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

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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

1. Black, Paul; Wiliam, Dylan (1998). "Assessment and classroom learning". *Assessment in Education: Principles, Policy & Practice* **5** (1)

Uses of Formative Assessment

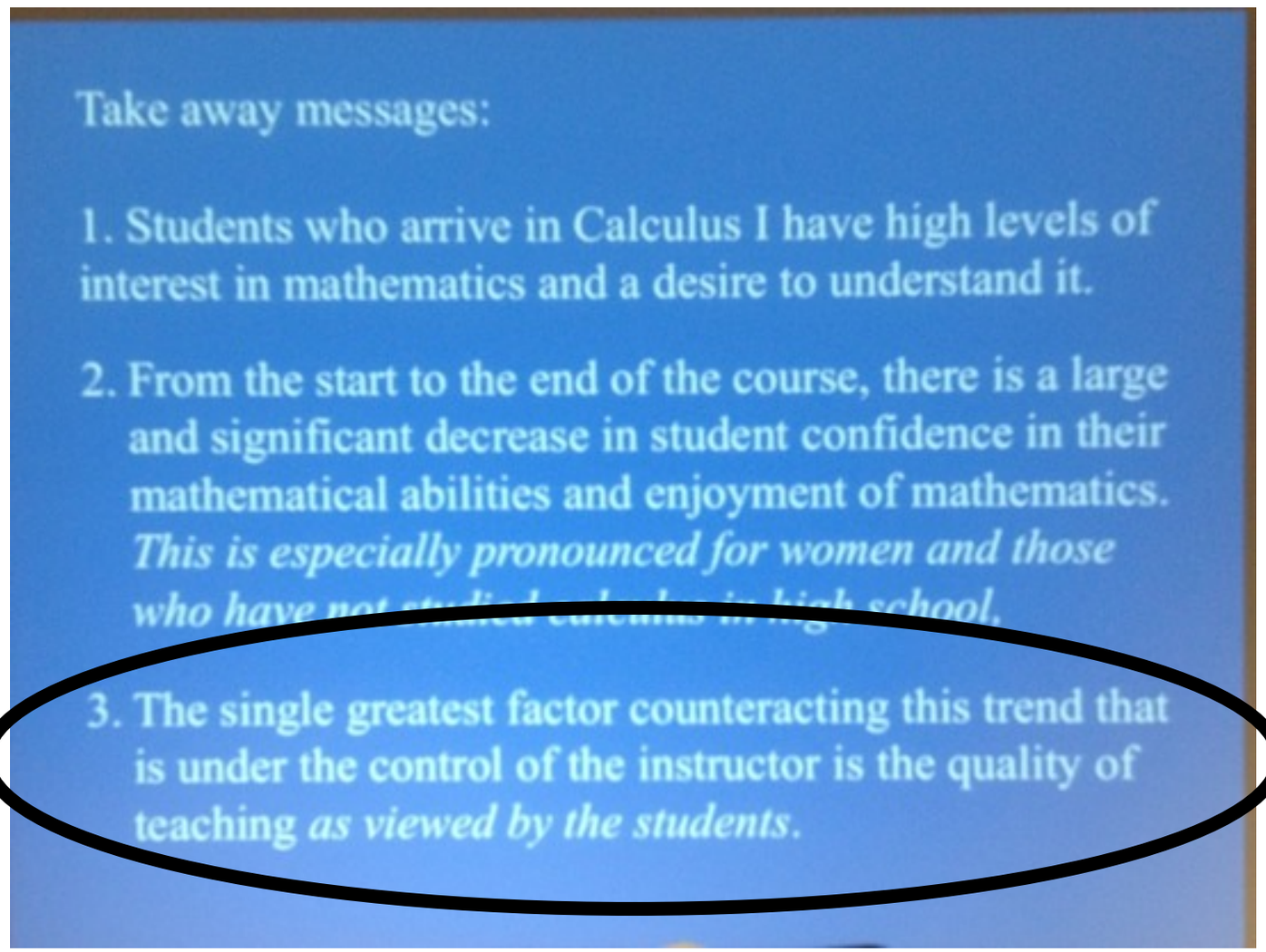
- Adjust instruction to focus on areas of difficulty
- Use students intuitive ideas to teach them correct physics
- Confront students with anomalous data

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.

Last night's examples of epistemological framing
Joe Redish

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

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Biology

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- 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

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- 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

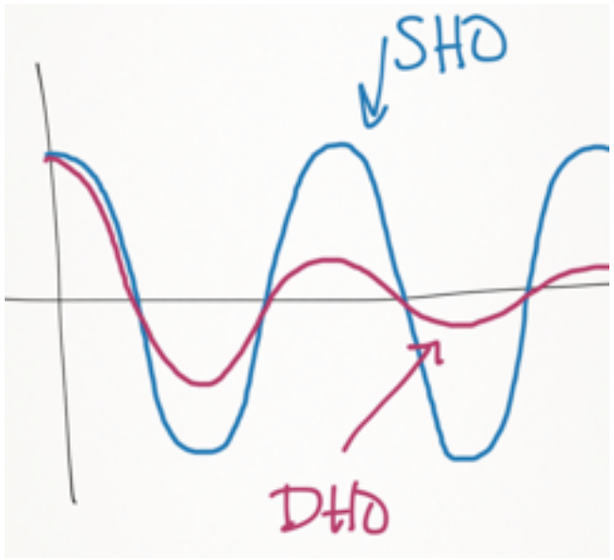
Student expectations: a laundry list

- 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

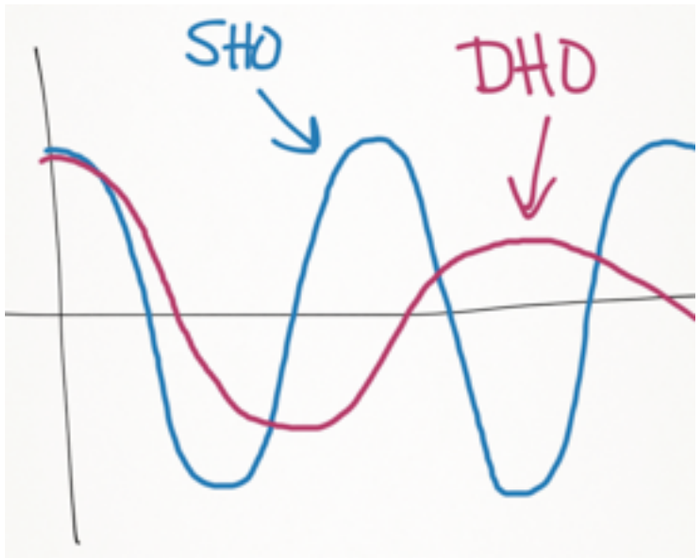
Sophomore level mechanics course at UMaine. Group of students working on the first of a series of group learning activities on damped harmonic motion (*Intermediate Mechanics Tutorials*)

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 ω 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:

omission
repetition
false starts
backtrack
hedges
negatives
inexact statements
generalization
inference
evaluative language
interpretation
moral judgement
incorrect statements
addition
contrastive connectives
modals

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...

James
00:23:14.27
You know neither of them seem to be perfect. Maybe, uh, maybe this is one of those things that works in, um, you know a p- spherical cow world

Keith
00:23:22.54
Ah.

Martin
00:23:23.12
Oh, okay. Even, like just read C for instance, your answers in part B above suggest that retarding force affects the period of oscillation.

James
00:23:30.02
Oh, my bad

Lindsey
00:23:31.62
(laughs)

James
00:23:32.61
Alright

Facilitator
00:23:33.45
Okay.

James
00:23:34.01
So what I'm curious is to why-

Facilitator
00:23:34.86
I'm seeing a textbook being pulled out it is time to finally engage with this group. I keep coming over and asking-

Lindsey
00:23:39.58
We're having a huge fight

Facilitator
00:23:40.70

No or few
"Tannen words"

Keith
00:19:17.23
I don't care (laughs) it's a fish

Martin
00:19:18.09
so how do you distinguish between um oscillators with different frequencies?

James
00:19:25.46
Uhh, that would be omega

Keith
00:19:27.31
yeah (inaudible)

Martin
00:19:27.58
Right, so omega changes

James
00:19:29.18
If it has a different frequency it'll have a different period, ope(?) you change omega

Martin
00:19:33.72
S- but, I- so then I don't get why you don't think omega can be different for?

Keith
00:19:38.94
Because

James
00:19:39.10
Omega can be different.

Keith
00:19:39.97
yeah

James
00:19:40.19
but what we're increasing is beta

Isolated use of
buts and modals

00:12:57.26
Uh, periods don't change

Keith
00:12:58.55
Yeah

James
00:12:58.76
Uh when you damp, um, an oscillator, just the amplitude ... but the period remains the same

Keith
00:13:04.77
Right.

Martin
00:13:04.99
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.

Keith
00:13:39.76
No wouldn't it always be (quietly)

James
00:13:42.14
The acceleration would be greater for an undamped force but als- undamped, but it also goes farther, so it has more distance to travel.

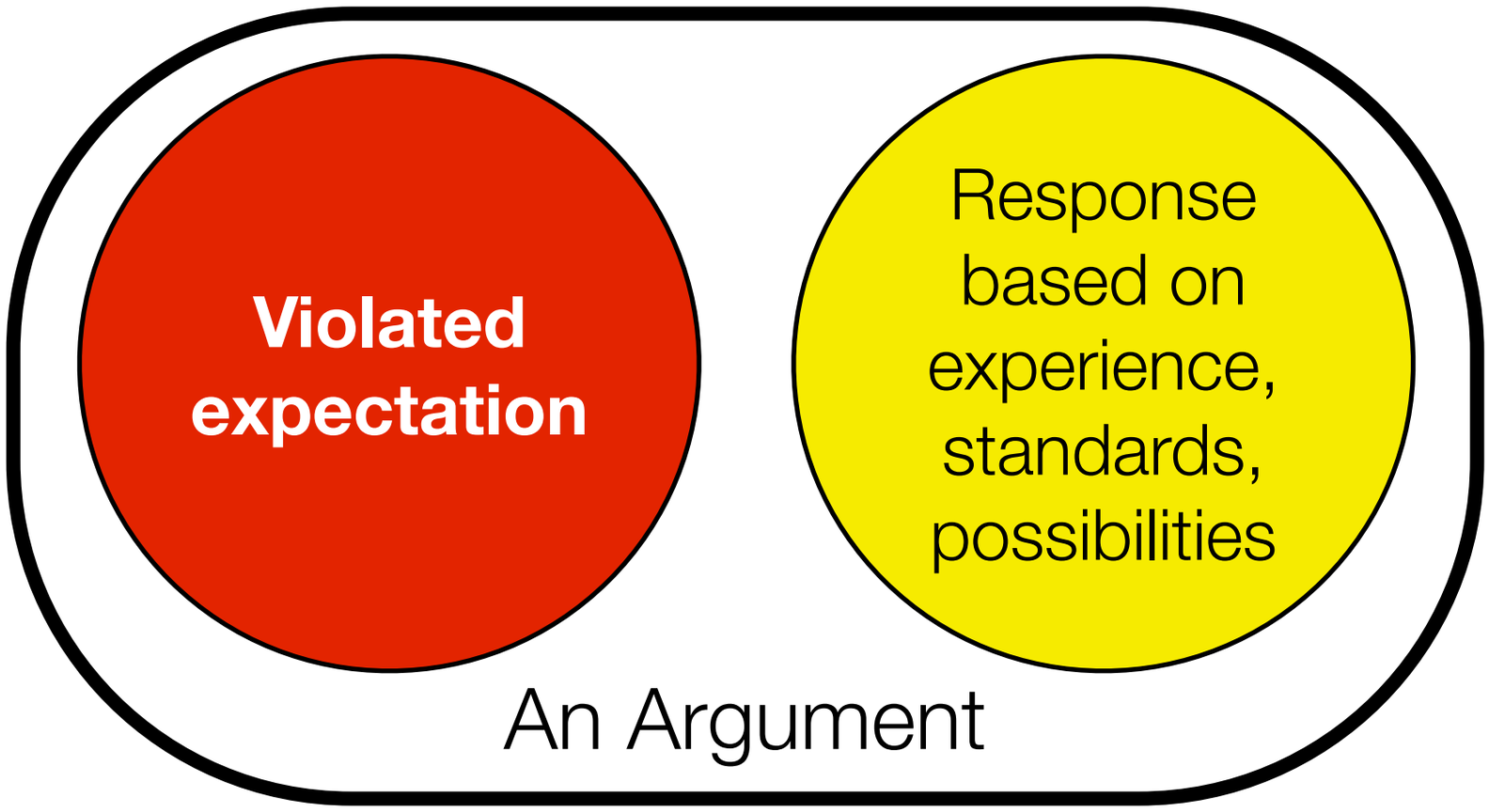
Martin
00:13:42.40
Well 'cause the- the net force is greater.

Martin
00:13:50.60
Right, no but in this- oh okay I th- no no this is just- this is just from X one to uh zero though

James

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”*

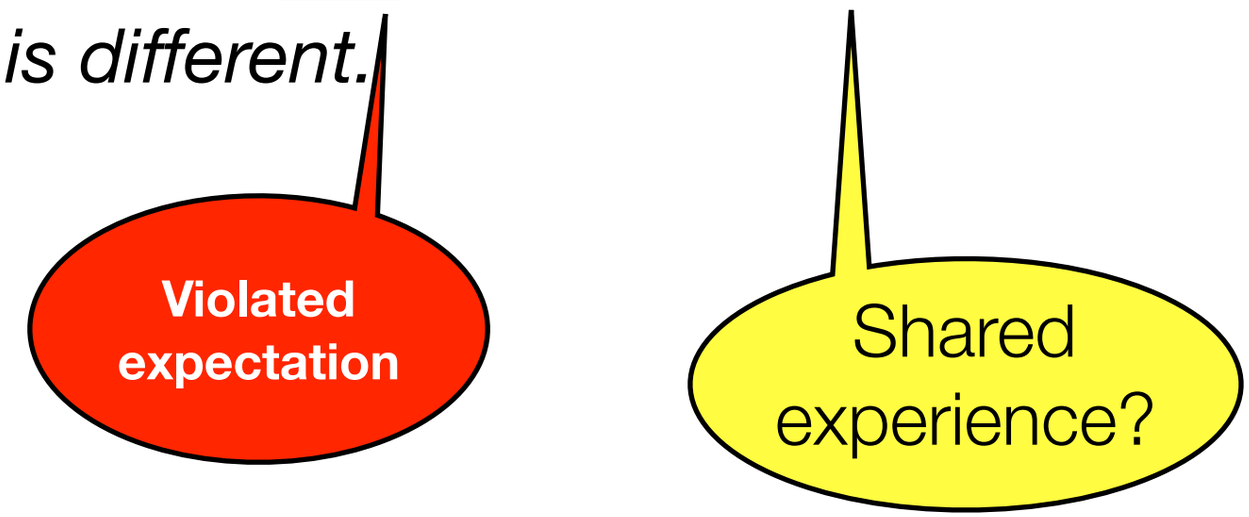
Example: James and Martin arguing

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.

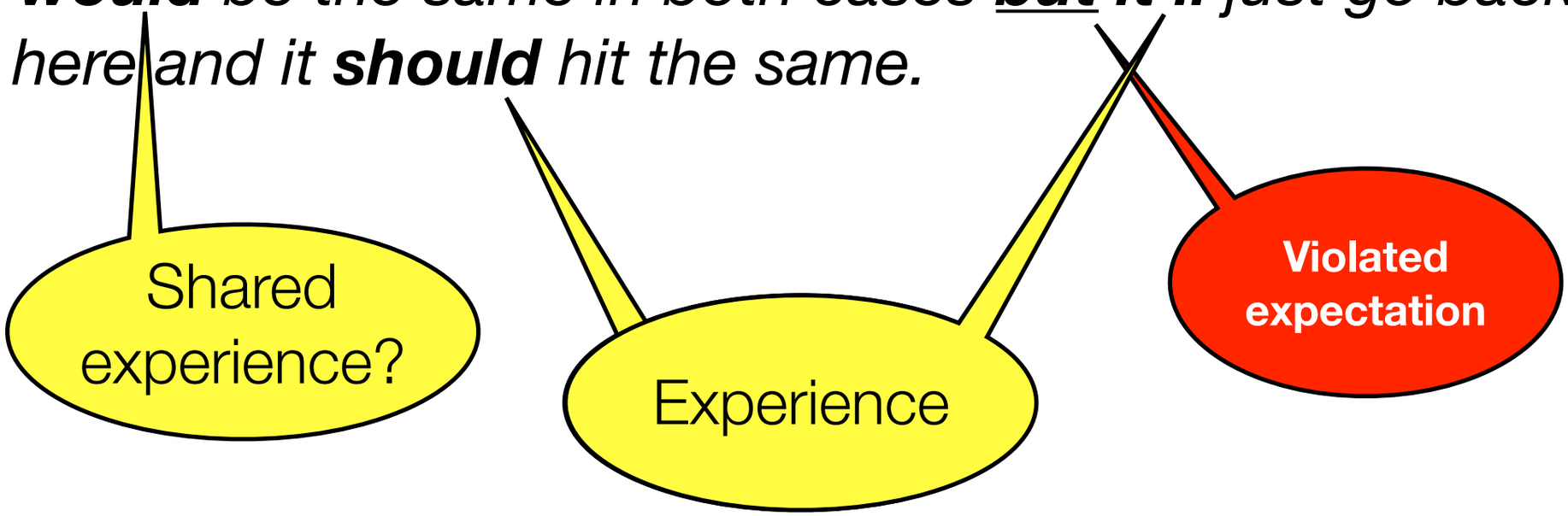
Example: A bid for shared experience

Martin: *No, no the distance is the same **but** the time **can't** be the same because the acceleration is different.*



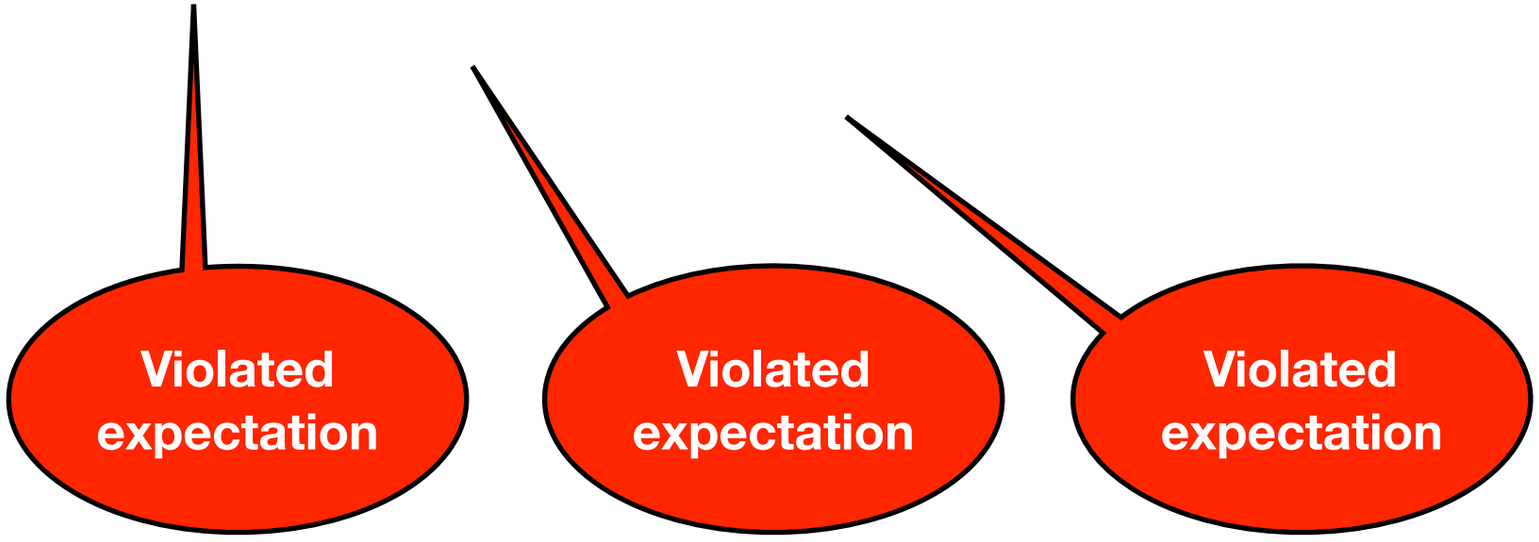
Example: Restricted shared experience, contrast

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.*



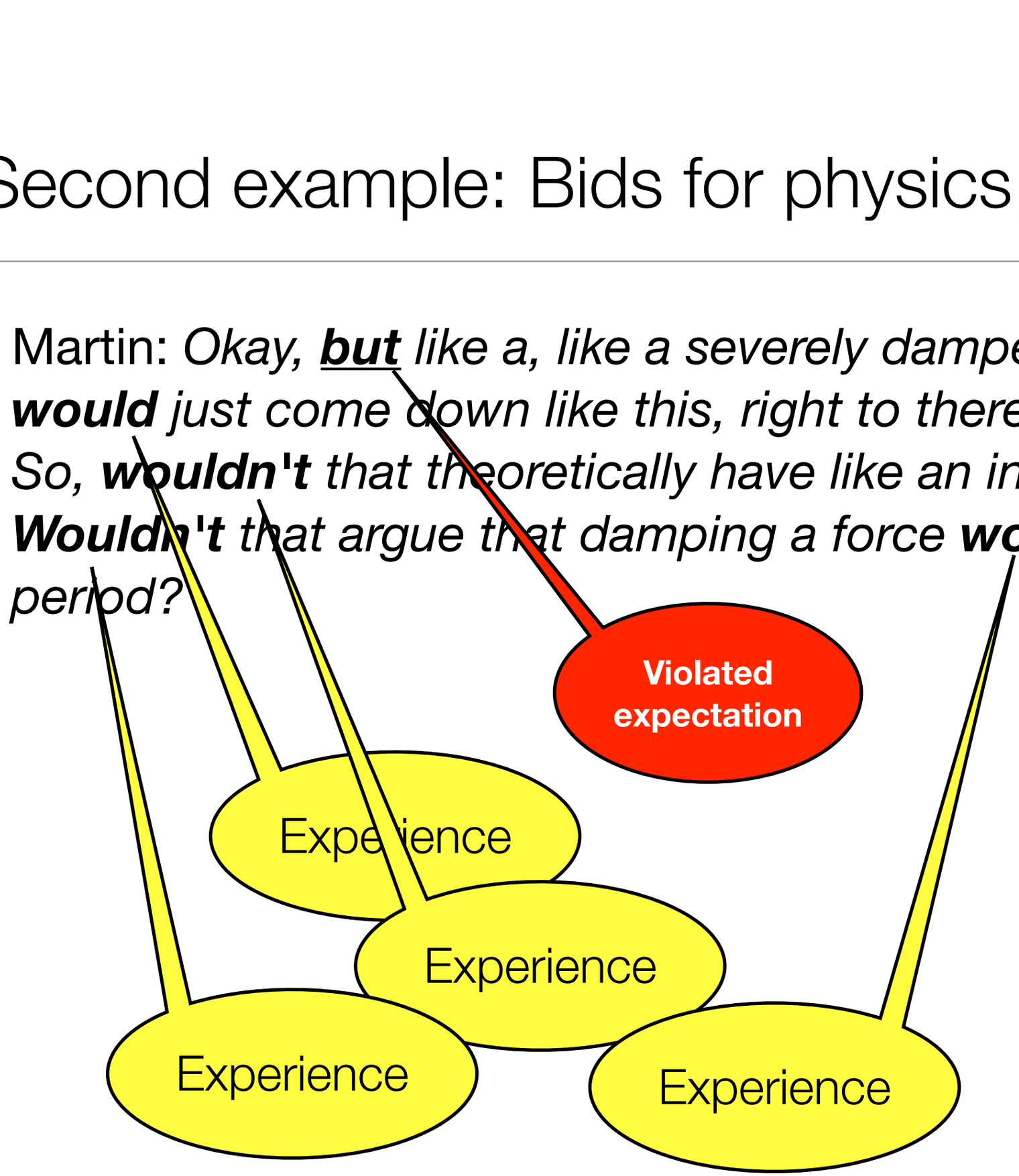
Second example: Bids for math, not physics

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.*



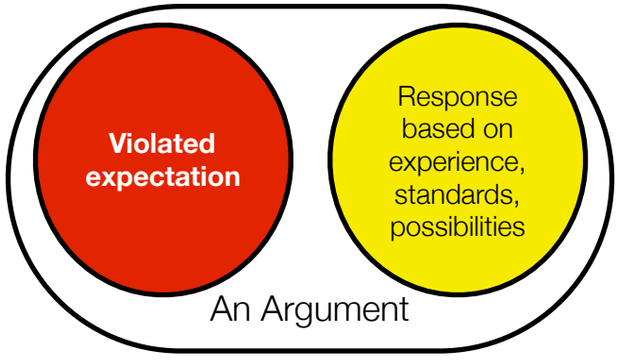
Second example: Bids for physics, not just math

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.



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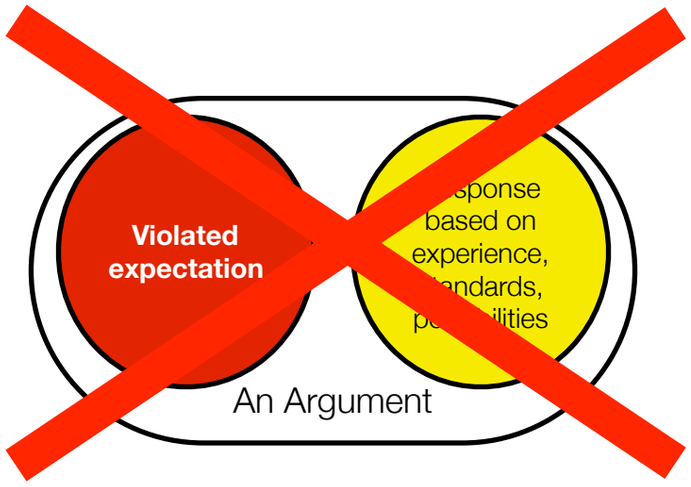

Later, when they have decided on a mathematical pathway, both buts & modals drop out of their discourse.

“Tannen word” use depends on activity

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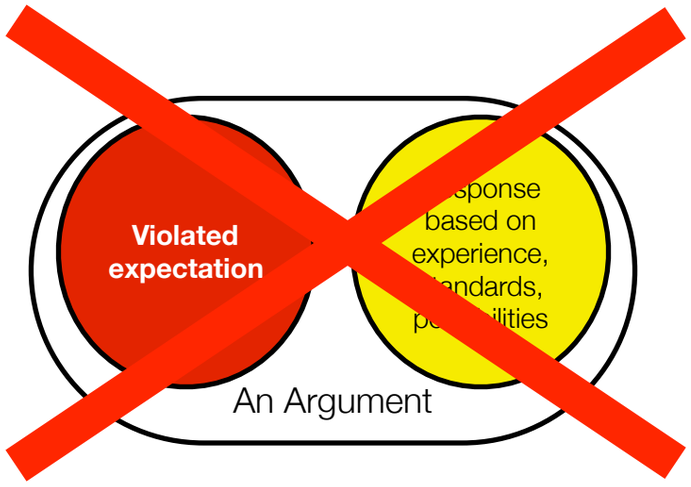


Later, when they have decided on a mathematical pathway, both buts & modals drop out of their discourse.

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

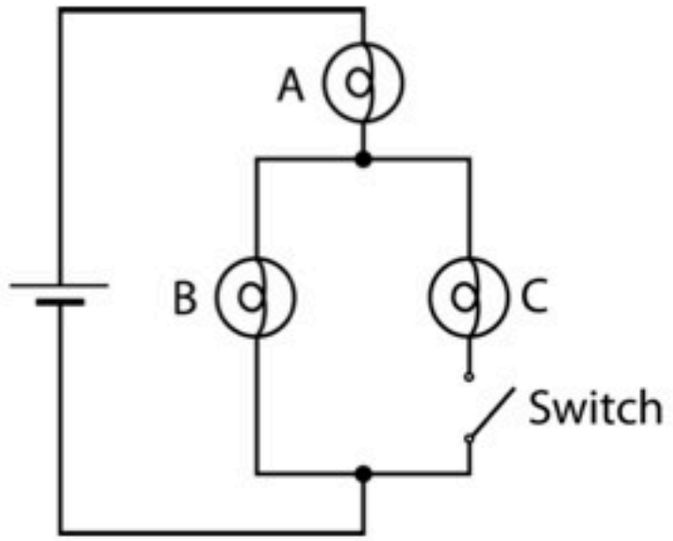
How robust is that kind of result?

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.

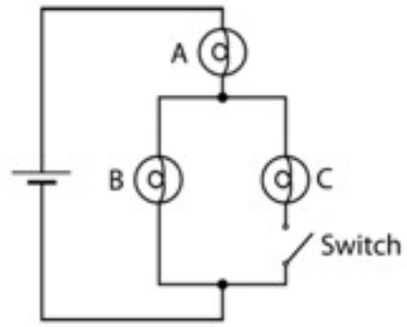
After the switch closes:

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



McDermott, L. C., Shaffer, P. S. (2002). Tutorials in Introductory Physics. New Jersey: Prentice Hall.

Can

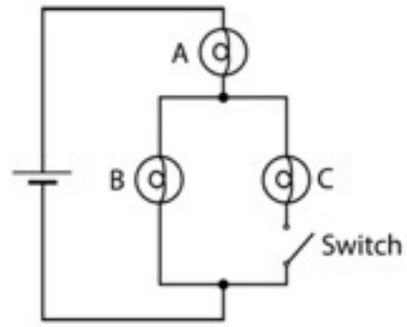


Canonical Version...

		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	**Canonical**		
	Decrease		**Canonical**	
	The Same			**Canonical**

Select a correct response and explain why it is correct.

Seeking Additional Information



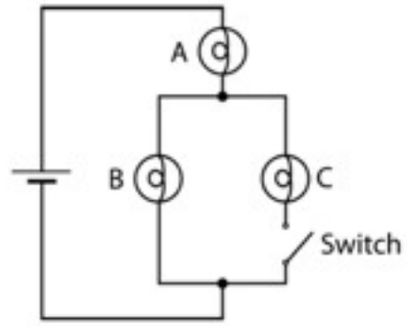
		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	Canonical		
	Decrease		Canonical	
	The Same			Canonical

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

Eliminate

Can

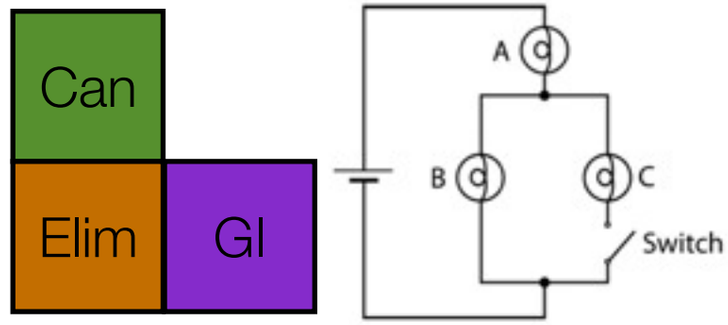
Elim



		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	Canonical	**Eliminate**	**Eliminate**
	Decrease	**Eliminate**	Canonical	**Eliminate**
	The Same	**Eliminate**	**Eliminate**	Canonical

Select an incorrect response and explain why it is incorrect.

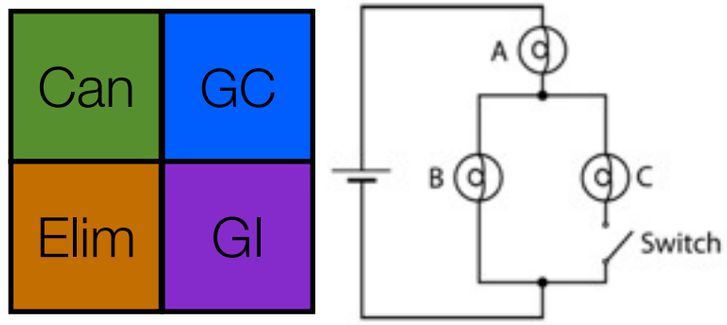
Consider Only One.



		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	Canonical **Consider A**	Eliminate **Consider B**	Eliminate **Consider C**
	Decrease	Eliminate **Consider A**	Canonical **Consider B**	Eliminate **Consider C**
	The Same	Eliminate **Consider A**	Eliminate **Consider B**	Canonical **Consider C**

Is A/B/C correct? Explain.

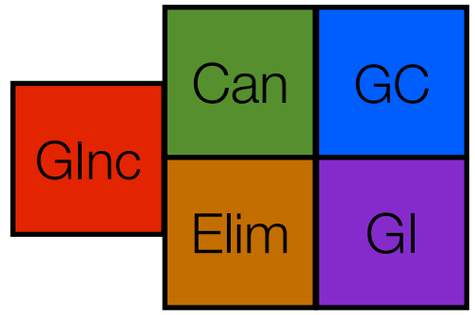
Given Correct

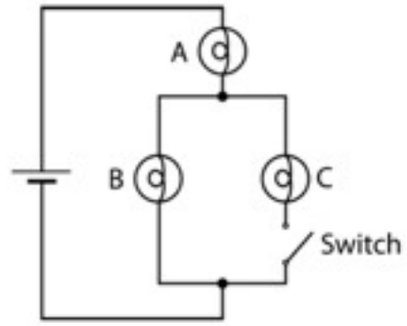


		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	Canonical Consider A **Given Correct**	Eliminate Consider B	Eliminate Consider C
	Decrease	Eliminate Consider A **Given Correct**	Canonical Consider B	Eliminate Consider C
	The Same	Eliminate Consider A **Given Correct**	Eliminate Consider B	Canonical Consider C

Justify why the correct answer (e.g., A) is correct. Explain.

Given Incorrect





		Response justified by student		
		Increase	Decrease	The Same
How a student would answer	Increase	Canonical Consider A **Given Correct**	Eliminate Consider B **Given Incorrect B**	Eliminate Consider C **Given Incorrect C**
	Decrease	Eliminate Consider A **Given Correct**	Canonical Consider B **Given Incorrect B**	Eliminate Consider C **Given Incorrect C**
	The Same	Eliminate Consider A **Given Correct**	Eliminate Consider B **Given Incorrect B**	Canonical Consider C **Given Incorrect C**

Justify why this incorrect answer (given) is incorrect. Explain.

Coin Toss problem (from the FMCE)

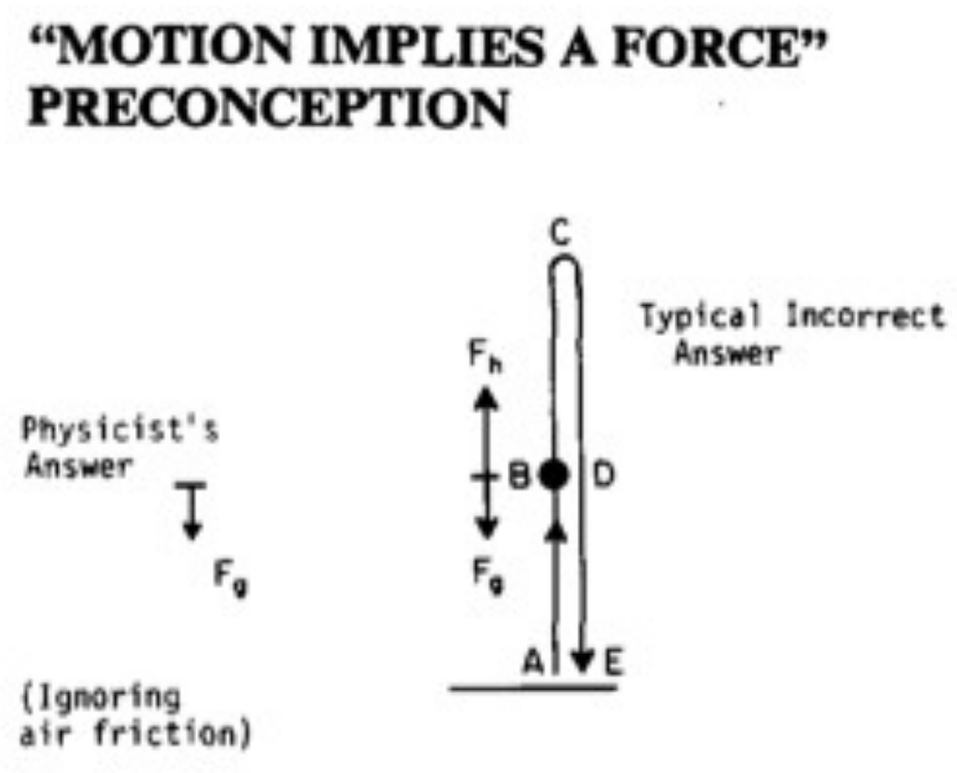
Questions 1–3 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (A through G) to indicate the acceleration of the coin during each of the stages of the coin's motion described 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)

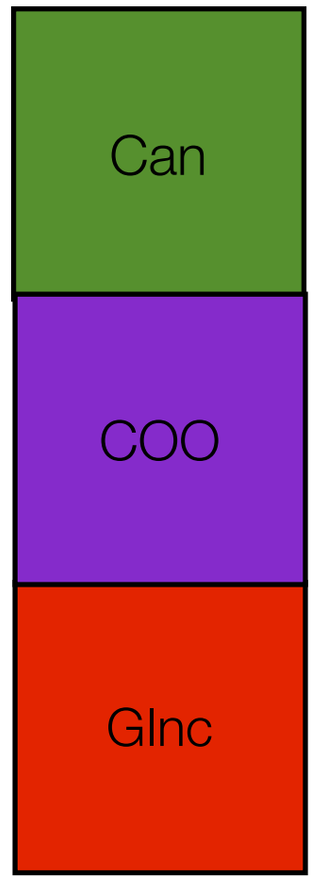
Everyone did the same multiple choice version of #1

For #2:

Traditional multiple choice question

“Is it zero at the top?”

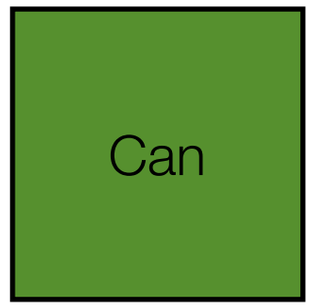
“It’s not zero at the top. Explain”



Answering G predicts answering D, or does it?

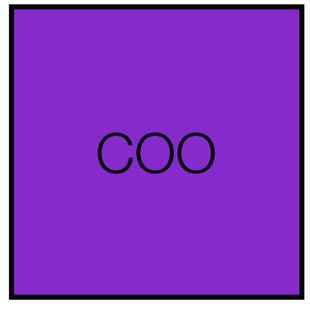
GDB response:

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

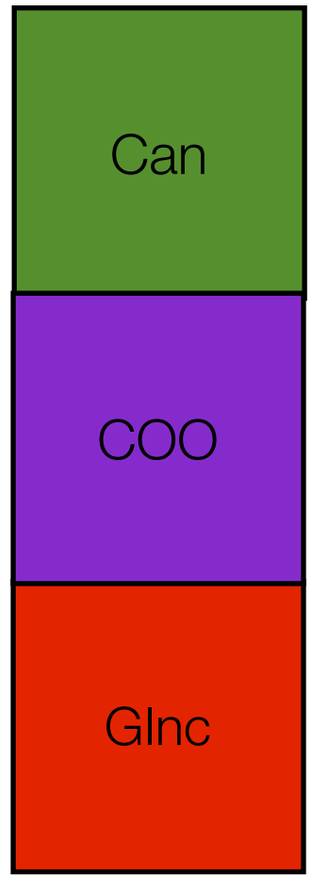
When **told** a ≠ 0 at the top,
3/4 of students
give good (enough) explanations

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

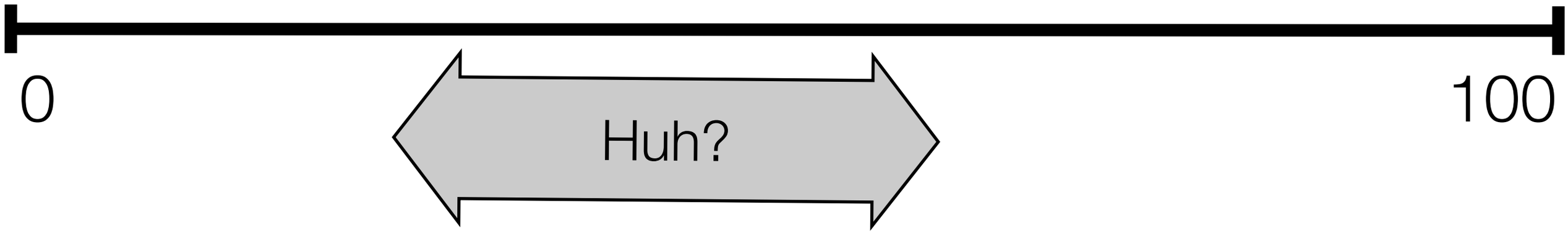
and 75% can justify why a=0 is incorrect.



How many students “really think” a = 0 at the top?

Can – 60% say a = 0

GInc – 75% explain why a ≠ 0

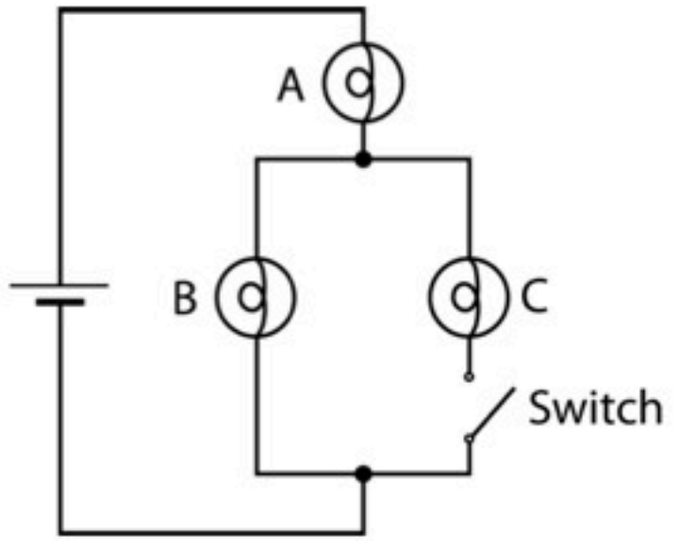


The indicator bulb question

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

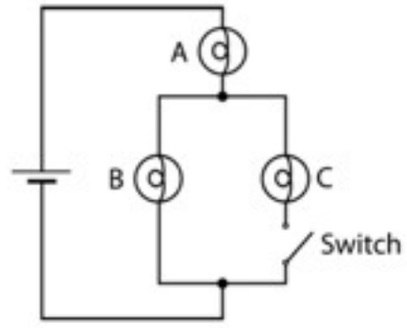
After the switch closes:

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



McDermott, L. C., Shaffer, P. S. (2002). Tutorials in Introductory Physics. New Jersey: Prentice Hall.

Electric Circuits Pilot Study



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

Previous research shows students perform poorly

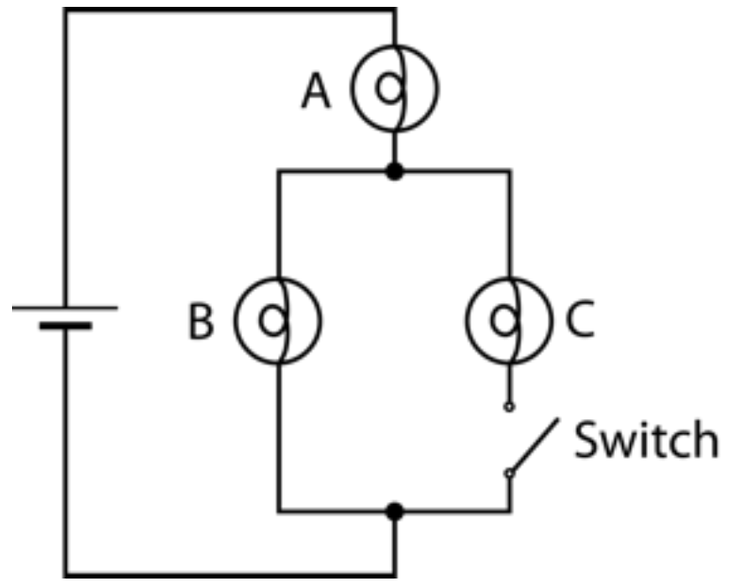
- Choosing questions targeting the correct answer will get reasoning Canonical questions don’t

- All four question types ask about *increase*

Question Design

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. – Canonical

Does the brightness of bulb A increase? Explain. – Consider Only One

The brightness of bulb A increases. Explain. – Given Correct

Pretest question from: McDermott, L. C., Shaffer, P. S. (2002). Tutorials in Introductory Physics. New Jersey: Prentice Hall.

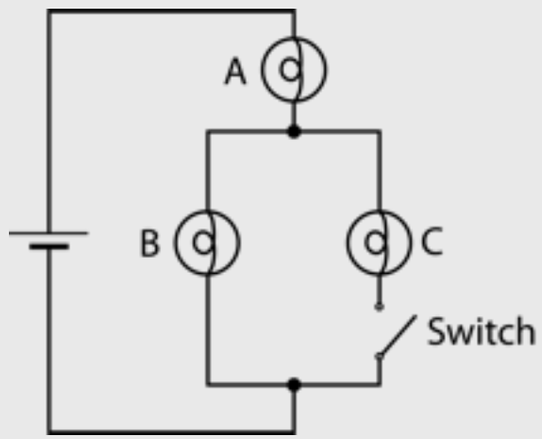
Question Design

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.



Pretest question from: McDermott, L. C., Shaffer, P. S. (2002). Tutorials in Introductory Physics. New Jersey: Prentice Hall.

Question Administration

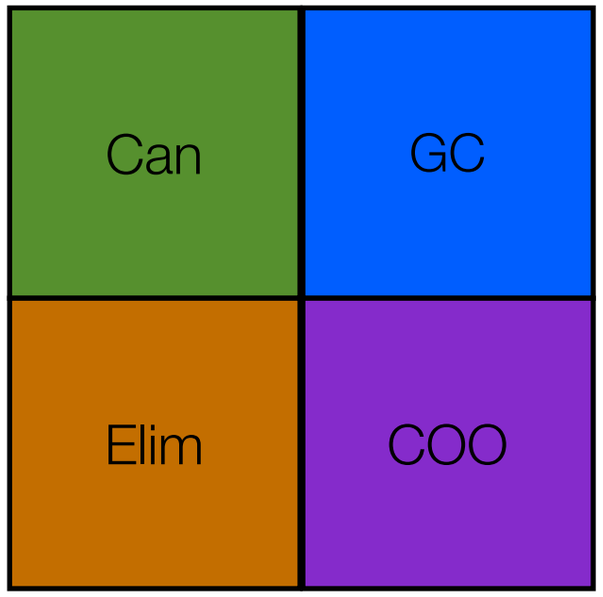
Pretest in a UMaine Calculus-based Introductory Physics Course

Each student received only one question type

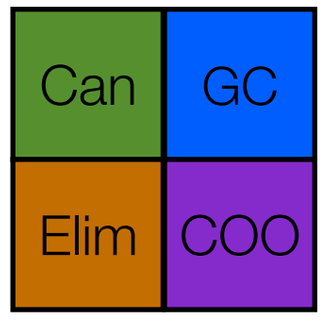
Administered in a lecture hall at the start of class

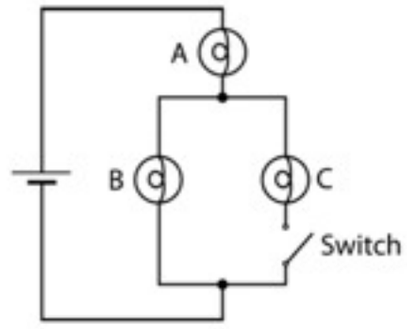
Each question was given to 1/4 of the class

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

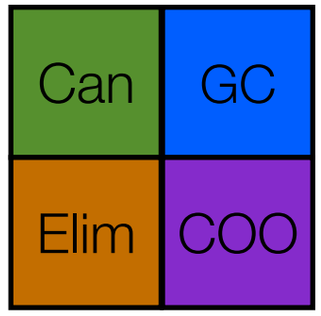
Select an incorrect response and explain why it is incorrect.

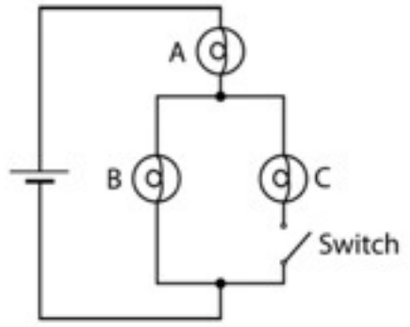
44% (7 out of 16) chose *increase* as the best response to eliminate

Does the brightness *increase*? Explain.

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

What do students think of *increase*?



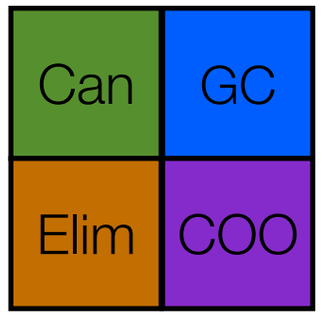


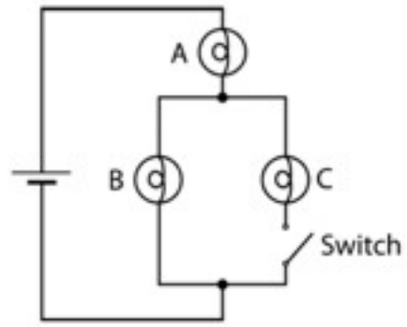
The brightness increases. Explain

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

- "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 an 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.."

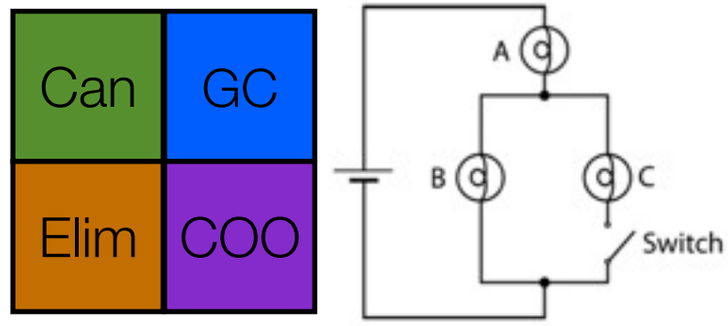
Summary of *Increase*





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.

Statistical analysis



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.

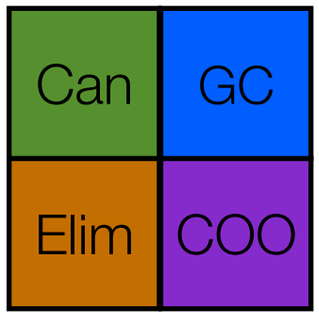
We’re confused and excited

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

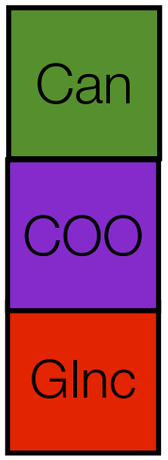
Excited: We get more information from this set of questions than from the Canonical question alone.

- 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



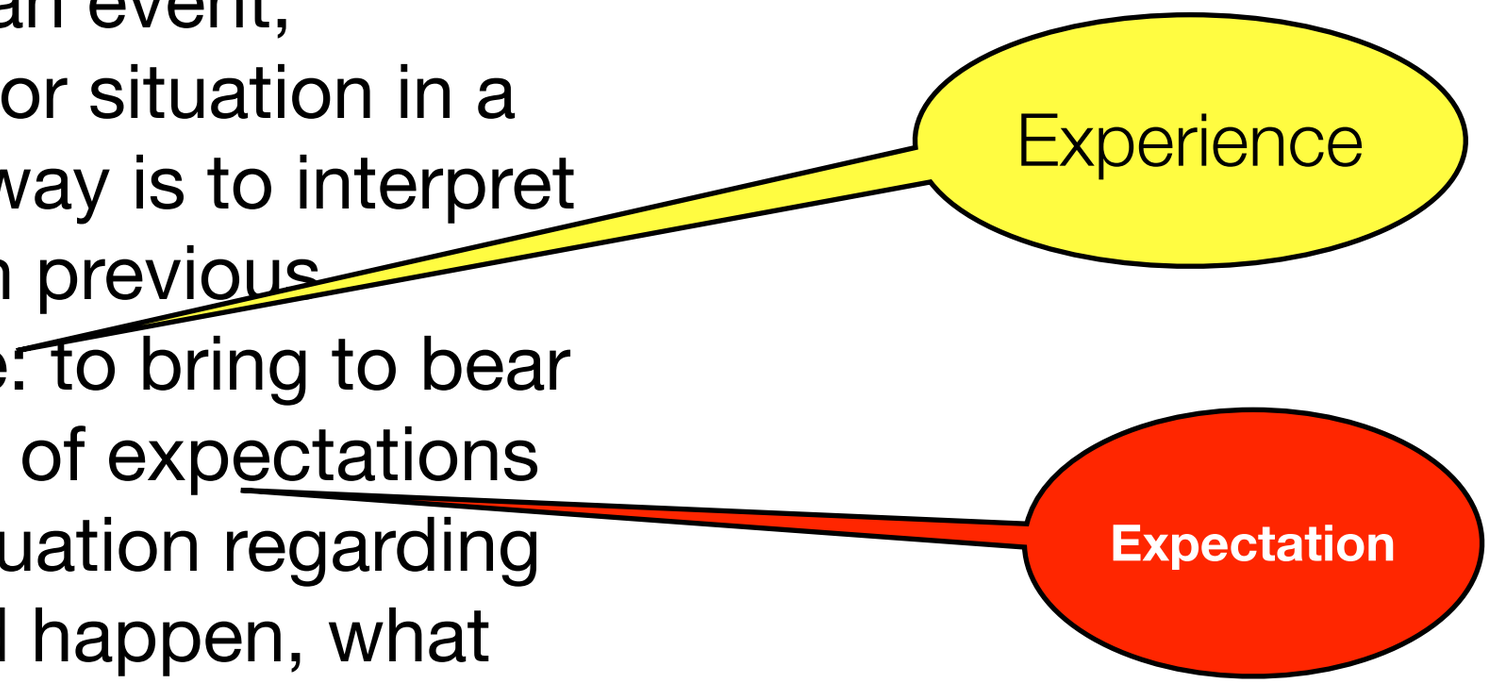
IF we assume that populations are roughly equal, variability can be caused by question format.

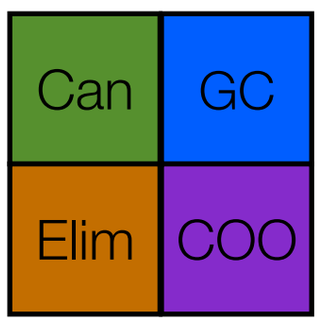
Expectations: Each question comes with a history of being answered and a sense of what counts as a correct answer.

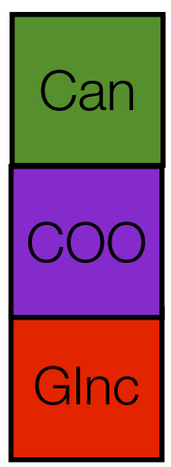
Cuing: Each question cues different kinds of thinking

Making sense of our observations: Epistemological Framing

"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)

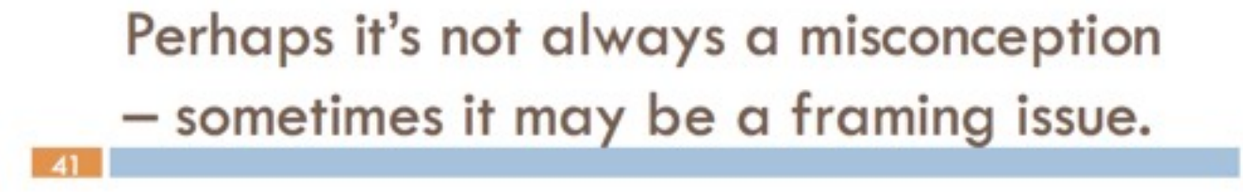






What are we learning?

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



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?