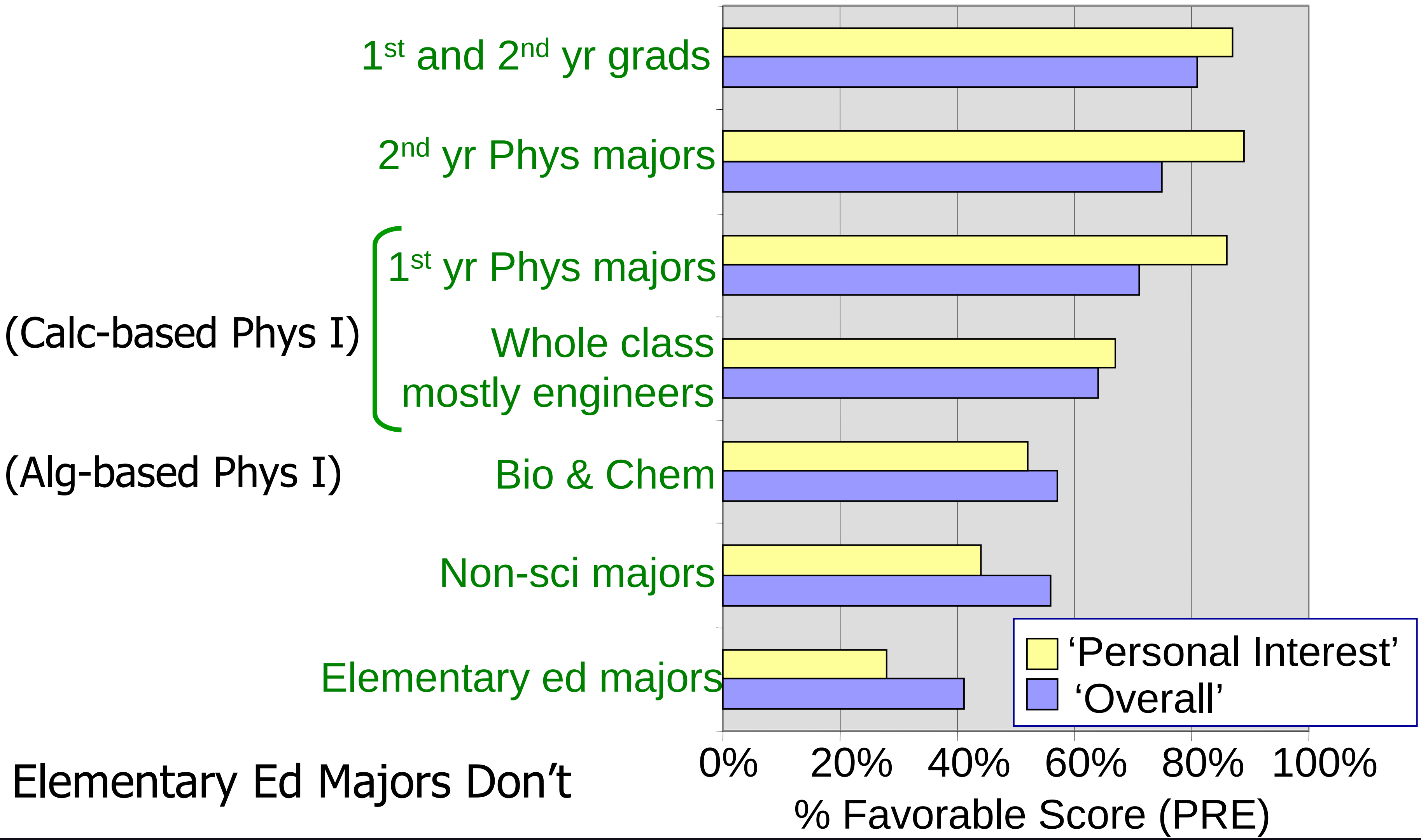
Surveyed beliefs and choice of major

- Students who choose to major in physics see physics as highly relevant and useful in everyday life.

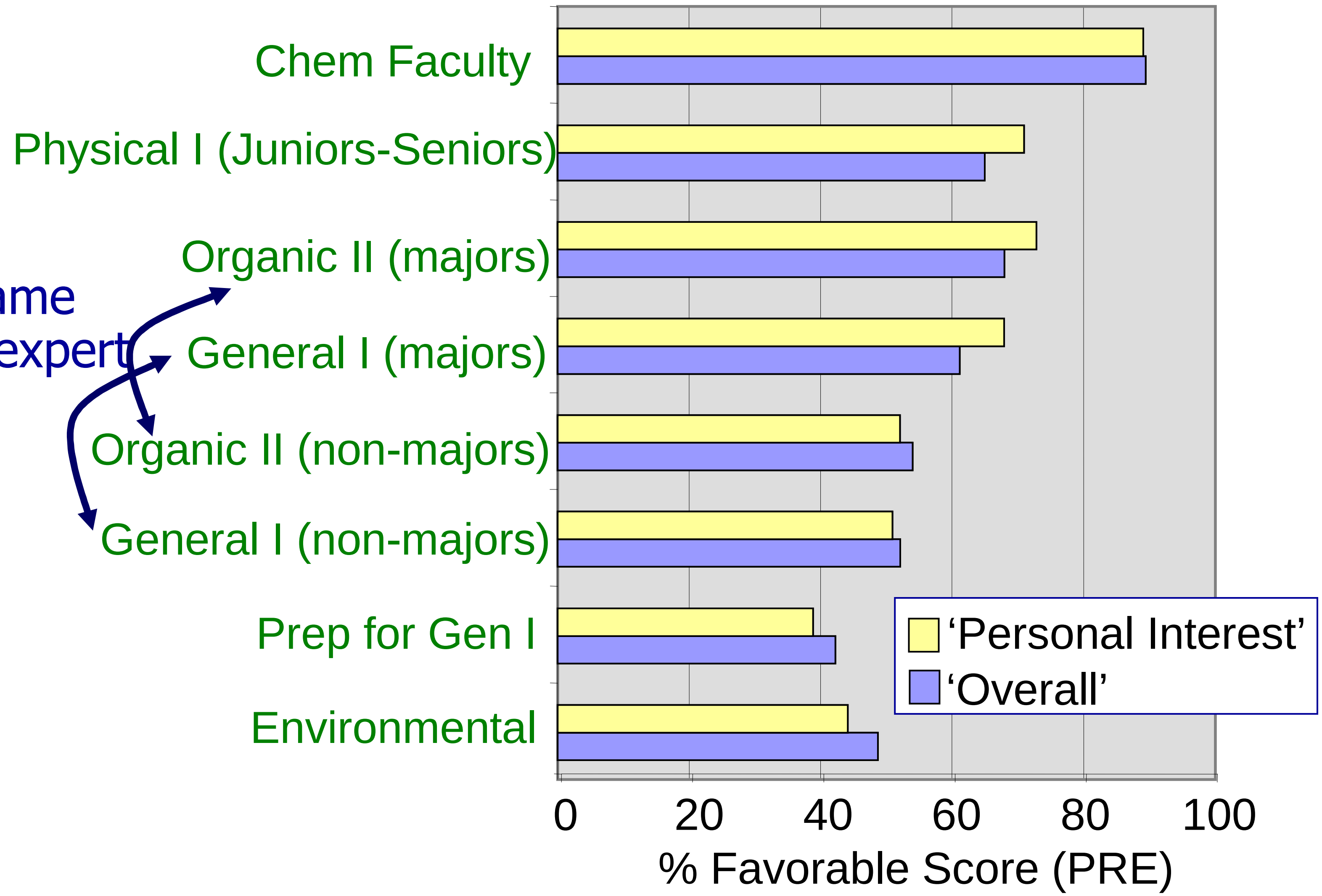


Elementary Ed Majors Don’t

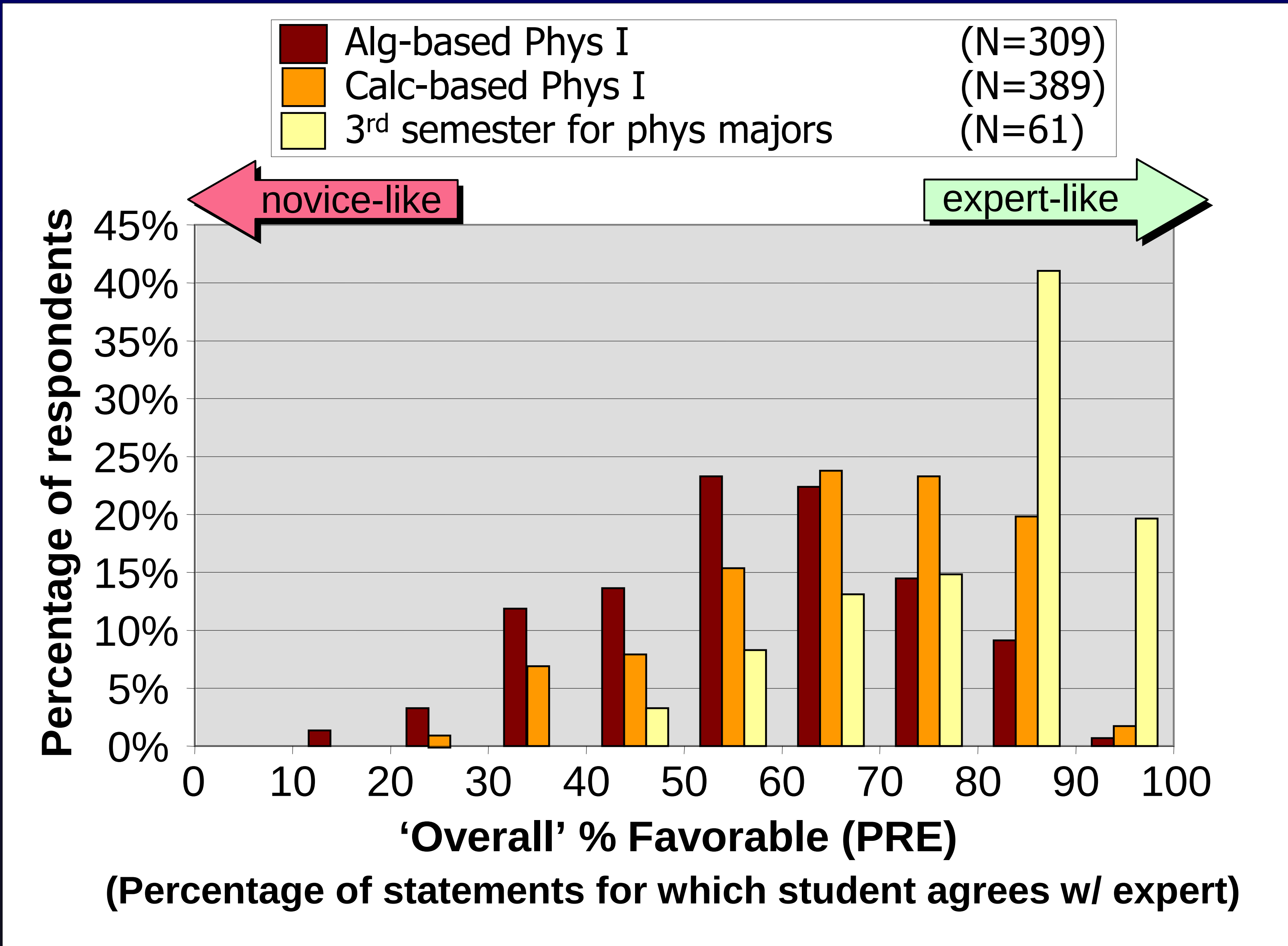
Chemistry: Surveyed beliefs & choice of major

- Students who choose to major in chemistry see chemistry as highly relevant and useful in everyday life.

Majors in same class more expert



Distribution of Beliefs



Are we …

Creating majors with expert-like beliefs

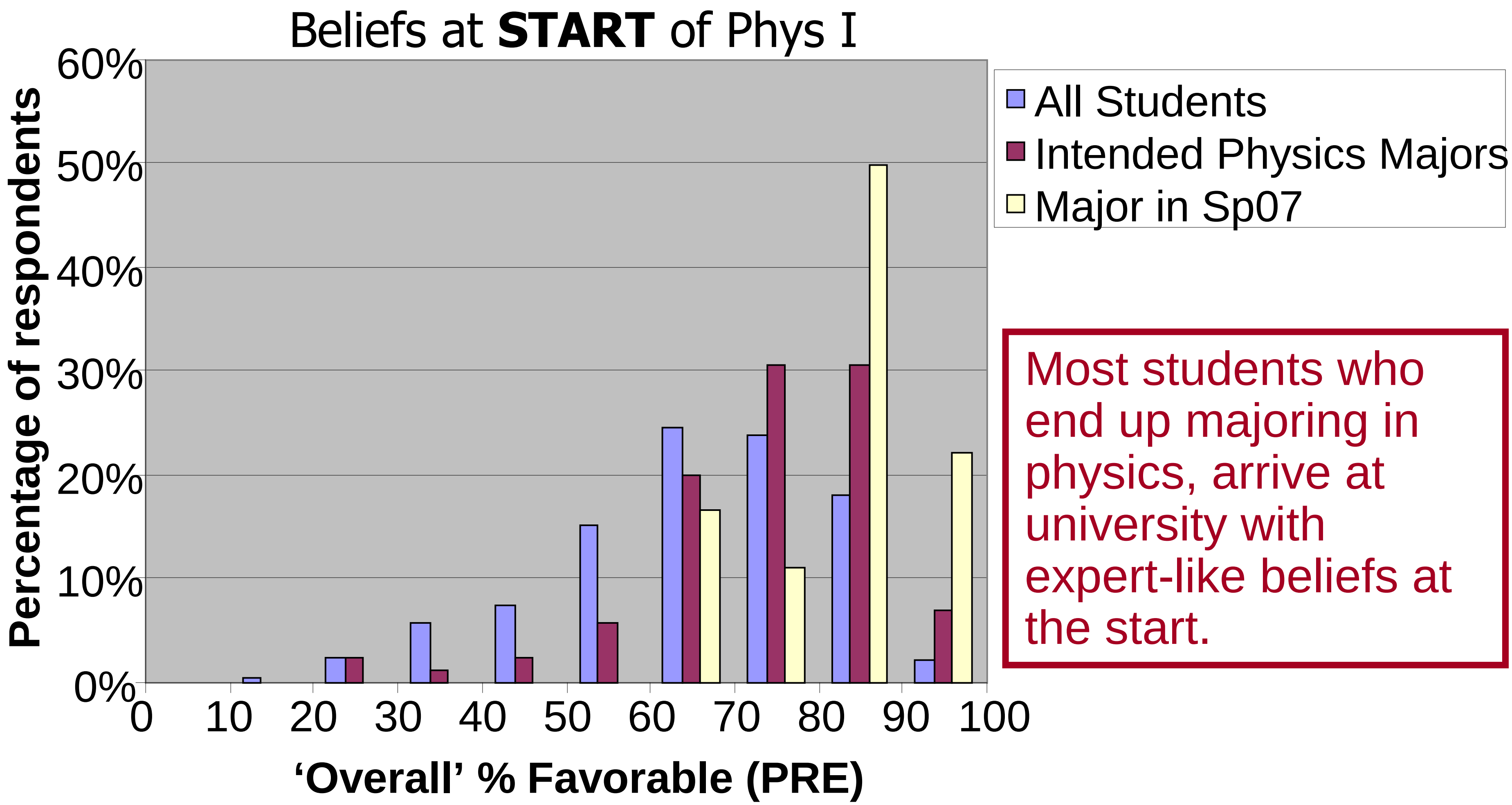
OR

Filtering out those without pre-existing expert-like beliefs

?

Who from Calc-based Phys I, majors in physics?

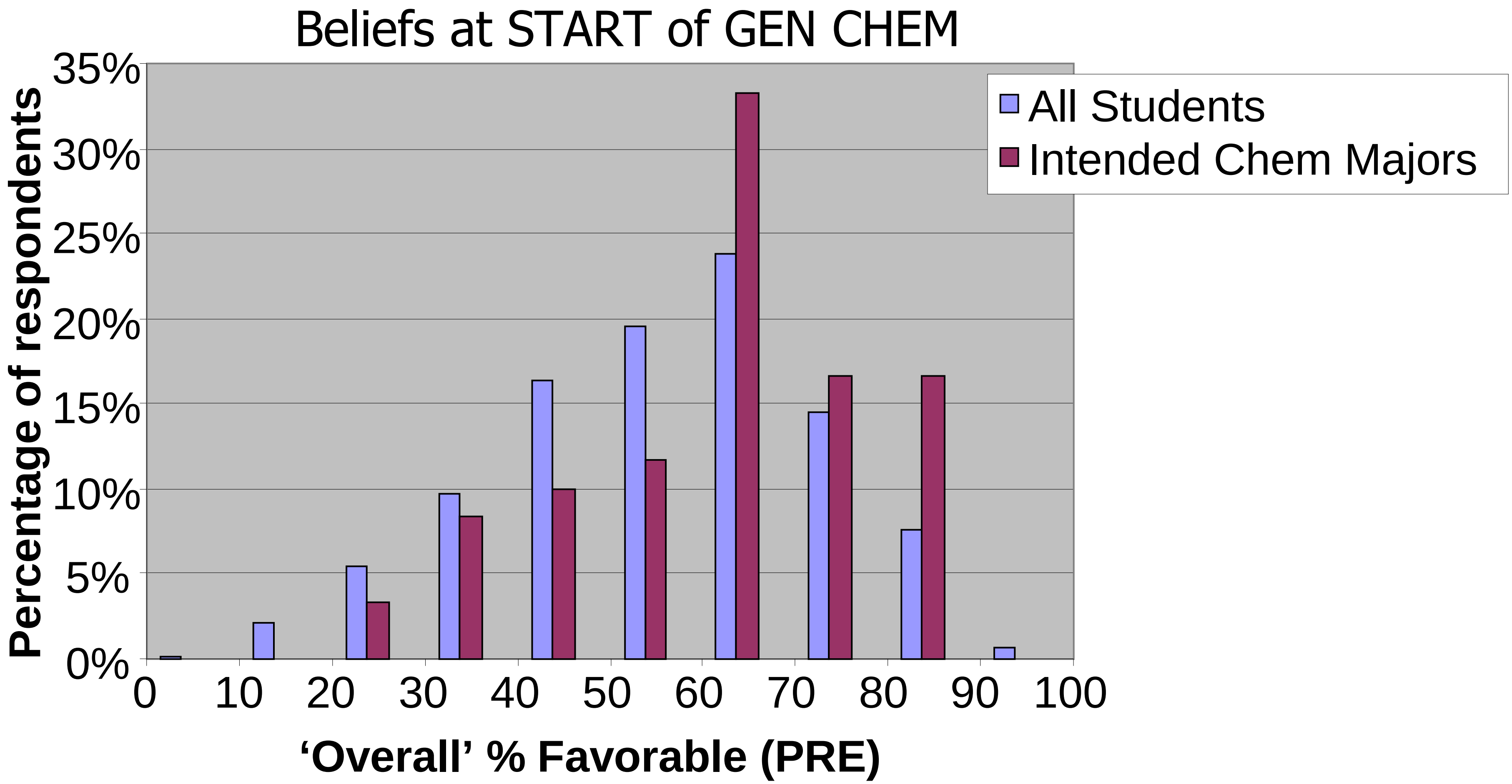
- Calc-based Phys I (Fa04-Fa05): 1306 students
  - “Intend to major in physics”: 85 students
  - Actually majoring in physics in Sp07: 18 students



Most students who end up majoring in physics, arrive at university with expert-like beliefs at the start.

Who from Gen Chem I, majors in chemistry?

- Gen Chem I (Fa06): 567 students
  - “Intend to major in chemistry”: 60 students



Looking at Individual Statements

Gen Chem I

Statements	Pre-fav
4. I think about the chemistry I experience in everyday life.	30%
29. When I see a chemical formula, I try to picture how the atoms are arranged and connected.	36%
43. To understand chemistry, I sometimes think about my personal experiences and relate them to the topic being analyzed.	38%
6. After I study a topic in chemistry and feel that I understand it, I have difficulty solving problems on the same topic.	45%

Surveyed Beliefs and Self-reported Interest

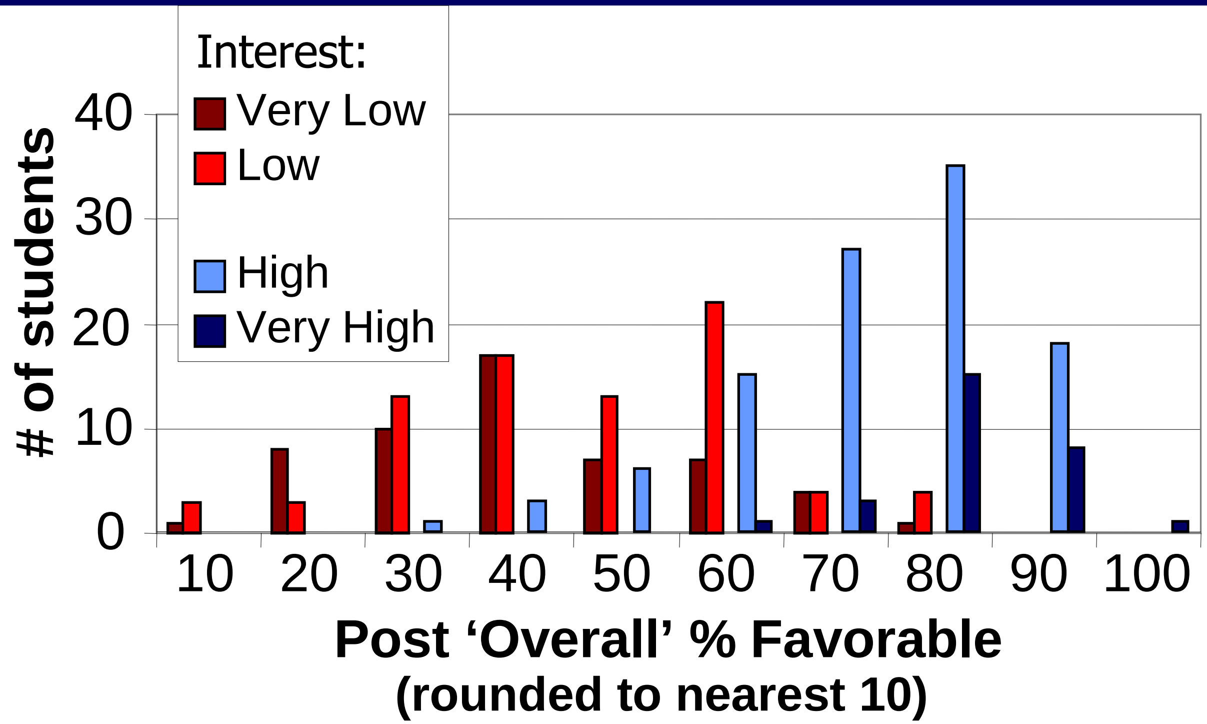
- Students’ beliefs as measured by CLASS, and
- Self-rated interest
  - supplemental questions

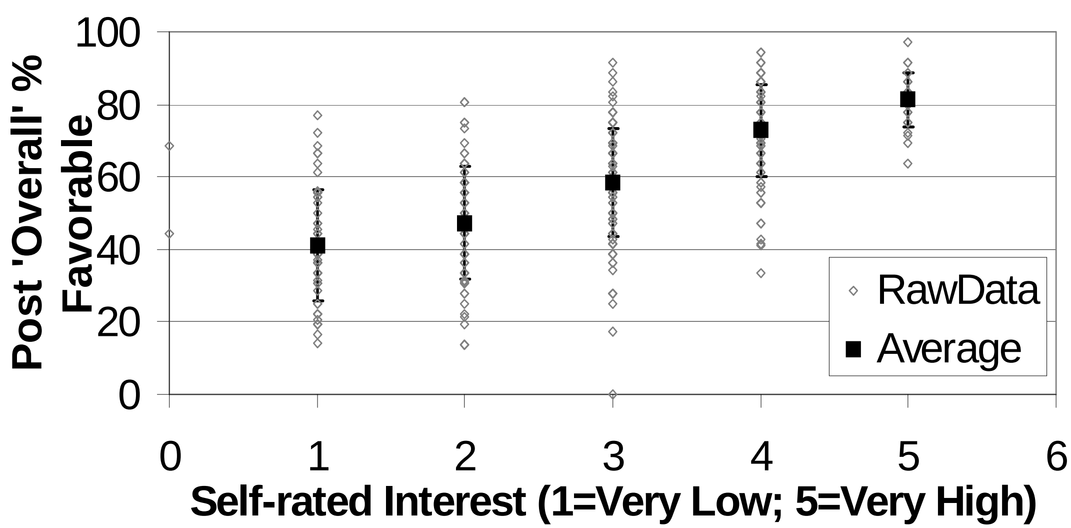
“Currently, what is your level of interest in physics? “
(very low, low, moderate, high, very high)

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

“Why?” (Open response)

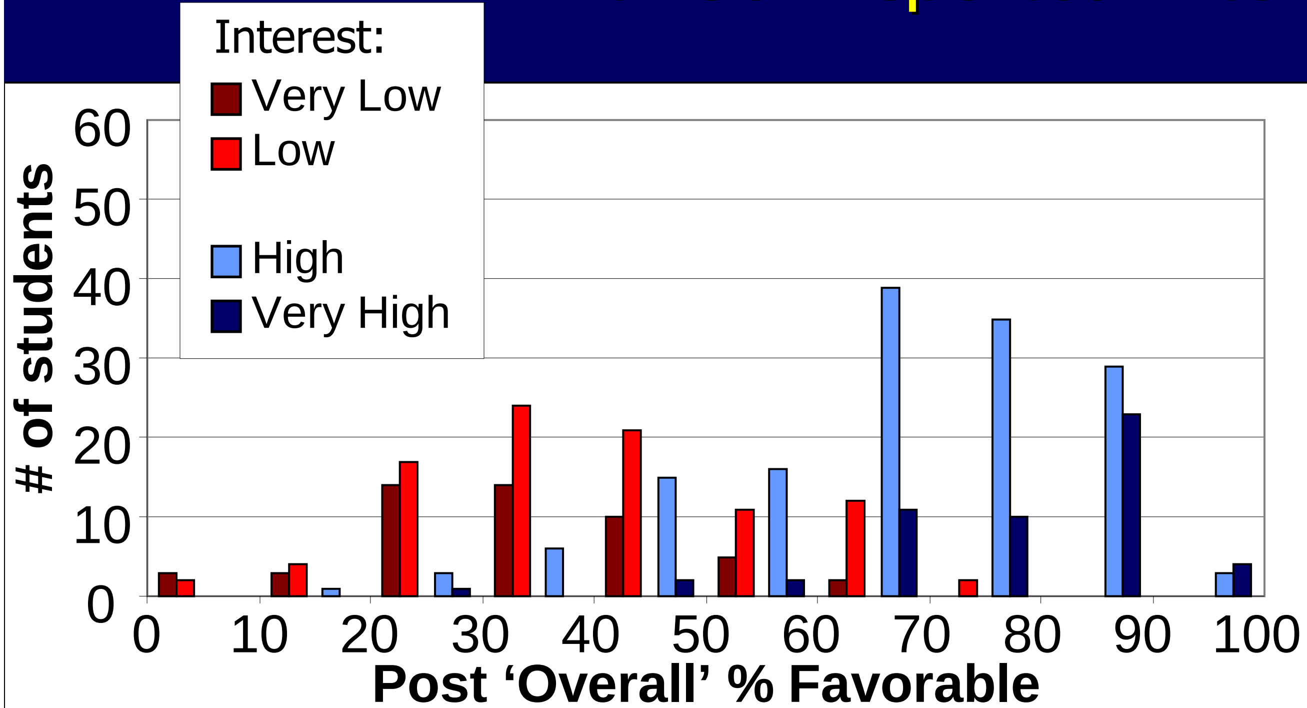
Surveyed Beliefs correlate with Self-reported Interest

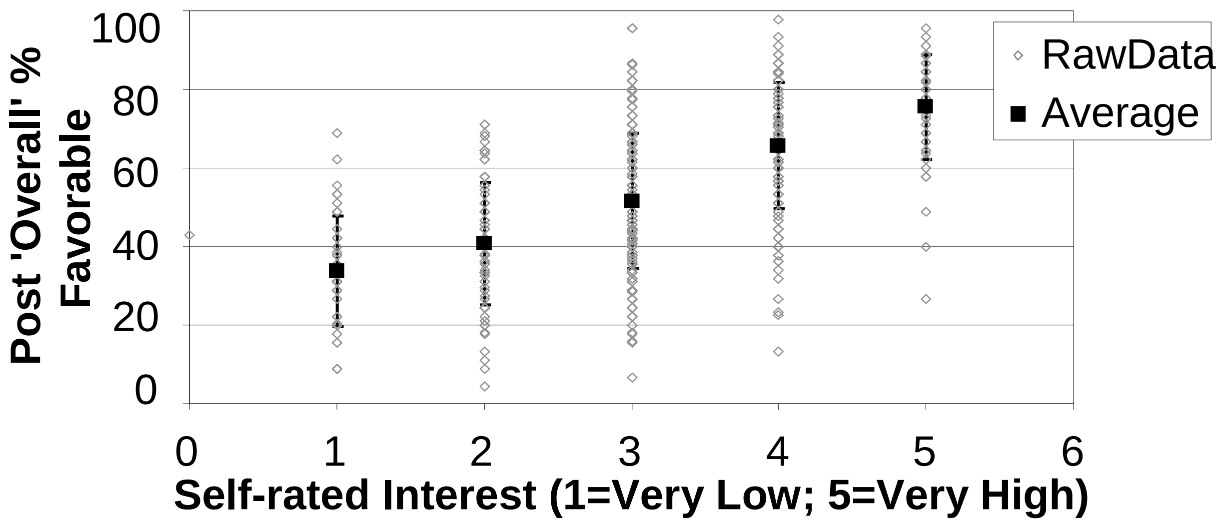




- Calc-based Phys I course (N=391)
- Students' with higher self-reported interest have more expert-like beliefs.
- Correlation of R=0.65

Chemistry: Surveyed Beliefs correlate with Self-reported Interest





- Gen Chem I Course (N=564)
- Students’ with higher self-reported interest have more expert-like beliefs.
- Correlation of R=0.60

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%

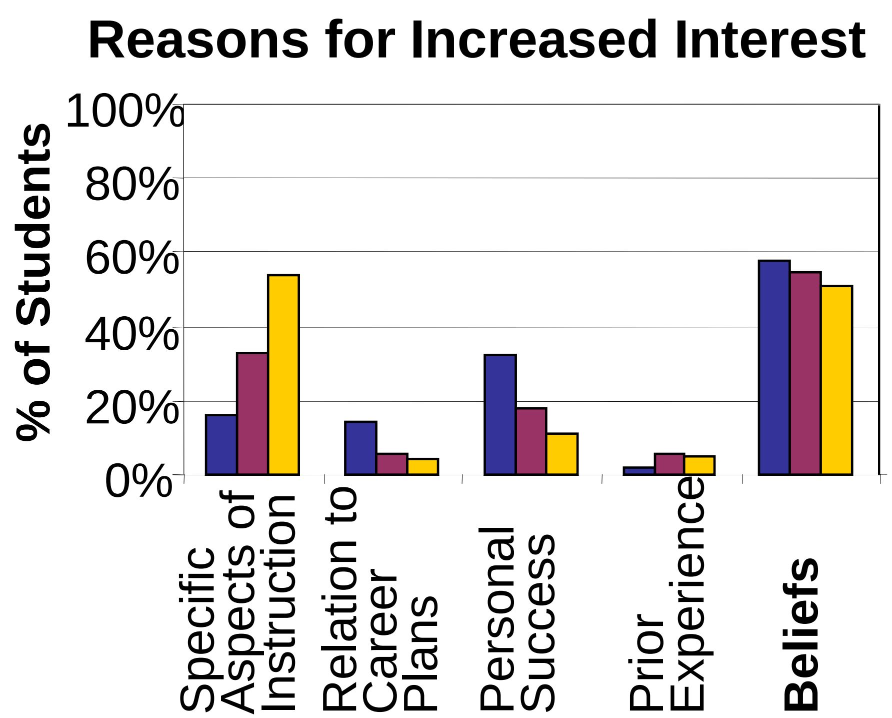
- Change in Beliefs :

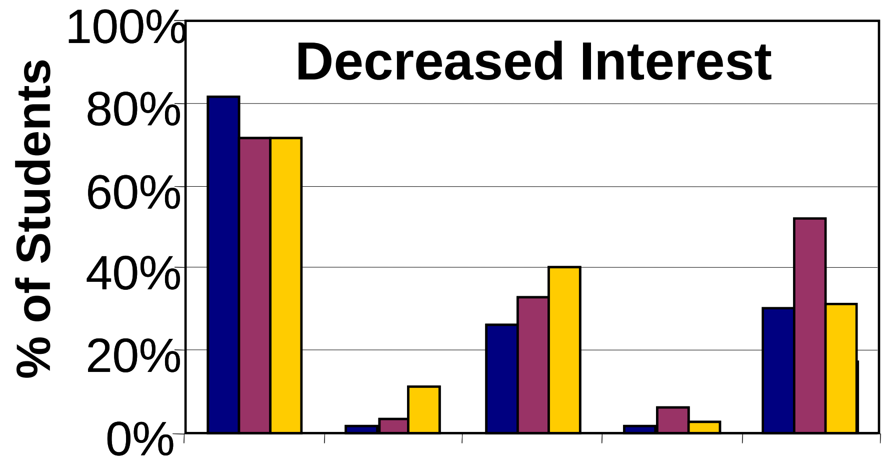
% Favorable on CLASS shifted toward novice (-7%)

- 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

Reasons 'Why' students' interest change



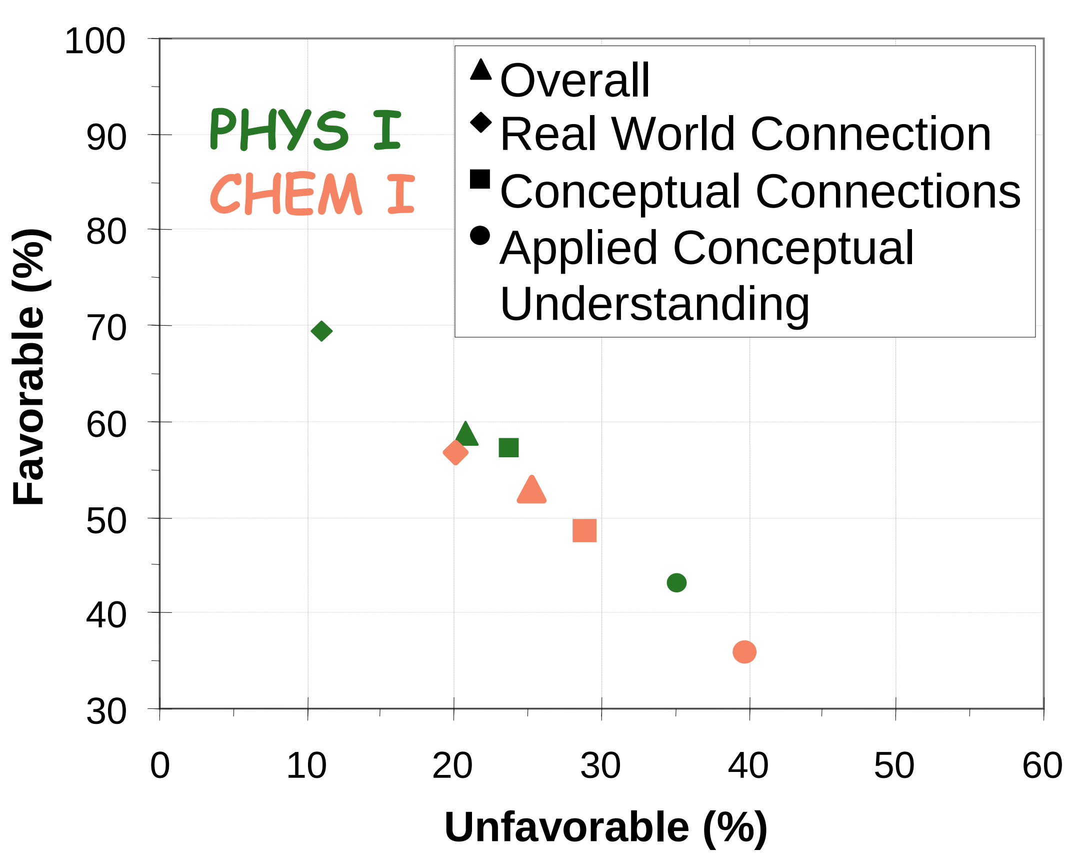


- Calc Phys 1 (A): 19%↑ and 45%↓
- Calc Phys 1 (B): 17%↑ and 39%↓
- Alg Phys 1: 45%↑ and 16%↓

- Over 50% of increased interest reasons related to surveyed beliefs
- Top 3 belief reasons:
  1. Real World Connection
  2. Personal Interest (usefulness)
  3. Prob. Solv. Confidence
- Top reason for decreased interest is Specific Aspects of Instruction

Chemistry vs Physics Beliefs

- Comparable population; 39 matching statements; PRE-beliefs
  Biology Majors in Chem I (CLASS-Chem, N=156)
  vs Biology Majors in Alg-based Phys I (CLASS-Phys, N=212)



- 'Overall' & 3 categories show statistically significant differences in <u>PRE</u> beliefs
- Biology Majors consistently have more expert-like beliefs about Physics

Chemistry vs Physics Beliefs: Individual Statements

Statements

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.

17. Understanding [] basically means being able to recall something you've read or been shown.

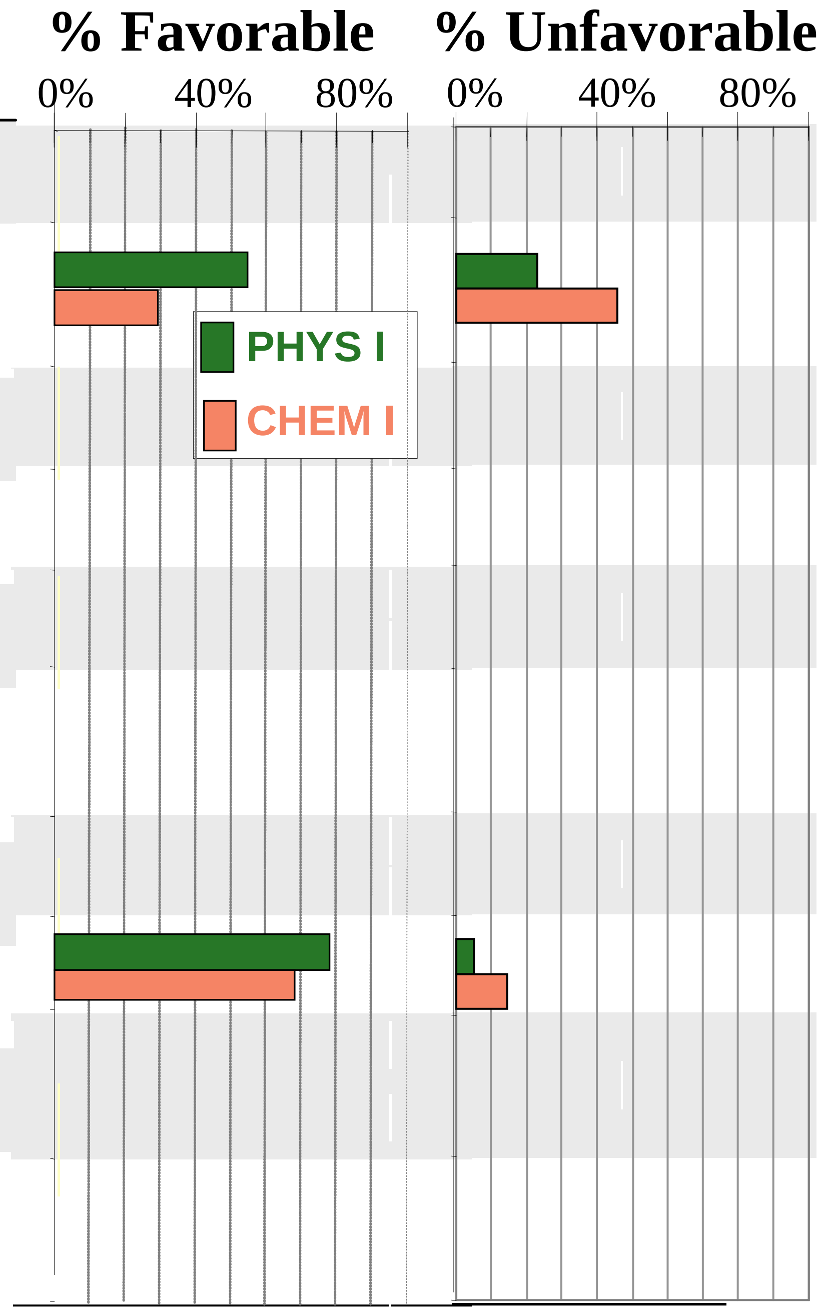
22. If I want to apply a method used for solving one [] problem to another problem, the problems must involve very similar situations.

29. To learn [], I only need to memorize solutions to sample problems.

35. The subject of [] has little relation to what I experience in the real world.

26. In [], mathematical formulas express meaningful relationships among measurable quantities.

13. I do not expect [] equations to help my understanding of the ideas; they are just for doing calculations.



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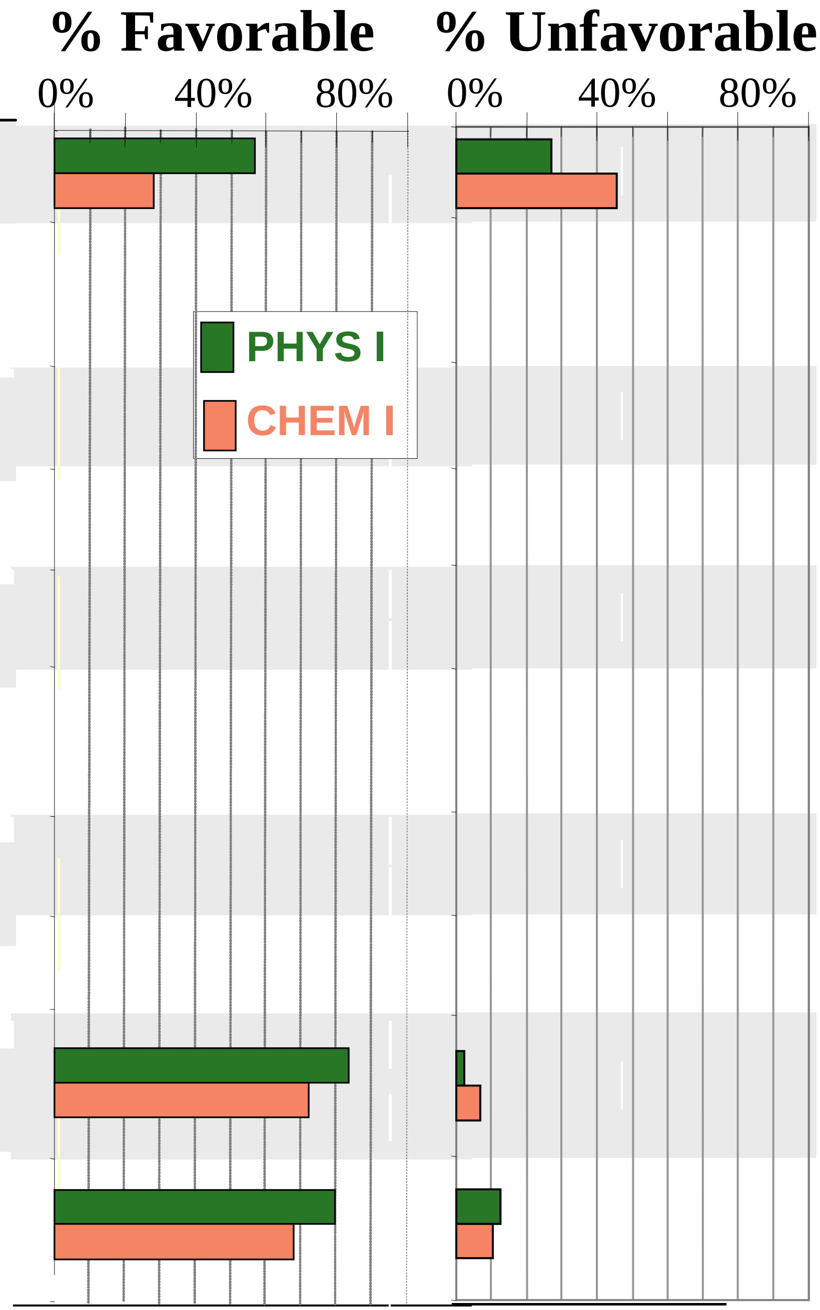

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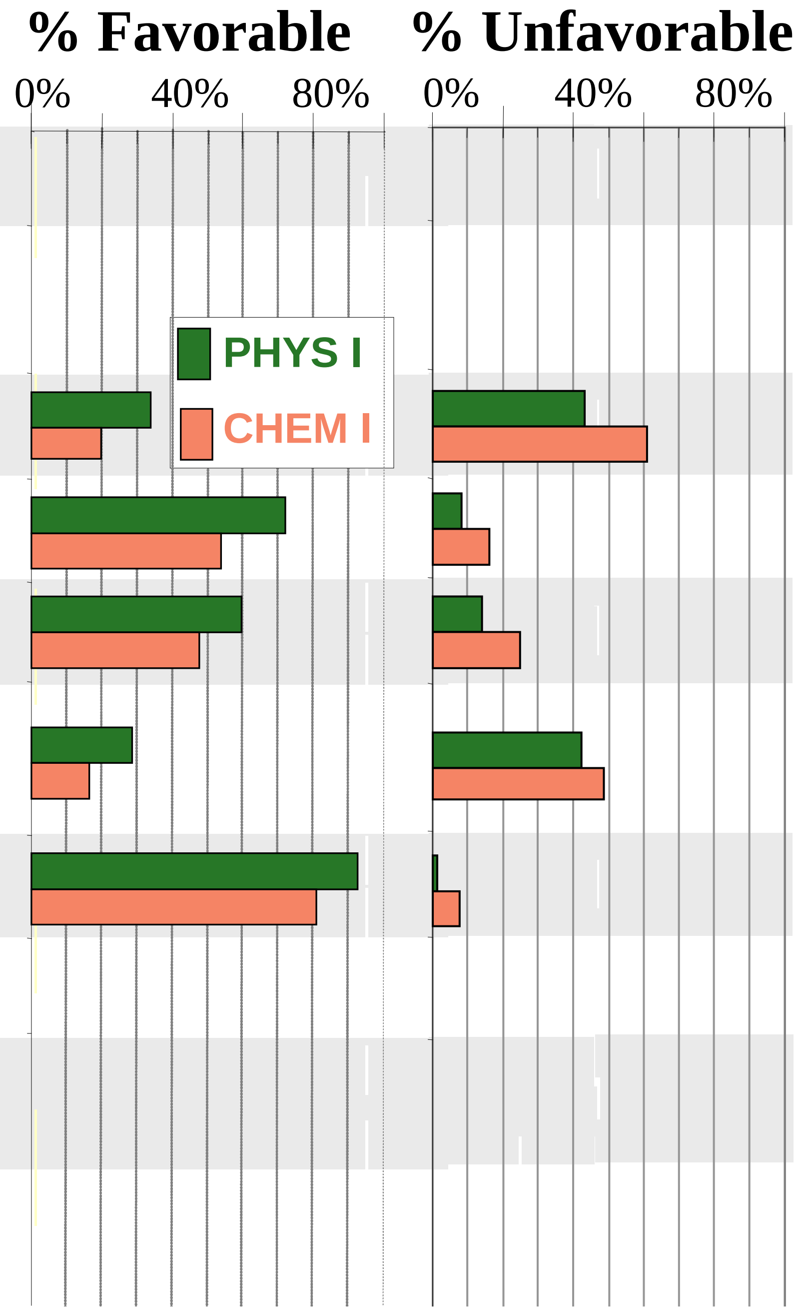

Chemistry vs Physics Beliefs: Individual Statements

?

Why do biology majors see chemistry ….

- as having ***less*** to do with the real world
- as being ***less*** conceptual, needing math to explain chemistry but not making sense of the math.
- as being ***more*** about memorizing disconnected pieces of information and sample problems,

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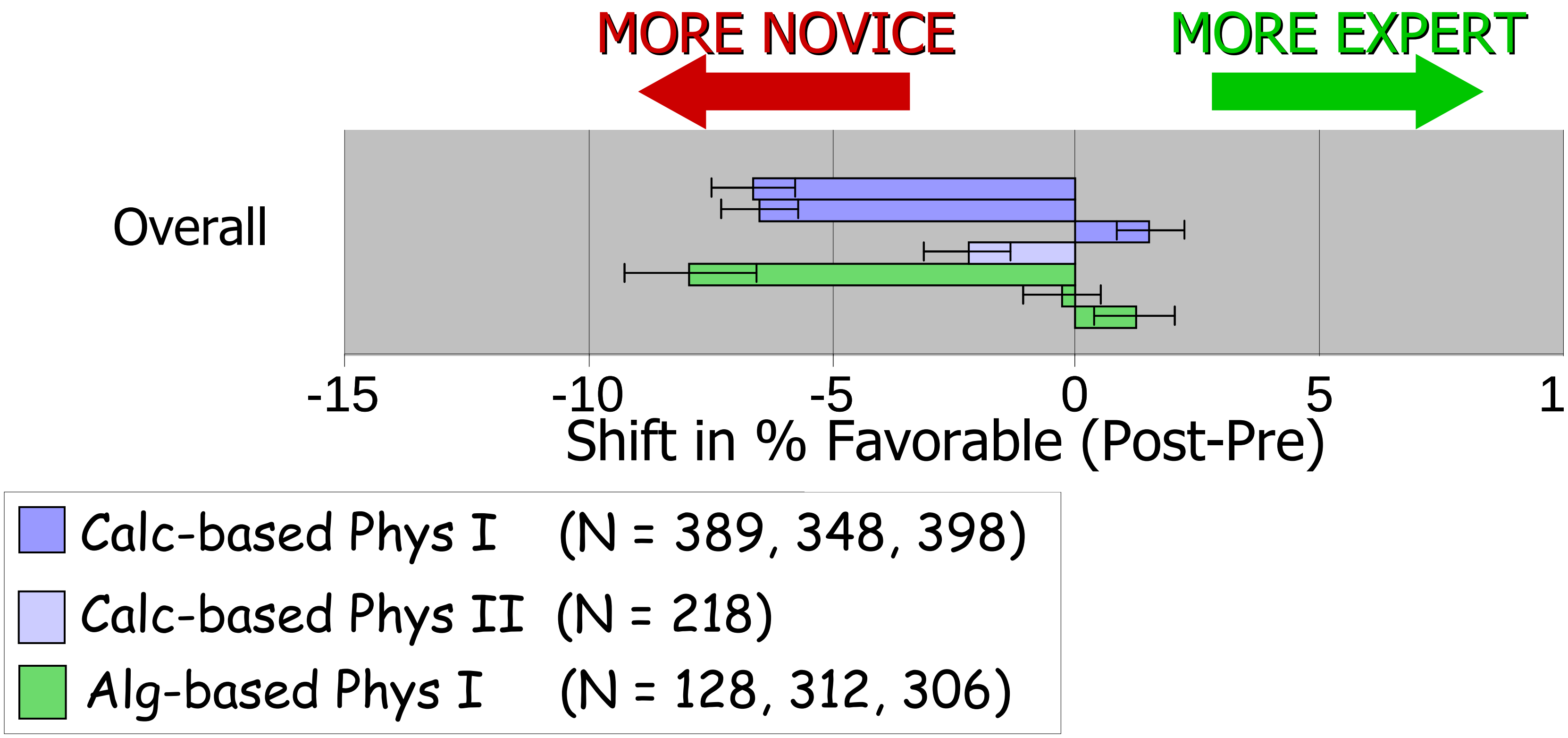
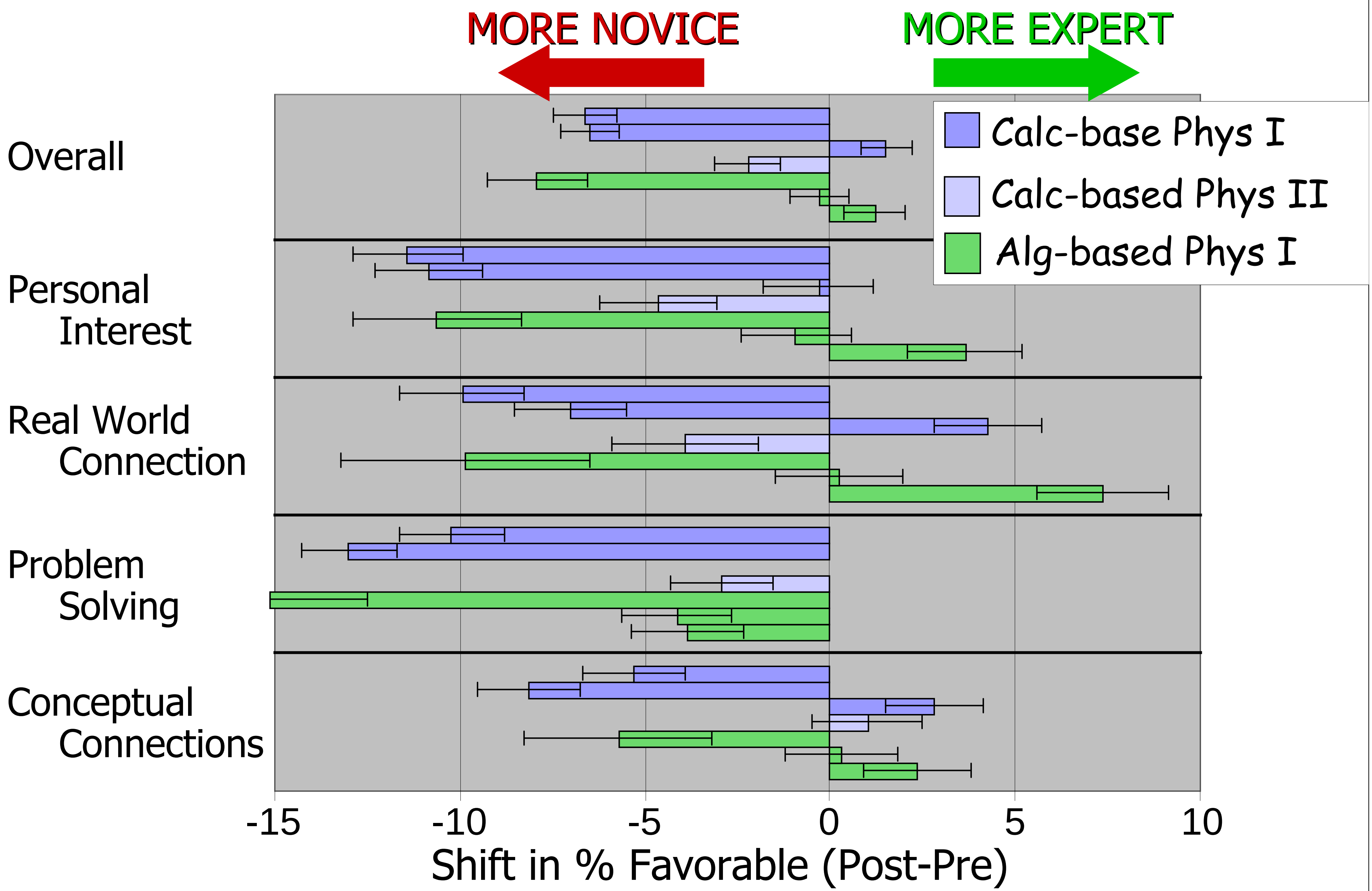
Can we impact students' beliefs through our teaching?

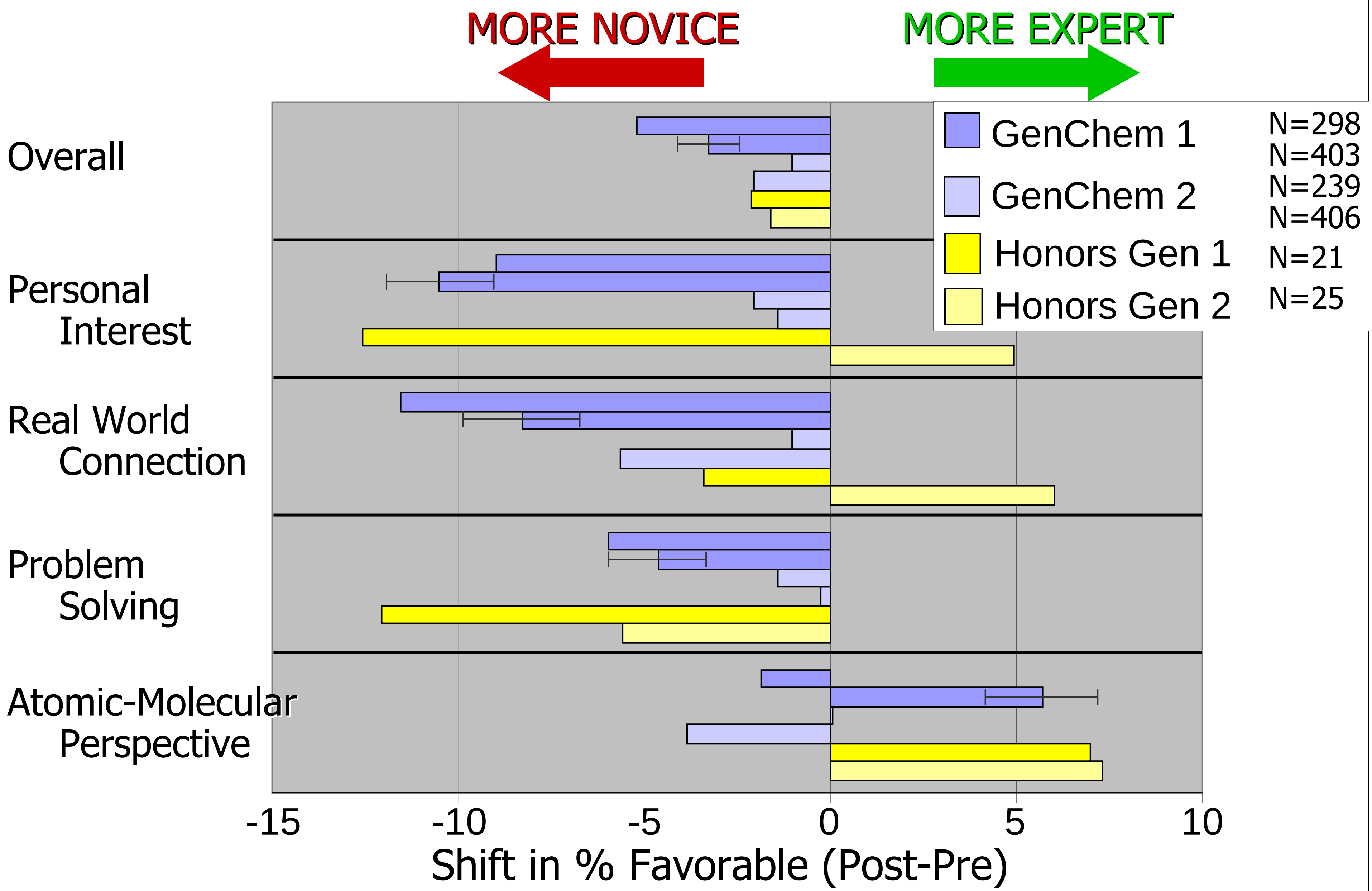
- MPEX work in Physics:
  Students' expectations shift to be *more* novice
  (decline of ~5-8% in 'Overall' %fav)
- CLASS-Phys results at CU-Boulder:



Impact on categories of students' beliefs



What about in chemistry?



Insights and successes in addressing students' beliefs

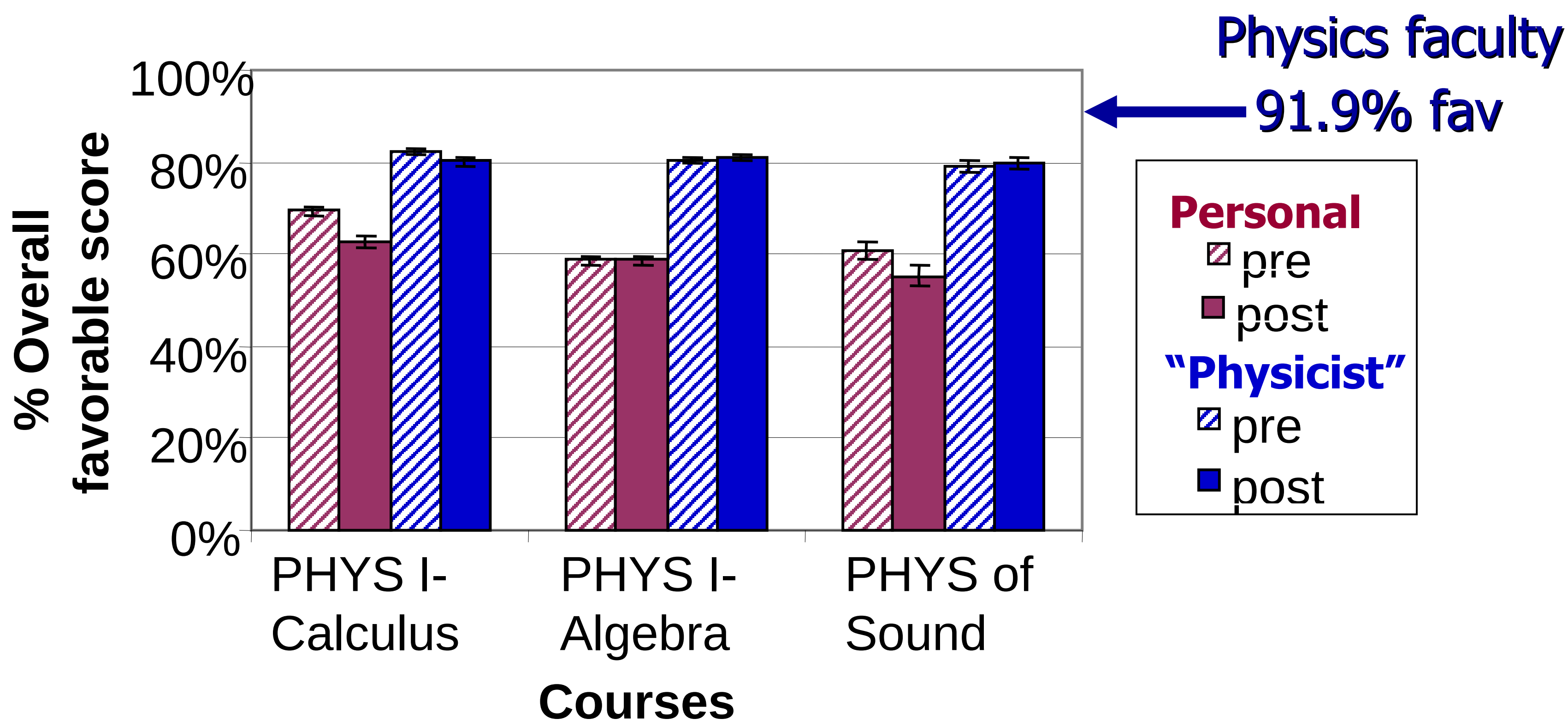
Important question:

Do students' know
what experts' believe or not?

Do students' know what physicists believe?

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

Strongly Agree	1	2	3	4	5	Strongly Disagree
What do YOU think?	○	○	○	○	○	**Personal Score**
What would a physicist say?	○	○	○	○	○	**"Physicist" Score**



Strategies that have helped

Explicitly attending to beliefs in **all** aspects of course

- Using many real-world, everyday-life contexts
- Including conceptual questions
- Emphasizing students' developing and explaining reasoning, e.g. using peer learning and requiring reasoning.
- Having students explicitly discuss/explain connections, e.g. using compare/contrast cases, including multiple representations.

CU Phys:
Seen beliefs hold steady

CU Chem:
Seen less regression in real world, and increase in A-M perspective

- Maryland PER group:

Andy Elby (AJP, 2001): Physics about refining intuitive ideas, e.g. Elby Pairs
Used metacognitive questions in HW
Practices to promote "learning-oriented" approach

Joe Redish: includes Elby pairs, metacognitive skills (paper soon!)

CLASS Development: Probing beliefs about science

Novice		Expert
Isolated pieces of information	**content and structure**	Coherent framework of concepts
Handed down by authority. No connection to real world	**source**	Describes nature. Established by experiment
Pattern matching to memorized recipes.	**problem solving**	Systematic concept-based strategies. Widely applicable.

Adapted from David Hammer (Cognition and Instruction)

CLASS: Development

- Creating statements

  represent novice – expert differences

  (how do biologists think about biology,
  what do students say that experts would disagree to?)

EXAMPLES SPECIFIC TO FIELD:

- Why chemicals react the way they do does not usually make sense to me; I just memorize what happens.
- A poem means anything I think it means.
- Programming is really mostly debugging.

CLASS: Development

- Creating statements

  represent novice – expert differences

    (how do biologists think about biology,
    what do students say that experts would disagree)

  clarity of language

    use students' voice

    avoid multiple ideas in one statement

    avoid "intuitive", "theory", "domain", "concept"

    (in chem: avoid "structure", specify "equation" and "formula" in chem)

  probe students general beliefs

    … avoid course-specific beliefs

      "in this course …." (also creates pre-survey issues)

    … make appropriate for all levels of students

EXAMPLES OF MPEX STATEMENTS DROPPED OR REVISED:

A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough.

Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation.

CLASS: Development

- Testing (validating) statements

  Interview with students (variety of levels)

  Collect responses from and interviews with professors (experts)

  Verify that:

  1) Interpretation is clear and consistent
  2) Students reasoning for response consistent with response and with novice-expertness of view
  3) Professors have consistent response
  4) Reasonable spread among student responses

- Conducting factor analysis to determine categories

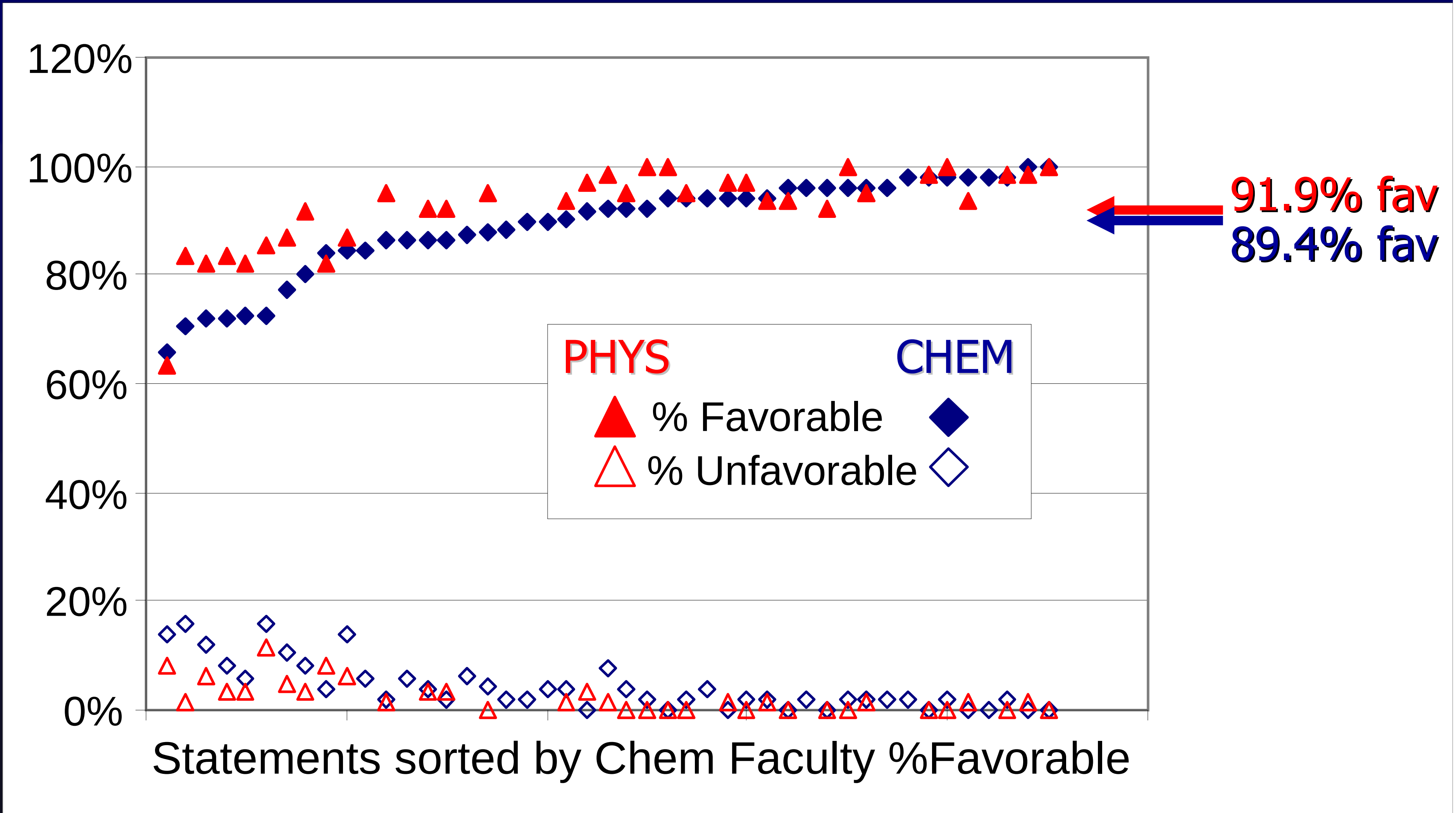
  need a lot of responses from a variety of students

  categories emerges from student data (represent student thinking)

  categories are not determined by expert.

Chemistry vs Physics Beliefs: Experts

Personal beliefs of Physics and Chemistry Faculty



Chemistry vs Physics Beliefs: Experts

CHEM Fav	CHEM Unfav	PHYS Fav	PHYS Unfav	
66%	14%	63%	8%	14. I cannot learn chemistry if the teacher does not explain things well in class.
71%	16%	84%	2%	1. A significant problem in learning chemistry is being able to memorize all the information I need to know.
72%	12%	82%	6%	9. When I solve a chemistry problem, I locate an equation that uses the variables given in the problem and plug in the values.
72%	8%	84%	3%	16. I study chemistry to learn knowledge that will be useful in my life outside of school.
73%	6%	82%	3%	19. Nearly everyone is capable of understanding chemistry if they work at it.
73%	16%	85%	11%	45. It is possible to explain chemistry ideas without mathematical formulas.
77%	10%	87%	5%	22. To understand chemistry I discuss it with friends and other students.
80%	8%	92%	3%	43. To understand chemistry, I sometimes think about my personal experiences and relate them to the topic being analyzed.

Conclusions

- CLASS probes general beliefs about physics or chemistry
- Major findings:
  - Majors more expert-like than non-majors from the start
  - Students' level of interest correlated with beliefs
    - Evidence that beliefs drive increases in interest
  - Biology majors: Less expert-like beliefs about chemistry
  - Specifically attending to beliefs can avoid regression

http://class.colorado.edu