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

Kathy Perkins

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Physics Education Research Group

University of Colorado

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*Wendy Adams
*Jack Barbera (chem)
Mariel Desroche
Pat Kohl
Lauren Kost
Noah Podolefsky
Chandra Turpen

School of Ed:
Valerie Otero,
Danielle Harlow
*Kara Gray
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**

- Isolated pieces of information
- Hand down by authority. No connection to real world
- Pattern matching to memorized recipes.
- *(boring, useless)*

**Expert**

- Coherent framework of concepts
- Describes nature. Established by experiment
- Systematic concept-based strategies. Widely applicable.
- *(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.

## CLASS: Scoring

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

*I think about the physics I experience in everyday life.*

- **Score ‘Overall’ % Favorable**: (%Unfavorable, %Neutral)
  - percentage of statements for which the student agrees with the expert

- **Score % Favorable on individual statements**: percentage of students agreeing 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)
Outline

• What do we mean by beliefs?
• Measuring beliefs: The CLASS-Phys and CLASS-Chem Survey
  • Importance of studying students’ beliefs:
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• Can we impact students’ beliefs?
• Developing belief surveys
Surveyed beliefs and choice of major

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

![Survey results for different majors and course levels.](image-url)
Students who choose to major in chemistry see chemistry as highly relevant and useful in everyday life.

- Majors in the same class are more expert.

The chart compares the percentage of favorable scores (PRE) for different courses and groups:

- Chem Faculty
- Physical I (Juniors-Seniors)
- Organic II (majors)
- General I (majors)
- Organic II (non-majors)
- General I (non-majors)
- Prep for Gen I
- Environmental
Distribution of Beliefs

Overall % Favorable (PRE) (Percentage of statements for which student agrees w/ expert)

- Alg-based Phys I (N=309)
- Calc-based Phys I (N=389)
- 3rd semester for phys majors (N=61)

Percentage of respondents

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Novice-like

Expert-like
<table>
<thead>
<tr>
<th>Are we ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating majors with expert-like beliefs</td>
</tr>
</tbody>
</table>

?
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

Beliefs at **START** of Phys I

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

Beliefs at START of GEN CHEM

- All Students
- Intended Chem Majors

Percentage of respondents

‘Overall’ % Favorable (PRE)
Looking at Individual Statements

Gen Chem I

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

<table>
<thead>
<tr>
<th>Change in Interest</th>
<th>Increased</th>
<th>No change</th>
<th>Decreased</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%)</td>
<td>19%</td>
<td>37%</td>
<td>45%</td>
</tr>
</tbody>
</table>

- 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

• Over 50% of increased interest reasons related to surveyed beliefs

• Top 3 belief reasons:
  1. Real World Connection
  2. Personal Interest (usefulness)

• 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 PRE beliefs

- Biology Majors consistently have more expert-like beliefs about Physics
13. I do not expect [ ] equations to help my understanding of the ideas; they are just for doing calculations.

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

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

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

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

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

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

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

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.

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

38. To understand [ ], I sometimes think about my personal experiences and relate them to the topic being analyzed.
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<th>% Unfavorable</th>
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<td>38. It is possible to explain [ ] ideas without mathematical formulas.</td>
<td>![chart]</td>
<td></td>
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<td>Statements</td>
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<td>% Unfavorable</td>
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<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>---------------</td>
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<td>CHEM I</td>
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<td>CHEM I</td>
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</table>
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,
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
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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:**

- **Overall**

  - **Calc-based Phys I** (N = 389, 348, 398)
  - **Alg-based Phys I** (N = 128, 312, 306)
Impact on categories of students’ beliefs

MORE NOVICE
MORE EXPERT

Overall

Personal Interest

Real World Connection

Problem Solving

Conceptual Connections

Calc-based Phys I
Calc-based Phys II
Alg-based Phys I

Shift in % Favorable (Post-Pre)
What about in chemistry?

The chart shows the shift in percentage favorable for various aspects of chemistry education, categorized by level of expertise (more novice vs. more expert) and type of course (GenChem 1, GenChem 2, Honors Gen 1, Honors Gen 2).

- **Overall**:
  - More Novice: GenChem 1 (N=298), GenChem 2 (N=403), Honors Gen 1 (N=239), Honors Gen 2 (N=406).

- **Personal Interest**:

- **Real World Connection**: Differences are observed between GenChem 1, GenChem 2, Honors Gen 1, and Honors Gen 2.

- **Problem Solving**: Similar to Personal Interest and Real World Connection, with differences noted for each course category.

- **Atomic-Molecular Perspective**: Significant differences are highlighted, showing a notable shift towards more favorable responses.

The y-axis represents the aspects of chemistry education, while the x-axis shows the shift in percentage favorable (Post-Pre).
Insights and successes in addressing students’ beliefs

Important question:

Do students’ know what experts’ believe or not?
1. A significant problem in learning physics is being able to memorize all the information I need to know.

What do YOU think?  
Strongly Agree 1 2 3 4 5 Strongly Disagree

What would a physicist say?  
"Physicist" Score

Physics faculty 91.9% fav

Physics faculty

Personal
- pre
- post

“Physicist”
- pre
- post
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.

- 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!)

**CU Phys:**
- Seen beliefs hold steady

**CU Chem:**
- Seen less regression in real world, and increase in A-M perspective
## CLASS Development: Probing beliefs about science

<table>
<thead>
<tr>
<th>Novice</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated pieces of information</td>
<td>Coherent framework of concepts</td>
</tr>
<tr>
<td>Handed down by authority. No connection to real world</td>
<td>Describes nature. Established by experiment</td>
</tr>
<tr>
<td>Pattern matching to memorized recipes.</td>
<td>Systematic concept-based strategies. Widely applicable.</td>
</tr>
</tbody>
</table>

- **content and structure**
- **source**
- **problem solving**

Adapted from David Hammer (Cognition and Instruction)
- 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**
  1. Interview with students (variety of levels)
  2. 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.
<table>
<thead>
<tr>
<th>CHEM</th>
<th>PHYS</th>
<th>Fav</th>
<th>Unfav</th>
<th>Fav</th>
<th>Unfav</th>
</tr>
</thead>
<tbody>
<tr>
<td>66%</td>
<td>14%</td>
<td>63%</td>
<td>8%</td>
<td>86%</td>
<td>4%</td>
</tr>
<tr>
<td>71%</td>
<td>16%</td>
<td>84%</td>
<td>2%</td>
<td>92%</td>
<td>8%</td>
</tr>
<tr>
<td>72%</td>
<td>12%</td>
<td>82%</td>
<td>6%</td>
<td>93%</td>
<td>7%</td>
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<td>3%</td>
<td>88%</td>
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</tr>
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<td>73%</td>
<td>6%</td>
<td>82%</td>
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<td>6%</td>
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<td>73%</td>
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<td>11%</td>
<td>95%</td>
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<td>77%</td>
<td>10%</td>
<td>87%</td>
<td>5%</td>
<td>97%</td>
<td>3%</td>
</tr>
<tr>
<td>80%</td>
<td>8%</td>
<td>92%</td>
<td>3%</td>
<td>98%</td>
<td>2%</td>
</tr>
</tbody>
</table>

1. A significant problem in learning chemistry is being able to memorize all the information I need to know.
2. To understand chemistry I discuss it with friends and other students.
3. Nearly everyone is capable of understanding chemistry if they work at it.
4. I study chemistry to learn knowledge that will be useful in my life outside of school.
5. It is possible to explain chemistry ideas without mathematical formulas.
6. 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