Teaching Strategies for Enacting PBL in Physics

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Some Math-Related PER Findings

Undergraduate students may do well in pure math courses but struggle when asked to apply math to physics courses, such as:

- having the right "tools" (resources) but applying them incorrectly or to the wrong contexts (Hammer et al., 2005; Gifford and Finkelstein, 2021; Zhao and Schuchardt, 2021)

- struggling to translate between physical world, graphs, diagrams, and algebraic symbols – treating equations as "recipes" (algorithmic thinking) rather than descriptions of the world (Tuminaro and Redish, 2007; Redish and Gupta, 2009)

Examples of research-based instructional strategies include:

Peer Instruction (Mazur), Interactive Lecture Demonstrations (Sokoloff and Thornton), POGIL (Farrell, Moog, and Spencer), Tutorials in Introductory Physics (McDermott and Shaffer), and Modeling Instruction (Hestenes et al.)

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Problem-Based Learning

Students learn by solving an **ill-structured problem** before instruction.

DIRECT INSTRUCTION

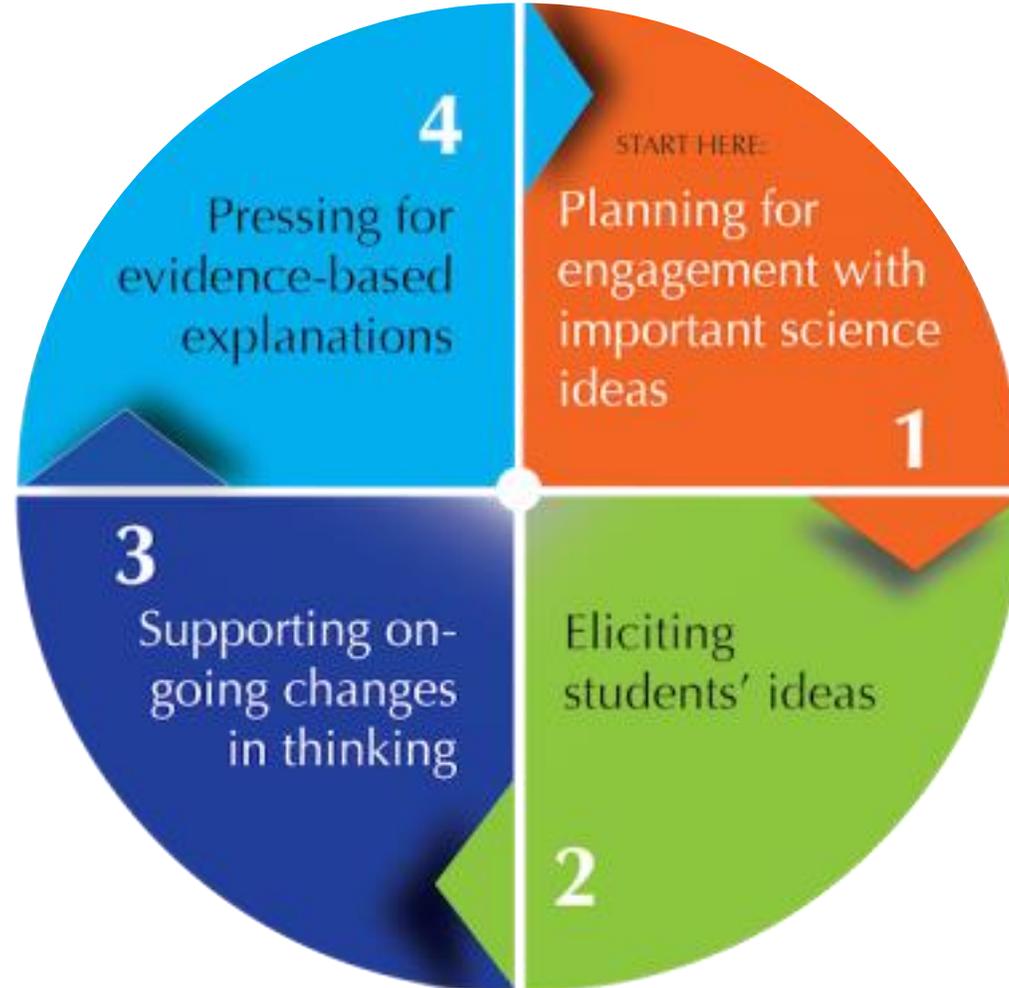| concept | → | example | → | problem |

PBL INSTRUCTION

| problem | → | investigation | → | concept |
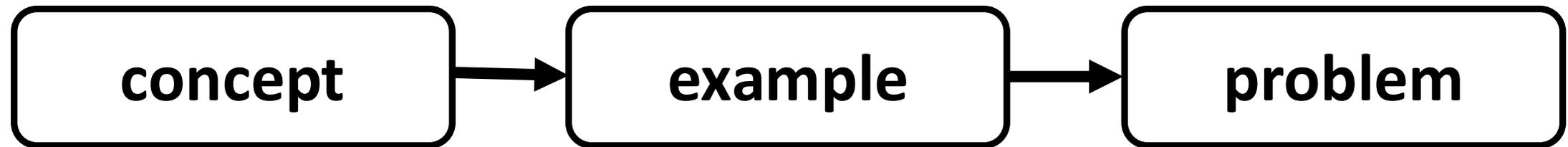
Today's Focus

- Lectures

- ~~Labs (Skills)~~

- Tutorials

http://ambitiousscienceteaching.org/

Talk Moves

- specific conversational "scripts" or strategies used to facilitate productive dialogue between students

- **share/expand/clarify own thinking**

- **deepen own reasoning**

- **listen to each other**

- **think with others**

Goal: Individual students share, expand and clarify their own thinking

1. **Time to Think:**

   Partner Talk

   Writing as Think Time

   Wait Time

2. **Say More:**

   "Can you say more about that?" "What do you mean by that?" "Can you give an example?"

3. **So, Are You Saying...?:**

   "So, let me see if I've got what you're saying. Are you saying...?" (always leaving space for the original student to agree or disagree and say more)

Goal: Students listen carefully to one another

4. **Who Can Rephrase or Repeat?**

   "Who can repeat what Javon just said or put it into their own words?"   (After a partner talk) "What did your partner say?"

Goal: Students deepen their reasoning

5. Asking for Evidence or Reasoning:

"Why do you think that?" "What's your evidence?" "How did you arrive at that conclusion?"
"Is there anything in the text that made you think that?"

6. Challenge or Counterexample:

"Does it always work that way?" "How does that idea square with Sonia's example?"
"What if it had been a copper cube instead?"

Goal: Students think with others

7. Agree/Disagree and Why?:

"Do you agree/disagree? (And why?)" "Are you saying the same thing as Jelya or something different, and
if it's different, how is it different?" "What do people think about what Vannia said?"
"Does anyone want to respond to that idea?"

8. Add On:

"Who can add onto the idea that Jamal is building?"
"Can anyone take that suggestion and push it a little further?"

9. Explaining What Someone Else Means:

"Who can explain what Aisha means when she says that?" "Who thinks they could explain in their words why
Simon came up with that answer?" "Why do you think he said that?"

Lectures

- What is the main challenge to student learning when using direct instruction during lectures?

**passive reception** → **active learning**
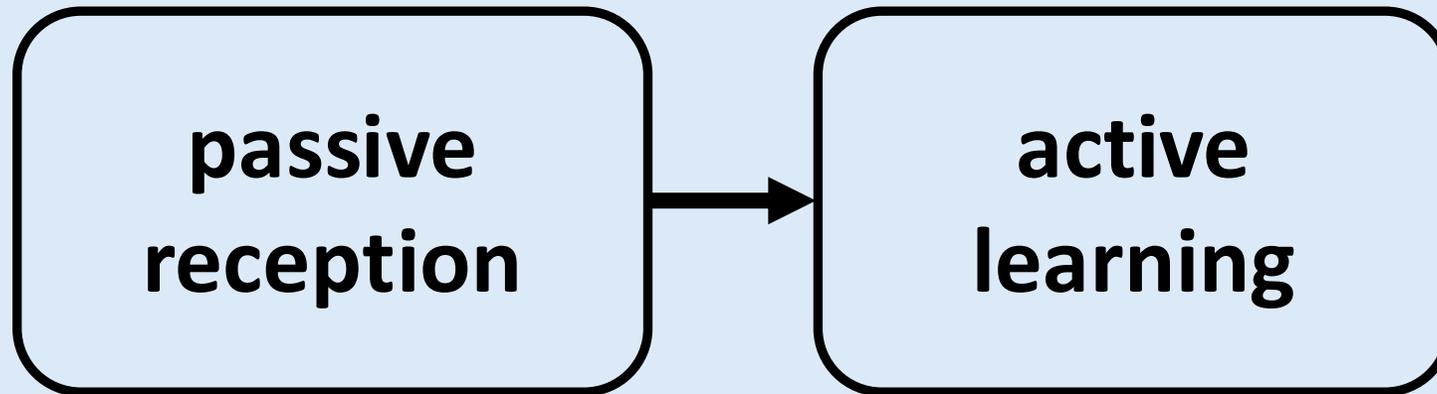
- **Peer Instruction** (Mazur)

- Ask a multiple-choice question (ConcepTest); can be designed such that common misconceptions are included as distractors.
- Students choose an answer (e.g., phone, card, hand) without talking to anyone. Note the distribution of responses *without saying the answer*.

> 80% confident / correct

**40% - 80% confident / correct**

< 40% confident / correct

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A bowling ball accidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the bowling ball most closely follow after leaving the airplane?
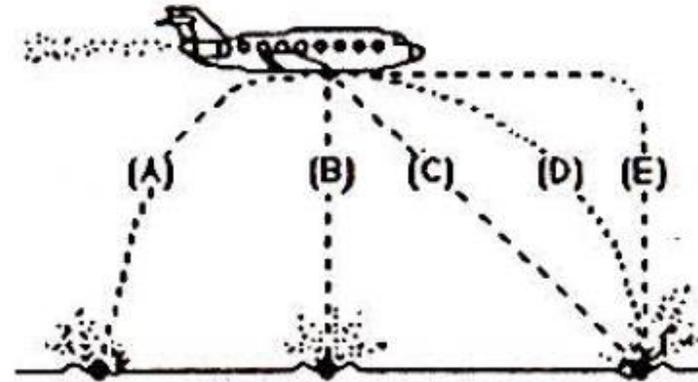
A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram to the right. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.
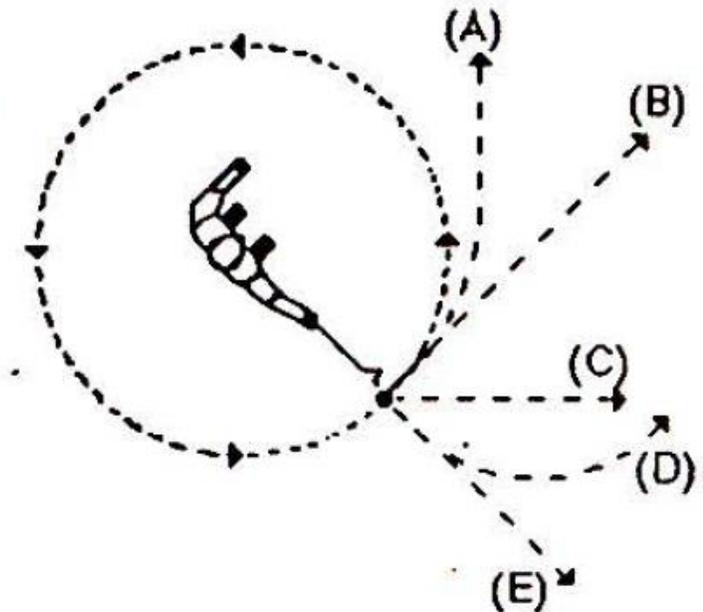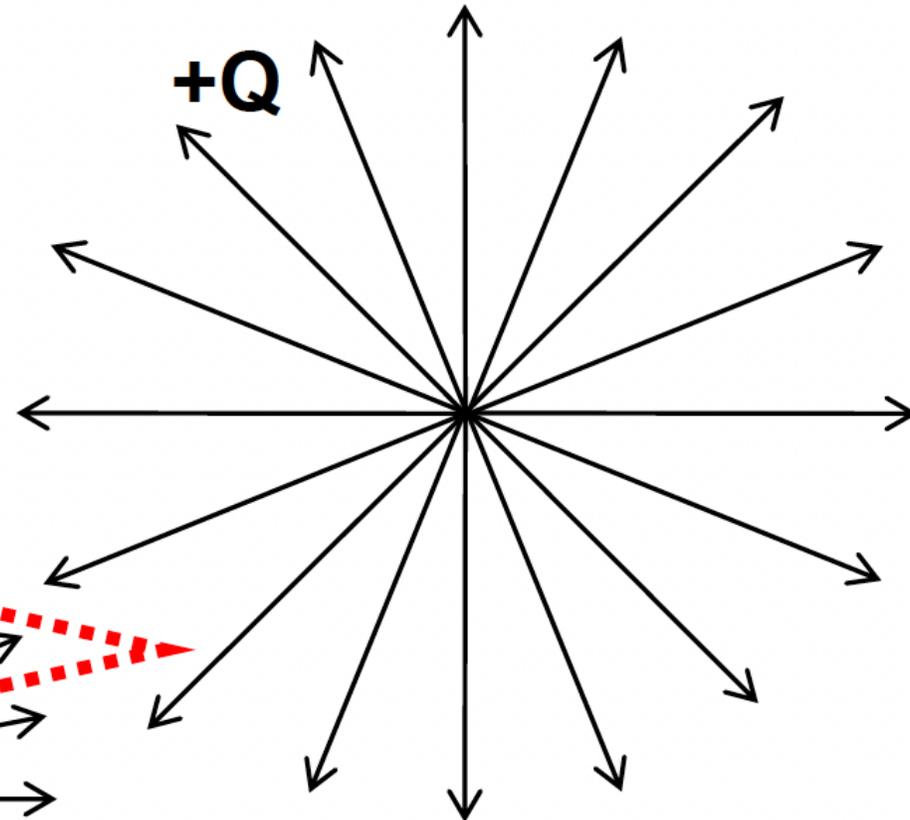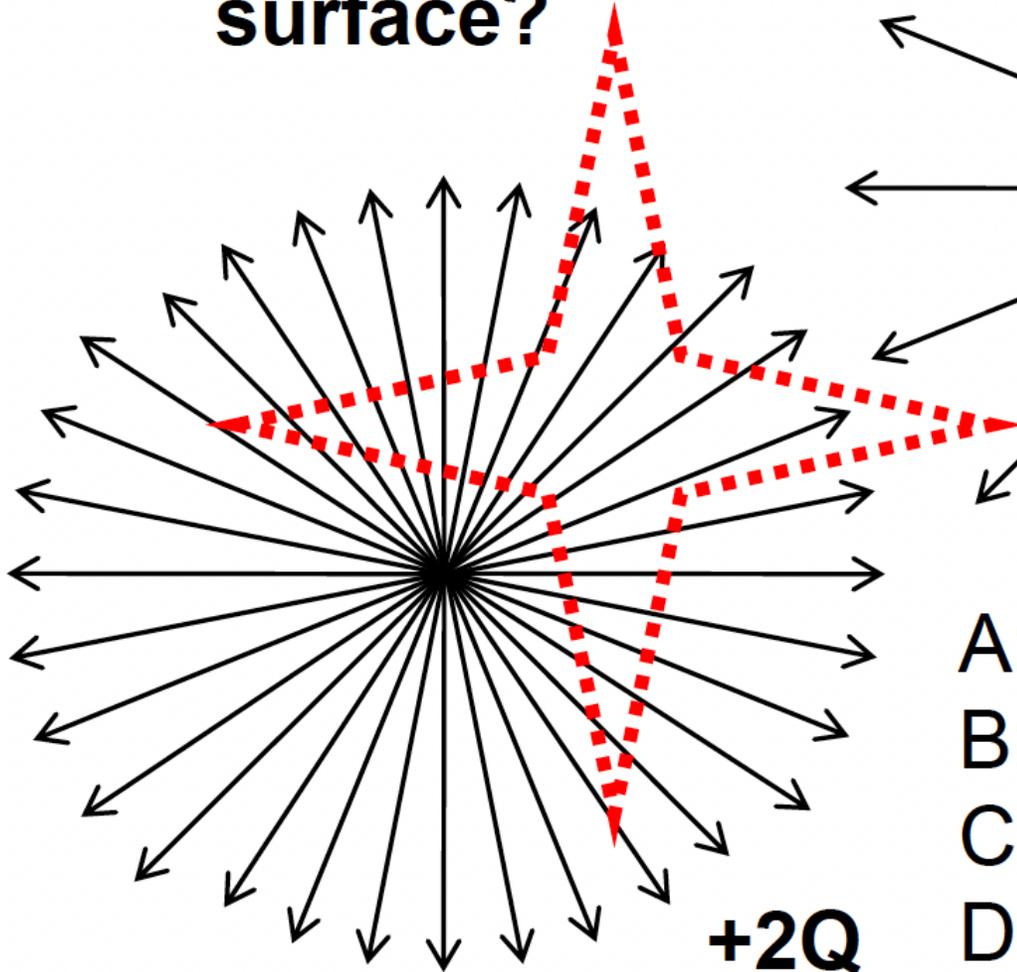
What is the flux through the surface?
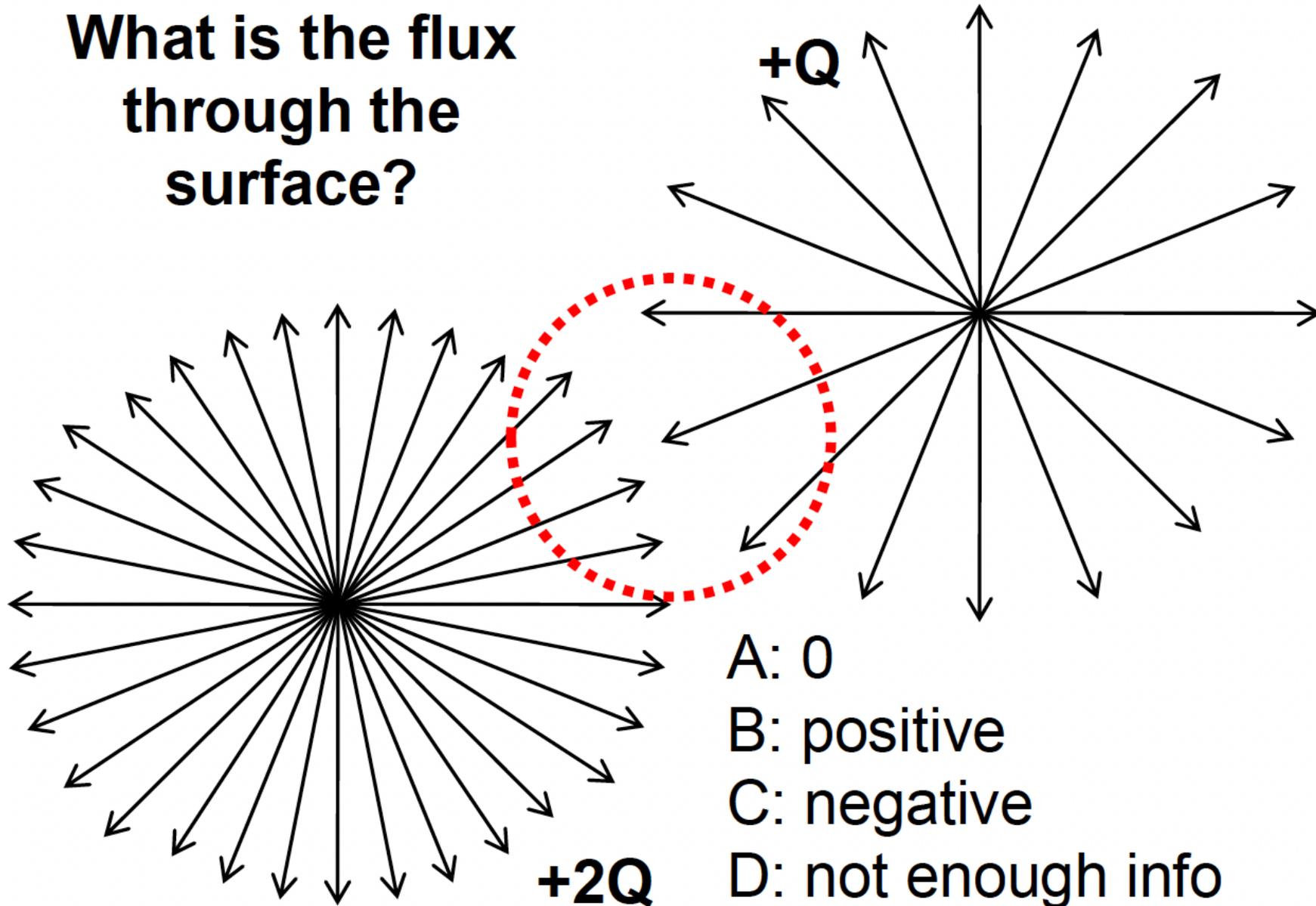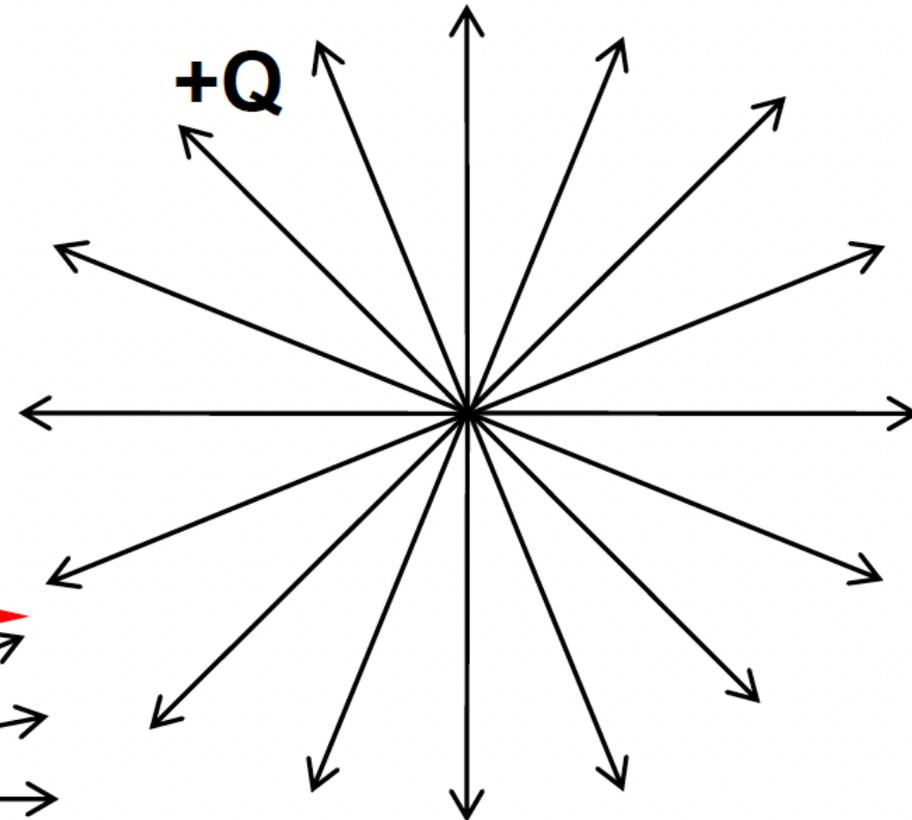
+Q

+2Q

A: 0
B: positive
C: negative
D: not enough info

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What is the flux through the surface?

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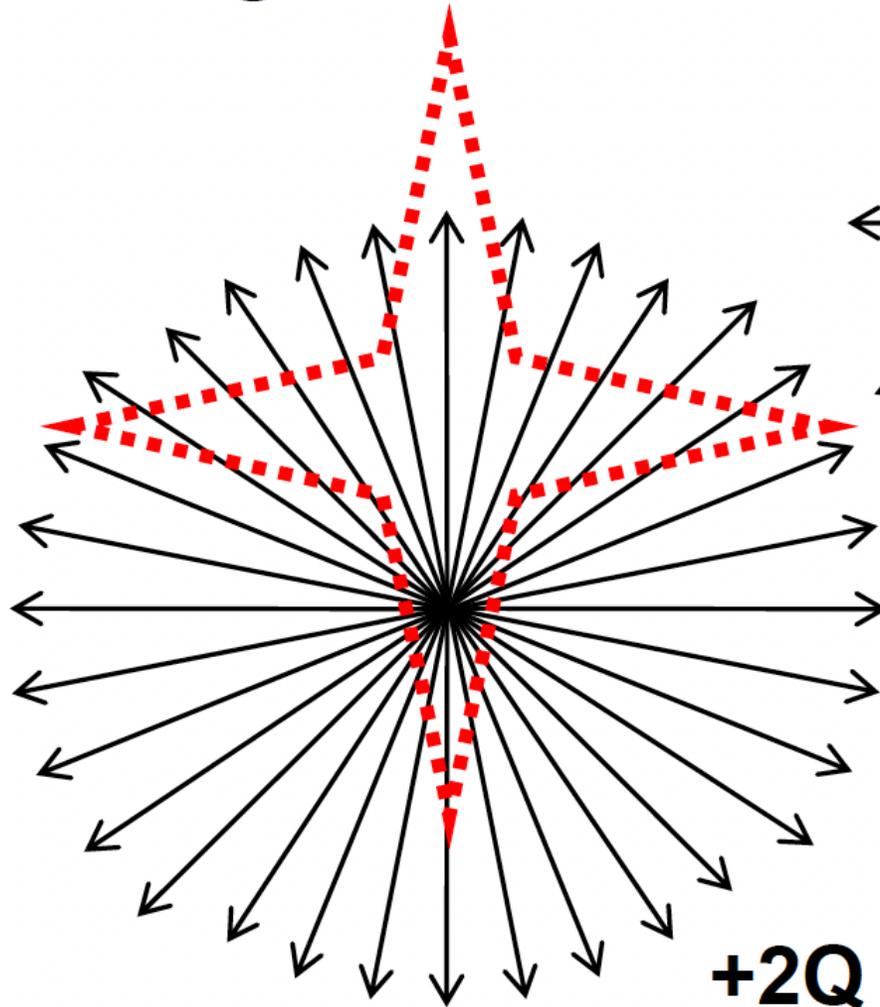
What is the flux through the surface?

+Q

+2Q

A: 0
B: positive
C: negative
D: not enough info

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Sample Talk Moves

After showing prompt:

- *I see a lot of A's and B's on the screen. Would someone who chose A/B explain why you chose A/B?*

- *I see 90% switched to B – can someone explain why?*

- *About 10% of you stayed with A, which is a common way to think about this. Can someone explain why?*

- *What would have to change in the diagram for C to be correct?*

- *If I chose D, how does Newton's Law disprove this?*

- *It's okay to not know – we can figure this out. Why do you think…?*

Designing PBL Problems

Students learn by solving an **ill-structured problem** before instruction.

Problems should:	They also typically have:
• be set in a realistic context	• missing information
• have multiple valid approaches	• vague goals
• require multiple representations	• multiple solutions

Strategies include:

• removing numbers (students estimate physical constants and dimensions based on their intuition or prior knowledge)

• using messy data (students filter out the noise to find the relevant signal)

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Whiteboarding Purposes, Strategies, and Ideas

- showing solutions to select homework sets
- interpreting data from inquiry labs
- demonstrating inductive or deductive reasoning processes*

- Presentation
- Board meeting*
- Gallery walk*
- Speed dating
- …

Whiteboard Discourse

Groups solve problems on whiteboards before sharing for critique and discussion.

- **co-construction**: make sure to include *representations*, *mathematics*, and *justification* to address ill-structured problem

knowns and presumptions	*derivations/ maths*
representations	*reflections*

- **board meeting**: gathers in circle (with whiteboards) to present solution; tutor uses Socratic questioning to group, rest of class, or both
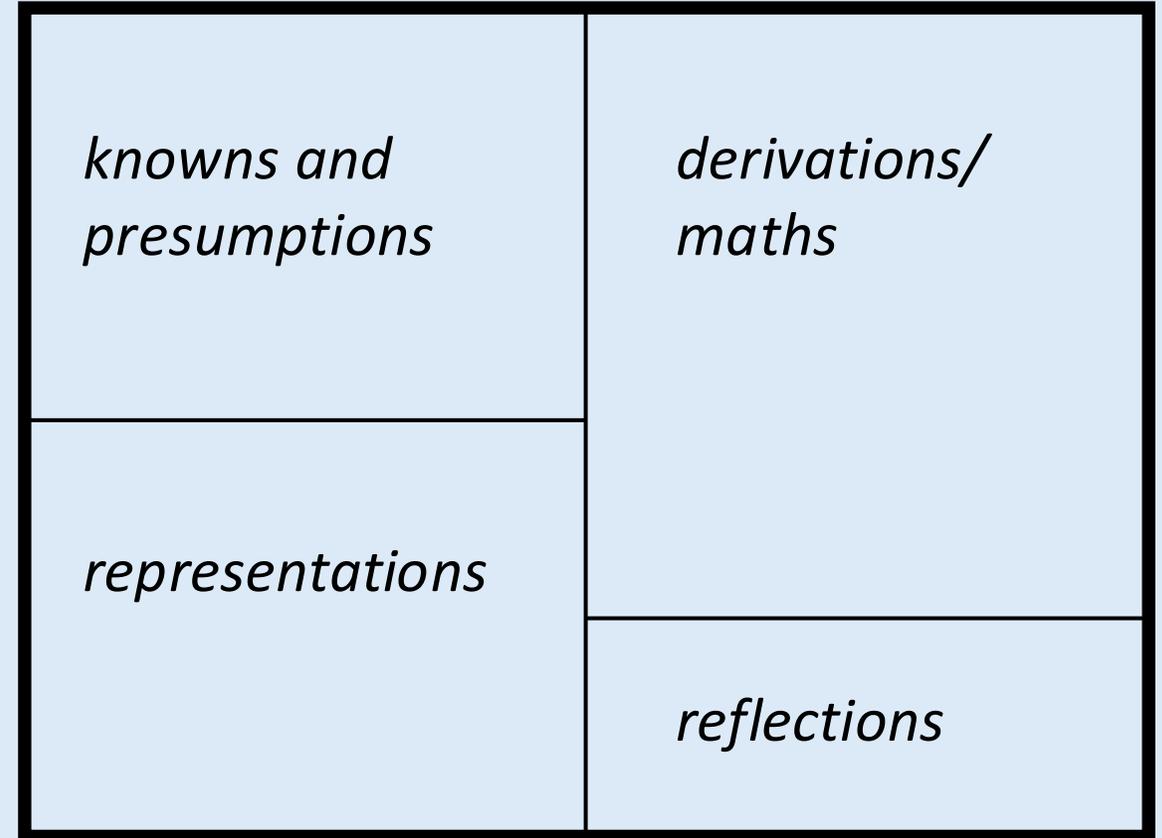
OR

- **gallery walk**: display whiteboards, then walk around and give comment on each with one like and one question (different colored marker)
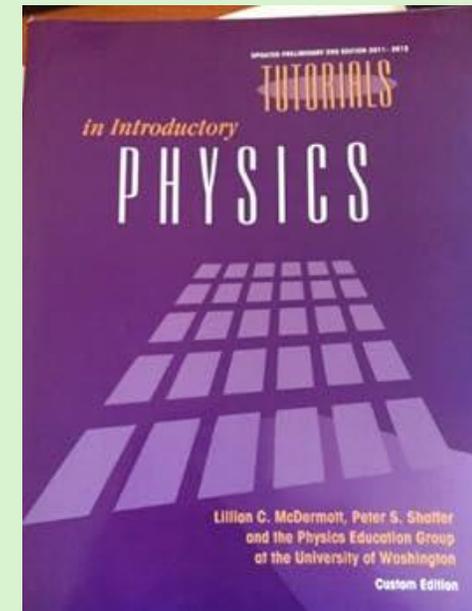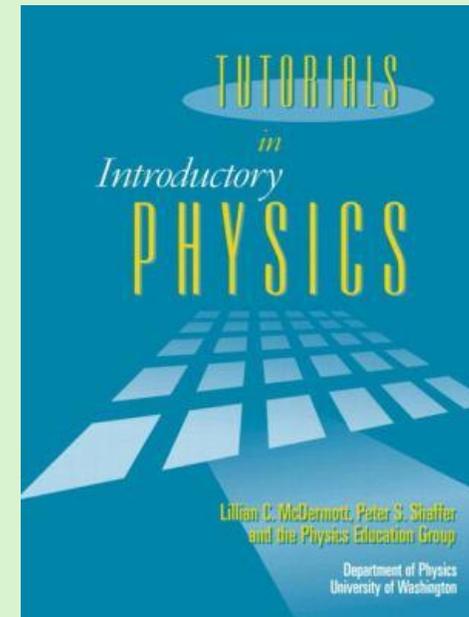
Tutorials

- What are the challenges to student learning during tutorials?

- prior knowledge (*e.g.*, p-prims)
- conceptual change
- cognitive load
- social dynamics in groups (e.g., perceived responsibilities/contributions, effects of status, pressure to conform)
- metacognition
- learning does not transfer automatically to other contexts

- diagnosing source of students' or group's struggles
- practicing wait time
- asking focusing (instead of funnelling) questions to group
- managing group dynamics
- knowing when and how to intervene (allowing for productive struggling)

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Tutorials in Introductory Physics (UW Model)

- specific documented conceptual difficulty

- concept construction via reasoning (instead of applying formulas)

- sequenced questions (wrong answers checked in follow-up questions)

- tutor only facilitates (no presentations of answers); should mostly ask (or redirect) questions instead of telling/explaining

Next Steps?

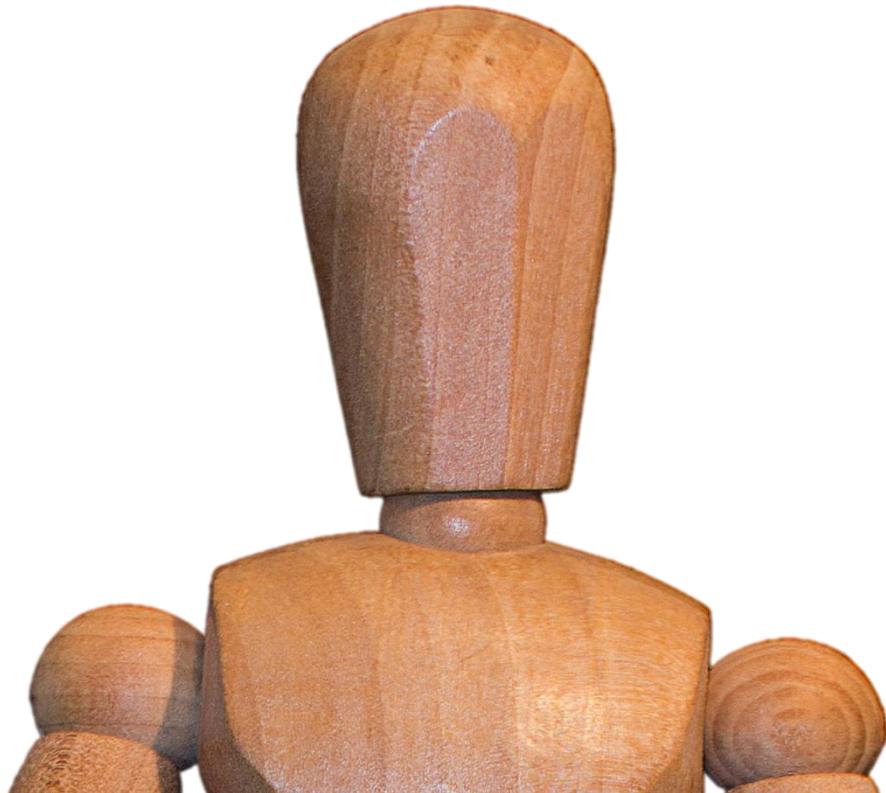| SHORT-TERM	IN-BETWEEN	LONG-TERM
→ use talk moves → add 2-3 clicker questions to lecture, using think-pair-share after any difficult concept	→ replace a tutorial with a UW-style worksheet → run whiteboard board meeting	→ implement modeling cycle? → revise lab?

Your thoughts?

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