Epistemological Framing as a Lens on Students, Teachers, and Researchers

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- Jon Shemwell (physics)

Stay tuned for the TRUSE mini-grant presentation Tuesday...
One possible goal of physics education research

To teach more effectively by listening to students’ ideas and using what we hear to respond to them more usefully.
Investigating knowledge of student thinking

To understand student thinking, we have to listen carefully.

What are we listening for?
Formative Assessment

“...all those activities undertaken by teachers, and/or by students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged” (Black & William, 1998)

- Giving students a survey
- Asking a student a question
- Holding a class discussion
- Performed before or after the subject is taught
- Performed as the subject is taught

Uses of Formative Assessment

• Adjust instruction to focus on areas of difficulty

• Use students intuitive ideas to teach them correct physics

• Confront students with anomalous data

  i.e. focus our attention on something and change our practice
Epistemological framing in our research

“To frame an event, utterance, or situation in a particular way is to interpret it based on previous experience: to bring to bear a structure of expectations about a situation regarding what could happen, what portions of the information available to the senses require attention, and what might be appropriate action.” (Scherr & Hammer 2010)
Last night’s examples of epistemological framing
David Bressoud

How the students frame calculus is correlated to whether they stayed in calculus:

- Calculus Switchers thought that calculus was about solving specific problems.
- Non-Switchers thought it was about logical reasoning and reasoning skills.

And faculty aren't responding: instructors think they are asking questions that the exams themselves don't reflect. There is a mismatch in how they are framing their practice and how researchers observe it.
Perhaps it’s not always a misconception — sometimes it may be a framing issue.

Biology
- By its very choice of subject biology is irreducibly complex. (Oversimplify and you die.)
- Most introductory biology is qualitative.
- Biology contains a fundamental historical component.
- Much of introductory biology is descriptive (and introduces a large vocabulary) though
- Biology — even at the introductory level — looks for mechanism and often considers micro-macro connections.
- Chemistry is much more important to intro bio than physics (or math).

Physics
- Intro physics often stresses reasoning from a few fundamental (mathematically formulated) principles.
- Physicists often stress building a complete understanding of the simplest possible (often abstract) examples — and often don’t go beyond them at the introductory level.
- Physicists quantify their view of the physical world, model with math, and think with equations.
- Introductory physics typically restricts itself to the macroscopic level and almost never considers chemical bonds.
Two examples of epistemological framing

1. Listening for what the words give away
   How does grammar tell us about what students think they’re doing? What happens when students disagree on method, not content?

2. Giving away the game to learn more about what students are thinking
   How does changing questions affect data? How are students framing the questions we ask them?
Listening for what students reveal

In our research, students tell us things and we figure out what they must have been thinking.

But they also tell us things they didn’t know they were telling us.

We can use “hidden” information to find out about the kind of activity they’re involved in.
Student expectations: a laundry list

- how to behave in a classroom
- how to interact with a worksheet
- how to interact with other students
- how to interact with teachers
- what science is
- what it means to learn particular phenomena
Debating Damped Harmonic Motion

Sophomore level mechanics course at UMaine. Group of students working on the first of a series of group learning activities on damped harmonic motion (*Intermediate Mechanics Tutorials*)

Task is to compare the period of oscillation for an underdamped harmonic oscillator to that of an identical simple harmonic oscillator

James: Same Period

Martin: Longer Period
James wants to use math...

“I could probably do out all the math”

“I think we can do this easier if we check out the formula”

“I agree it makes sense, but I’m pretty sure there’s math that evens out behind the scenes so to speak”

“The math checks out. The math makes sense.”
Martin responds to James

\[ x(t) = Ae^{-kt} \cos(\omega t - \delta) \]

Is this the same \( \omega \) as in undamped motion?

James: *Uh when you damp, um, an oscillator, just the amplitude, but the period remains the same*

Martin: Okay, well, see, *but isn't it that like it- the- so there's like a object at the end of the spring, it would experience a force based on its displacement from the origin, but, uh- which- and its acceleration would be based on that force, but in the underdamped case there would be a- like say a frictional force or something opposing that force whereas the- in a undamped case there would be no such frictional force so the acceleration would always be greater for a undamped force.*
Our language is full of markers

We tell stories. Our ways of talking uncover our expectations in a story (and how those expectations are violated). (Tannen 1979)

Some markers:

<table>
<thead>
<tr>
<th>omission</th>
<th>inference</th>
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</thead>
<tbody>
<tr>
<td>repetition</td>
<td>evaluative language</td>
</tr>
<tr>
<td>false starts</td>
<td>interpretation</td>
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<tr>
<td>backtrack</td>
<td>moral judgement</td>
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<td>hedges</td>
<td>incorrect statements</td>
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<tr>
<td>negatives</td>
<td>addition</td>
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<tr>
<td>inexact statements</td>
<td>contrastive connectives</td>
</tr>
<tr>
<td>generalization</td>
<td>modals</td>
</tr>
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</table>
Contrastive connectives: But

Contrastive connective – denial or violation of an expectation (Tannen 1979).

“No, no. Uh, periods don’t change. Uh when you damp, um, an oscillator, just the amplitude- **but** the period remains the same”
Modals: can may must shall will and derivatives

Modals – an expectation based on past experience, standards or possibilities (Tannen 1979).

“it would experience a force based on its displacement from the origin ... in the underdamped case there would be a- like say a frictional force or something opposing that force whereas the - in a undamped case there would be no such frictional force so the acceleration would always be greater for a undamped force.”
Searching for but’s and modals in dialogue

Take transcript - highlight the “Tannen words”

Shrink the page size appropriately

Look for dense color patterns...

No or few “Tannen words”

Isolated use of buts and modals

Mixed buts and modals
Buts and Modals together

"it would experience a force based on its displacement from the origin, but, uh- which- and its acceleration would be based on that force"
Example: James and Martin arguing

James: *That distance is the same* but *the time* i- *the distances are different* but *the time is the same.*

James is contradicting a statement Martin made (not shown...) as well as his own statement about distance.
Example: A bid for shared experience

Martin: *No, no the distance is the same* but *the time can’t be the same because the acceleration is different.*
Example: Restricted shared experience, contrast

James: I'm confused. Oh yeah in the undamped case yeah the distance **would** be the same in both cases but **it'll** just go back down to here and it **should** hit the same.
Second example: Bids for math, not physics

James: *Umm. I- I could probably do out all the math,*  
*but* I think the gist of it is, is, sure, there is less resisting force  
*but* it's also going out further so it's accelerating more,  
*but* it's also got a greater distance.
Martin: Okay, **but** like a, like a severely damped force **would** just come down like this, right to there. ... So, **wouldn't** that theoretically have like an infinite period? **Wouldn't** that argue that damping a force **would** change the period?
“Tannen word” use depends on activity

When James and Martin are debating which *kind* of reasoning to use (math or physics), their language is full of but+modal arguments.
“Tannen word” use depends on activity

When James and Martin are debating which *kind* of reasoning to use (math or physics), their language is full of but+modal arguments. Later, when they have decided on a mathematical pathway, both buts & modals drop out of their discourse.
“Tannen word” use depends on activity

When James and Martin are debating which kind of reasoning to use (math or physics), their language is full of but+modal arguments.

Later, when they have decided on a mathematical pathway, both buts & modals drop out of their discourse.

Suggests that they agree on the details of doing the math...

... but disagree on whether it’s the right tool to use.
(Martin can do the math, but doesn’t think it’s the right choice)
Why should we care about this?

The “difficulty” the students are having isn’t about the content or the math.

It’s about what they think is the relevant activity and how they negotiate what to do next...

As researchers, what are we studying? Which part of this is “the physics” and which is not?
Turning canonical PER tasks on their head

We have a history of seemingly simple yet challenging questions

The “UW style question” is often answered correctly by 15%

• before instruction

• after instruction

• by undergraduates, graduate students, and faculty

How robust is that kind of result?
The indicator bulb question

1. The circuit at right contains an ideal battery, three identical light bulbs, and a switch. Initially the switch is open.

After the switch closes:

Does the brightness of bulb A increase, decrease, or remain the same? Explain.
Select a correct response and explain why it is correct.

<table>
<thead>
<tr>
<th>How a student would answer</th>
<th>Response justified by student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase</td>
<td>Increase Canonical</td>
</tr>
<tr>
<td>Decrease</td>
<td>Decrease Canonical</td>
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<tr>
<td>The Same</td>
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## Seeking Additional Information

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Can we learn more about students ideas by investigating these other areas?
## Eliminate

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<td>Eliminate</td>
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Select an incorrect response and explain why it is incorrect.
Consider Only One.

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<tr>
<td><strong>Increase</strong></td>
<td>Canonical Consider A</td>
<td>Eliminate Consider B</td>
<td>Eliminate Consider C</td>
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<tr>
<td><strong>Decrease</strong></td>
<td>Eliminate Consider A</td>
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<td>Eliminate Consider B</td>
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Is A/B/C correct? Explain.
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<td>Eliminate</td>
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<tr>
<td></td>
<td>Consider A</td>
<td>Consider B</td>
<td>Consider C</td>
<td></td>
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<tr>
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<td>Given Correct</td>
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Justify why the correct answer (e.g., A) is correct. Explain.
### Given Incorrect

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Justify why this incorrect answer (given) is incorrect. Explain.
Questions 1–3 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (A through G) to indicate the acceleration of the coin during each of the stages of the coin's motion described below. Take up to be the positive direction. Answer choice J if you think that none is correct.

A. The acceleration is in the negative direction and constant.
B. The acceleration is in the negative direction and increasing
C. The acceleration is in the negative direction and decreasing
D. The acceleration is zero.
E. The acceleration is in the positive direction and constant.
F. The acceleration is in the positive direction and increasing.
G. The acceleration is in the positive direction and decreasing.

G 1. The coin is moving upward after it is released.
D 2. The coin is at its highest point.
B 3. The coin is moving downward.
A canonical PER problem: Interpreting the GDB response

Clement 1982

Impetus Theory

The force of the throw stays in the hand and gets used up as the object travels to the top - then gravity takes over.

Failure to...

Students have not disambiguated “motion” into “velocity” and “acceleration” ($v$ and $dv/dt$)
Expected common response: $a = 0$ at top

$a = 0$ at top for 60%

About 40% say $a = 0$ at top after saying $a$ points up on way up (GDB pattern)

About 10% say $a = 0$ at top after saying $a$ points down on way up (ADA pattern)

About 10% say $a = 0$ at top, connected to other response pattern
Questions for #2 (at the top)

Everyone did the same multiple choice version of #1

For #2:

Traditional multiple choice question

“Is it zero at the top?”

“It’s not zero at the top. Explain”
Answering G predicts answering D, or does it?

GDB response:

When given canonical version, nearly 100% of students who answer G on #1 answer D (a = 0) at the top.

But not when asked differently:

When asked if it’s zero at the top, only 40% who gave G on #1 say yes.
Explaining why it isn’t zero

When told $a \neq 0$ at the top, 3/4 of students give good (enough) explanations
Summary of \( a = 0 \) at top

60\% say \( a = 0 \) at top,

but when GDB responders are asked differently, half no longer say \( a = 0 \) at top

and 75\% can justify why \( a = 0 \) is incorrect.
How many students “really think” $a = 0$ at the top?

Can – 60% say $a = 0$

GlnC – 75% explain why $a \neq 0$

Huh?
The indicator bulb question

1. The circuit at right contains an ideal battery, three identical light bulbs, and a switch. Initially the switch is open.

After the switch closes:

Does the brightness of bulb A increase, decrease, or remain the same? Explain.
Electric Circuits Pilot Study

Limit to four different questions because of low number of students (N=100)

Previous research shows students perform poorly

- Choosing questions targeting the correct answer will get reasoning Canonical questions don’t

- All four question types ask about *increase*
The circuit at right contains an ideal battery, three identical light bulbs, and a switch. Initially the switch is open. After the switch closes:

Does the brightness of bulb A increase, decrease, or remain the same? Explain.

The brightness of bulb A increases. Explain.

Imagine you are taking an exam with the question shown in the box below. You want to first eliminate one response you are pretty sure is incorrect. Which response would you eliminate? Why is that response the best one to eliminate?

The circuit at right contains an ideal battery, three identical light bulbs, and a switch. Initially the switch is open. After the switch closes:

Does the brightness of bulb A increase, decrease, or remain the same? Explain.

Question Administration

Pretest in a UMaine Calculus-based Introductory Physics Course

Each student received only one question type

Administered in a lecture hall at the start of class

Each question was given to 1/4 of the class

We assume the 1/4’s of the class consist of equivalent students
What do students think of *increase*?

Select a correct response and explain why it is correct.

23% (5 out of 22) chose *increase* as correct

Select an incorrect response and explain why it is incorrect.

44% (7 out of 16) chose *increase* as the best response to eliminate

8% (2 out of 26) say *increase* is correct.
92% say it is incorrect.

Does the brightness *increase*? Explain.
What do students think of increase?

65% (17 out of 26) of students provide appropriate reasoning

The brightness increases. Explain

• "The addition of bulb C in a parallel circuit reduces the resistance in the system."

• "After the switch is closed, the charge will go through both the Left (B) side and the Right (C) side to increase the total charge bulb A is receiving."

• "The closing of the switch opens another path for electricity to flow to lightbulb A."

• "The electricity is able to come up through bulb C and enter A from below."
Summary of *Increase*

Some students choose it as correct, nearly half eliminate it as incorrect, very few say it is correct, and most can justify why it is correct.
No statistical significance:
between the number of students choosing *increase* when asked
the Canonical question, or asked to choose only one
(i.e., if the brightness of the bulb increased).

Statistically significant:
between the number of students who could provide valuable
reasoning *when told increase is correct*, and the number of
students who chose it as correct (*p*<.0077, *w*=.427).

NB: This study had low statistical power for finding lower effect
sizes due to the low number of students.
We’re confused and excited

Confused: What does it mean for a researcher to notice “student thinking” when it’s so dependent on question format?

Excited: We get more information from this set of questions than from the Canonical question alone.

- Many students have good reasoning for the correct response
- Many students recognize incorrect responses that they also give
Modeling results using epistemological framing

Changes in responses due to how the question was asked

**IF** we assume that populations are roughly equal, variability can be caused by question format.

**Expectations:** Each question comes with a history of being answered and a sense of what counts as a correct answer.

**Cuing:** Each question cues different kinds of thinking
“To frame an event, utterance, or situation in a particular way is to interpret it based on previous experience: to bring to bear a structure of expectations about a situation regarding what could happen, what portions of the information available to the senses require attention, and what might be appropriate action.”
(Scherr & Hammer 2010)
What are we learning?

Listening for the stories they think they should be telling changes what we attend to.

Perhaps it’s not always a misconception – sometimes it may be a framing issue.

Telling them the answer (or asking slightly different questions) changes what we hear from students
(1/4 answer correctly what 2/3 can explain)

How are students framing the question?
How does our answer raise new questions for researchers?
Epistemological Framing at different scales

Students

What kind of activity is this? What are they asking me?

Researchers

What kind of data is this? What are we looking for?

Teachers

What is most relevant in the classroom? What should I do?