Guiding and Gauging Student Metacognition in Physics

AAPT Summer Meeting - University of Minnesota

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How People Learn: *Key Findings*

Metacognition as *"the ability to monitor one's current level of understanding and decide when it is not adequate … extremely important for learners at all ages."*

"Expert teachers know the kinds of difficulties that students are likely to face, and they know how to tap into their students' existing knowledge" (Pedagogical content knowledge)

"Metacognition can help students develop personally relevant pedagogical content knowledge … In short, students need to develop the ability to teach themselves."

Arons: *Guide to Introductory Physics Teaching*

"Developing self-consciousness concerning one's own thinking is perhaps the highest reasoning skill. It involves standing back and recognizing the processes one is using, providing the basis for conscious transfer of reasoning methods from familiar to unfamiliar contexts. Given such awareness, one can begin to penetrate new situations by asking oneself probing questions and constructing answers."

How People Learn: *Implications for Instruction*

"The teaching of metacognitive skills should be integrated into the curriculum . . .

. . . instruction in metacognition must take place within discipline-specific content . . ."

Metacognition is extremely important.

Lippman Kung and Lindner, 2007

"Research on students natural-in-context metacognitive activity is rare."

"Whether a statement is simply cognition or metacognition is not straightforward to determine."

Metacognition is extremely important.

Metacognition is largely private.

Can metacognition be fostered within the constraints of a traditional physics course?

How can we determine the extent to which it was learned?

Outline

- Background and motivation
- An instructional approach for promoting reflection
- Analyzing students' reflective writing: *Metacognitive Elements Rubric*
- Preliminary findings

Metacognition: *Foundations*

- Schoenfeld, 1987

  - What (exactly) are you doing? (Can you describe it precisely?)
  - Why are you doing it? (How does it fit into the solution?)
  - How does it help you? (What will you do with the outcome when you obtain it?)

- Veenman, 2012

  "One of the reappearing problems with metacognition research is the 'fuzziness' of the concept...

Metacognition is extremely important.

Metacognition is largely private.

Metacognition is “fuzzy.”

Redish: *Teaching Physics*

Metacognition as *executive function* – a thinking process that is used to manage and control other thinking processes.

> *"The key element in the mental model I want my students to use in learning physics [is] reflection – thinking about their own thinking. This includes a variety of activities, including evaluating their ideas, thinking about consistency, considering what other ideas might be possible . . . "*

Students may waste time and effort following unproductive approaches through a lack of metacognitive activity.

"Flavors" of metacognition

- Forward looking
- In-the-moment
- Backward looking
  - ✦ *Reflective Thinking*

Components of Reflective Thinking: *Retracing the learning pathway*

- Identify problematic and productive aspects of my initial reasoning.
- Diagnose the conceptions (*i.e*, mental models) underlying that reasoning.
- Describe specific differences in my thinking *then* compared to *now*.
- Retrace my learning pathway:

  How did I come to know what I know?

Recent PER work on Reflective Thinking

- Yerushalmi et al (2012)
- Huang and Calman (2012)
- Mason and Singh (2009)
- May and Etkina (2002), Etkina (1999)

Defining a concept: *What is mass?*

The amount of matter an object contains...

or . . .

The number of hex nuts needed to balance an object.

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Can metacognition be operationalized?

Context:
Intro calc-based physics at WWU

- required 3-hr lab section (N ~ 25 each) taught by undergraduate TA
- 2-4 lecture sections (N ~ 60 each) with students mixing in labs

Labs in Introductory Mechanics

- Lab 1: Concepts of Motion
- Lab 2: Acceleration in One Dimension
- Lab 3: Motion in Two Dimensions
- Lab 4: Forces
- Lab 5: Newton's 2nd Law and Static Friction
- Lab 6: Tension and Newton's 3rd Law
- Lab 7: Momentum

Elicit

↓

Confront

↓

Refine and Resolve

↓

Reflect ⟷ Scaffolded activity in which students reflect on own learning pathways

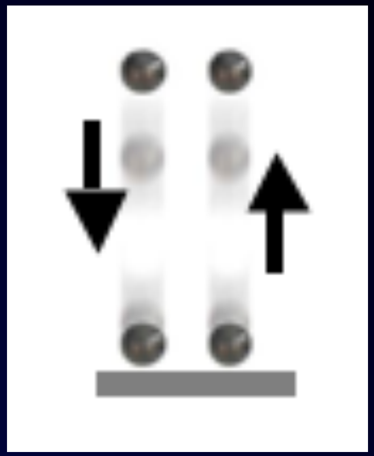
Reflective Thinking: *Instructional Sequence*

- Prelab: Eliciting initial ideas
- Lab: Research-based instructional sequence
- Lab: Revisiting initial ideas
  (small group discussion)
- Lab HW: Post-lab question
- Lab HW: Written Learning Commentary

Kinematics Prelab (for Lab 2):

A bouncy ball is released from rest above the ground. The ball moves downward with increasing speed, hits the ground, bounces, and moves upward with decreasing speed.

- Sketch position and velocity graphs.
- During the bounce, is the acceleration of the ball *upward, downward,* or *zero?* Explain.

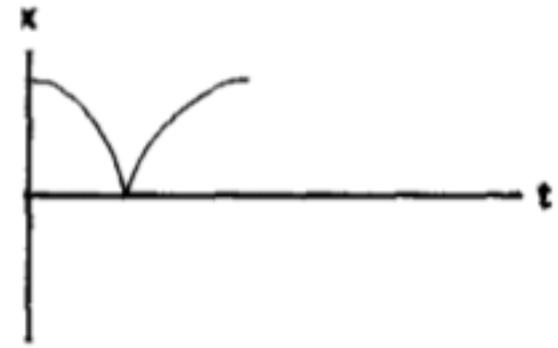


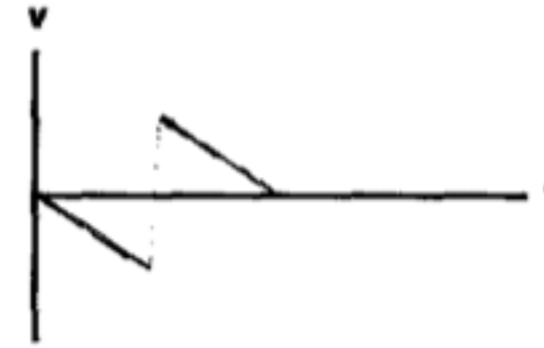
Dynamics Prelab (for Lab 7):

Imagine that you are an actor in the movie *Jurassic Park.* In one scene, you are walking down a hallway toward a door that is slightly ajar. When you are 10 feet away, you realize there is a Velociraptor on the other side. You have one chance to close the door – by throwing a large ball at it. (You happen to have a large ball in your hand . . .)

Would you rather have a super-bouncy ball or a sticky lump of clay (assuming equal mass and size)? Explain.

[redacted]

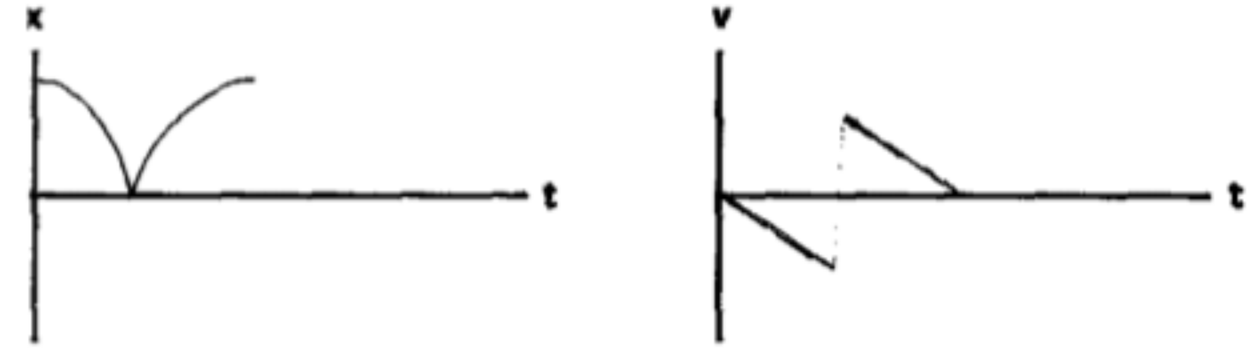




4. During the bounce, is the acceleration of the ball *upward, downward,* or *zero?* Explain.

During the bounce, the acceleration of the ball is either very high and positive, or it is undefined because the ball changes instantly from a large negative velocity to a large positive velocity.

[redacted]



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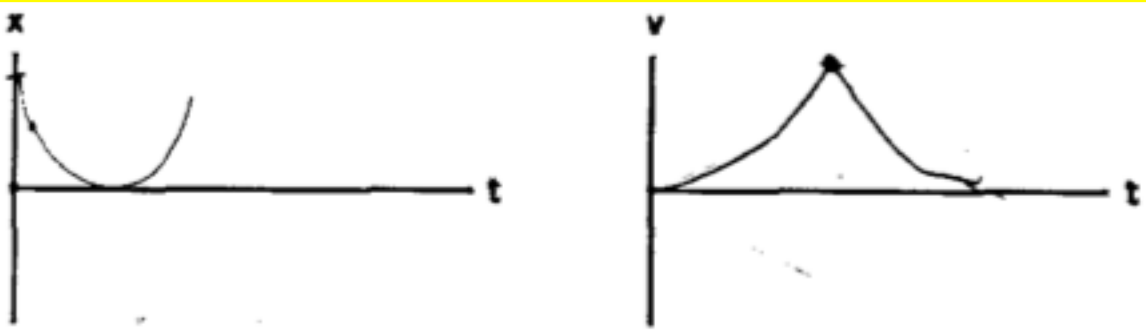

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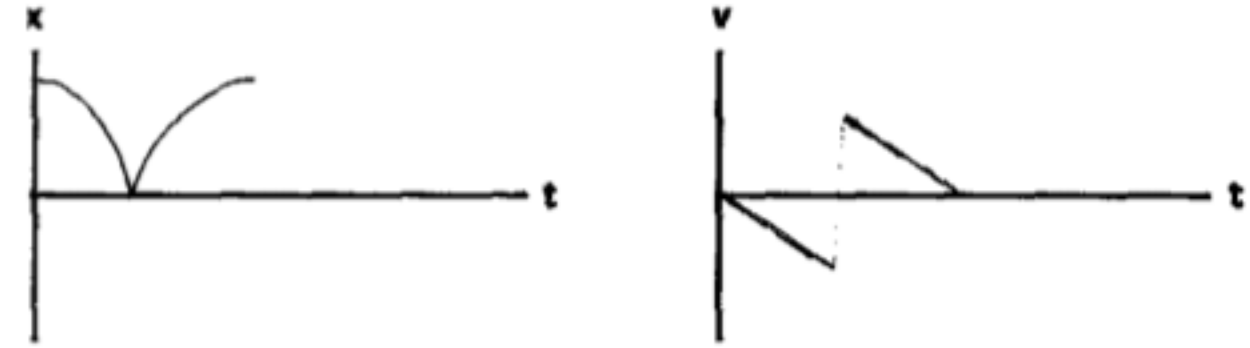
The acceleration of the ball is downward because the ball is in free fall and therefore has a negative acceleration due to gravity (when positive is defined as up)

[redacted]



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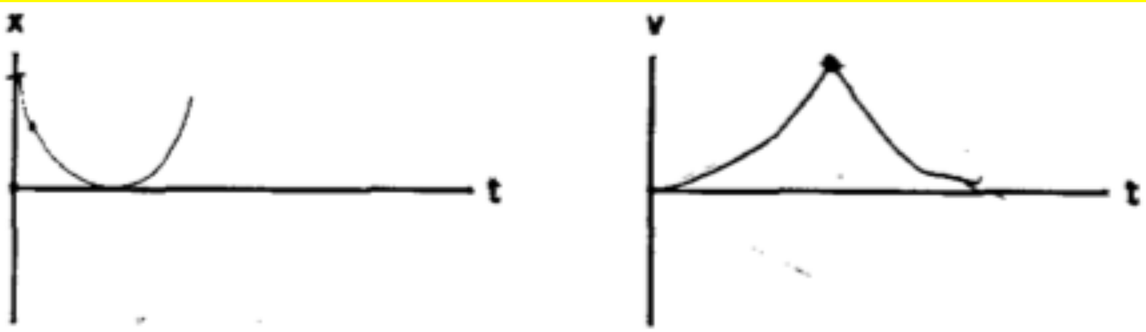

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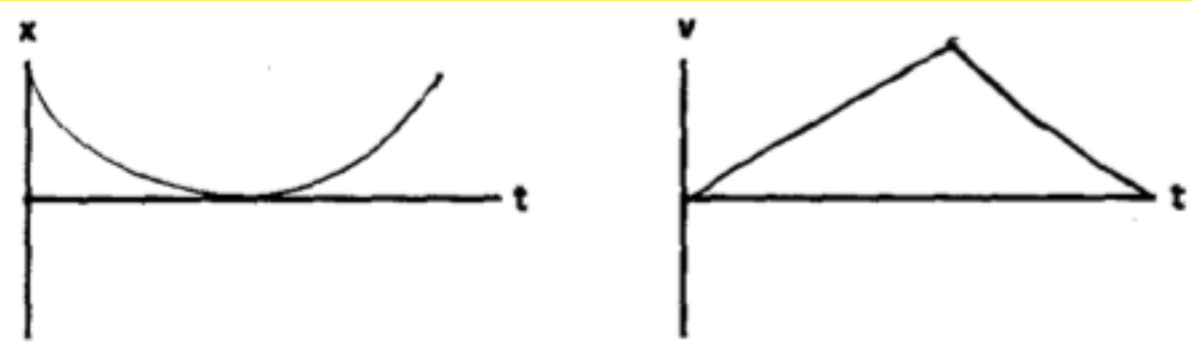
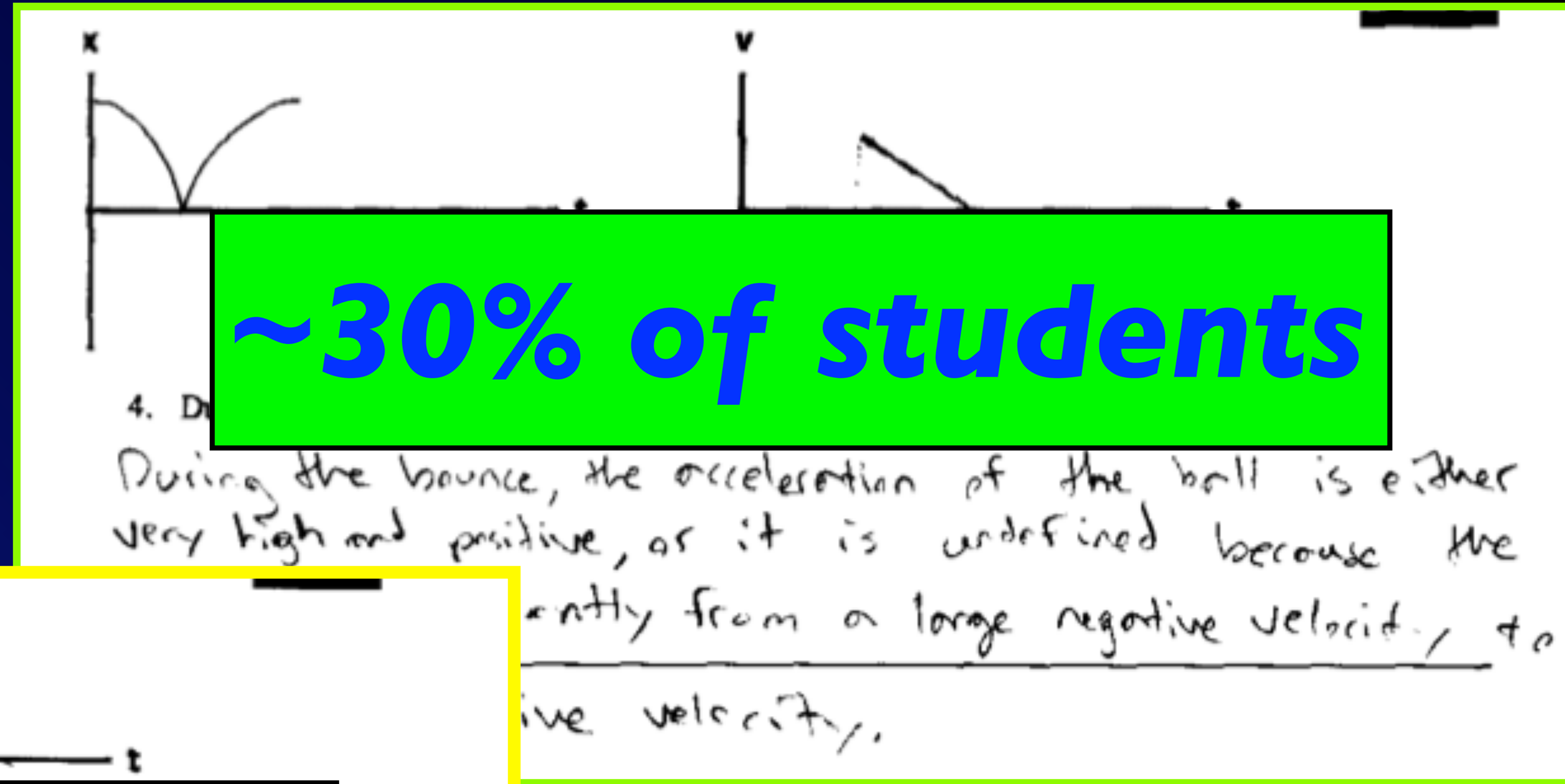


4. During the bounce, is the acceleration of the ball *upward, downward,* or *zero?* Explain.

Zero, because at this point the ball is experiencing a change from acceleration to decelleration, which means it must pass through zero at this point. It can also be seen to be zero on the slope of the v vs. t graph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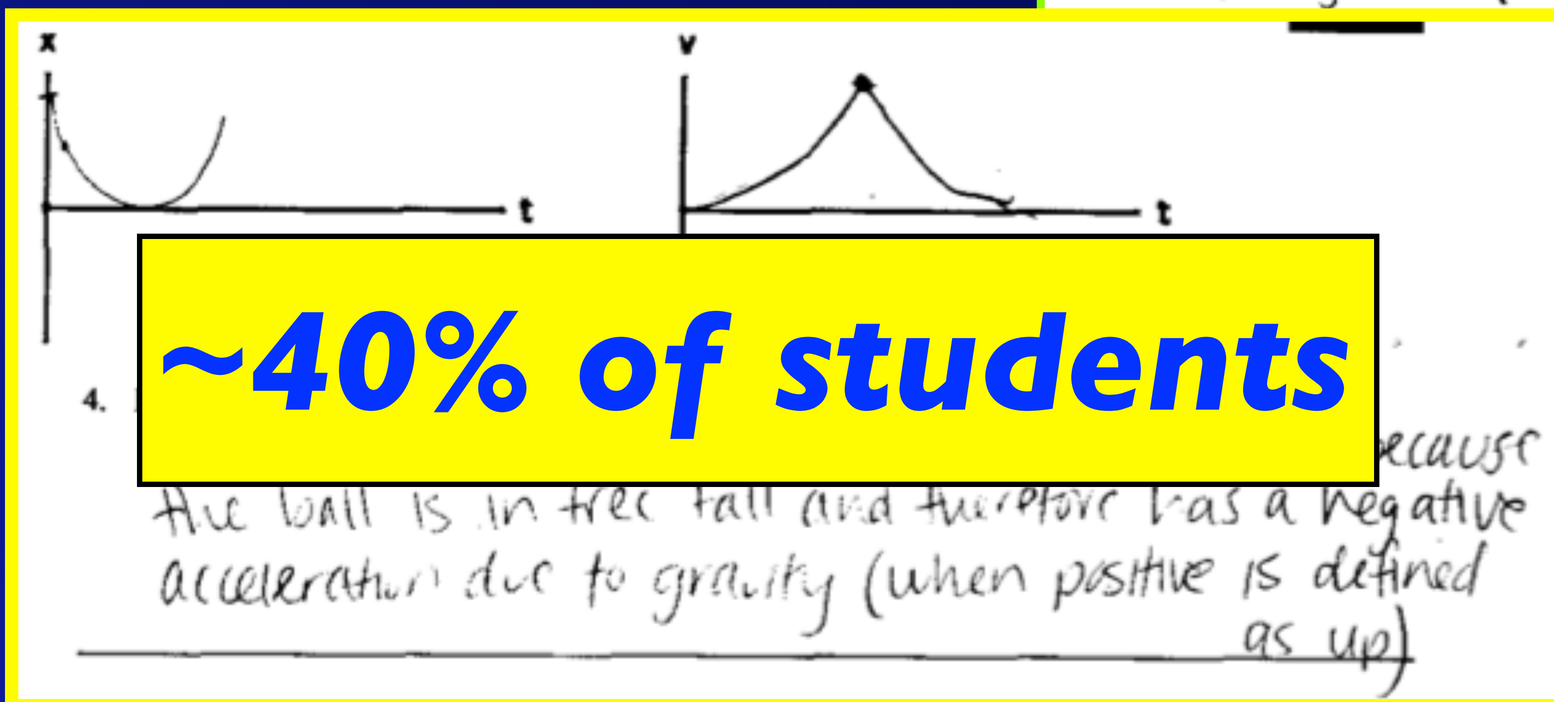
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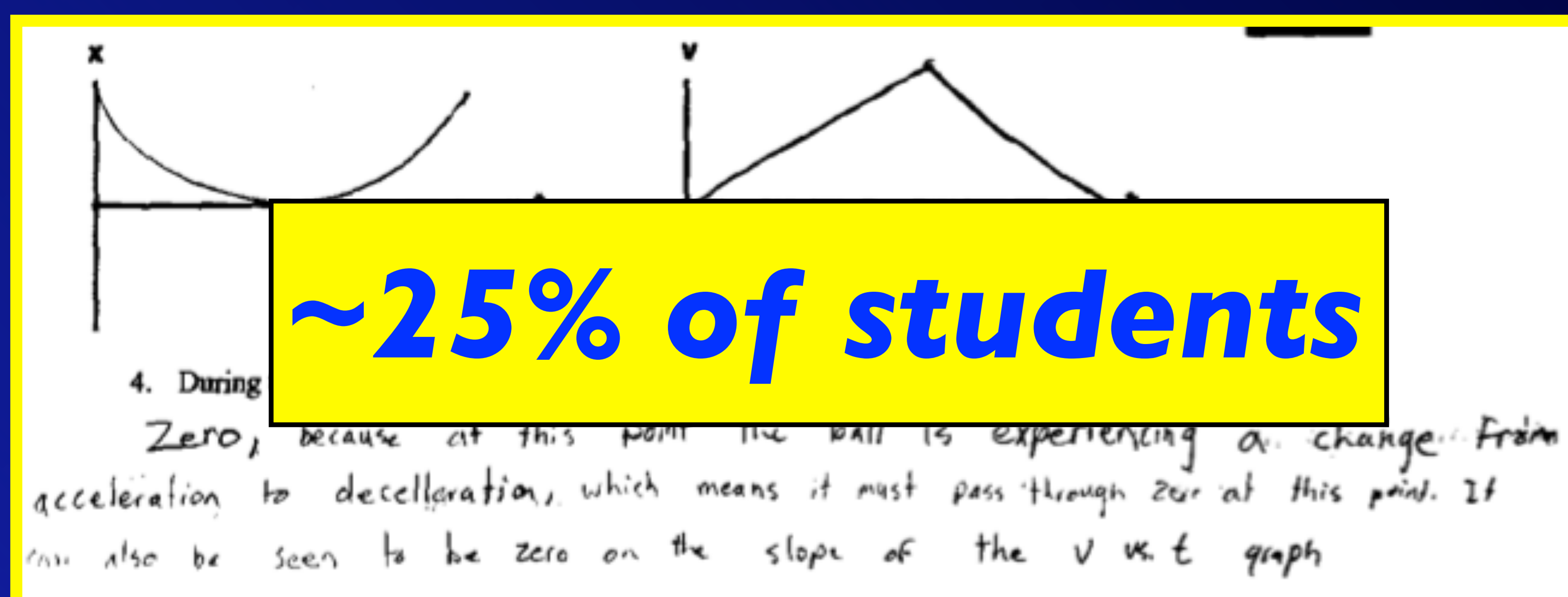
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Lab: *Acceleration in One Dimension*

Lab 2: Acceleration in One Dimension

Name:

Introduction

Last week you used graphs, words, and equations to represent the motion of objects along a straight-line path. This week you will continue to analyze motion in one dimension, with a focus on the concept of acceleration. Galileo pioneered this concept in the early 1600's. He famously noted that a rock dropped from the top of the mast of a ship that is moving steadily across the sea will travel straight down the mast to its base, rather than "falling behind." Galileo concluded that uniform motion is, in a fundamental sense, the same as being at rest, while accelerated motion is different. Today acceleration is the central concept of kinematics. As you'll explore later, acceleration forms the main link between the way things move and what *causes* them to move (force). But we're getting ahead: in today's lab you will conduct some variations of Galileo's famous free-fall experiment, using modern technology to collect data.

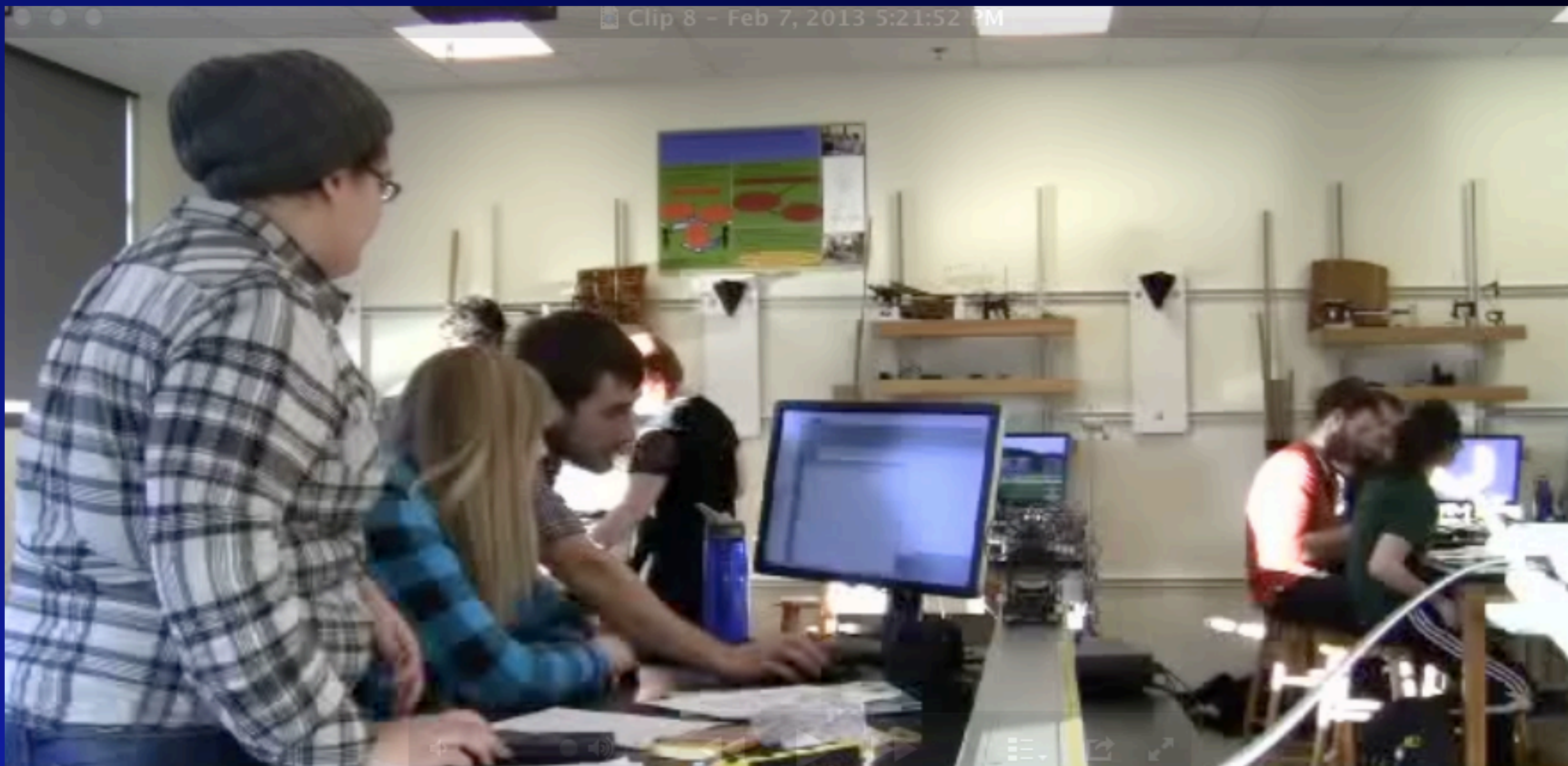
Learning targets

Listed below are the main learning goals for this lab. These goals have overlap with the learning targets from last week, so that you have multiple opportunities to think about the key concepts. Each activity states up front which of the learning targets it focuses on.

After this lab, you should be able to:

1. Translate back and forth between multiple representations of motion (including graphs, equations, and natural language).
2. Analyze the turnaround point of a one-dimensional accelerated motion.
3. Use a velocity graph to measure acceleration in m/s^2 *and* in "g's."

Inside the WWU Introductory Mechanics Lab:



Lab: *Research-based instructional sequence*

Activity I: Motion in one dimension with a turnaround

This activity focuses on Learning Target 2, analysis of a "turn around," and Learning Target 3, measuring acceleration.

Obtain a track and a low friction cart. Using a folder, book, or other object, incline the track by a few degrees. Place the cart at the bottom of the track and give it a quick shove such that it moves up the incline and back down again.

A. In a moment, you will place a motion sensor at the bottom of the incline and repeat the experiment. First, sketch a prediction of the velocity vs time graph that will be produced. Make your sketch for the part of the motion that starts *just after* the quick shove and ends *just before* the catch.

B. Connect a motion sensor to the interface box, with the yellow plug in Ch.1 and black plug in Ch. 2. Start up the computer program required for graphing the motion sensor data. (Either create your own

Lab: *Research-based instructional sequence*

C. When Victor, Kate and Devon were going through this activity together they had different ideas about the cart's acceleration at the turnaround point.

Victor: *"The acceleration should be zero at the turnaround. That's when the cart switches from moving up to moving down."*

Kate: *"From just before the turnaround to just after, there is a change in velocity. That means there should be an acceleration."*

Victor: *"But nothing changes in an instant. The instantaneous acceleration should be zero right at the top."*

Lab: *Research-based instructional sequence*

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Victor: "*The acceleration should be zero at the turnaround. That's when the cart switches from moving up to moving down.*"

Kate: "*From just before the turnaround to just after, there is a change in velocity. That means there should be an acceleration.*"

Victor: "*But nothing changes in an instant. The instantaneous acceleration should be zero right at the top.*"

Discuss the dialogue with your partners and annotate it with colored pencil. Use blue or green to mark the parts that make sense and are good building blocks for understanding, and red to mark the parts that are problematic and need modification. Add brief comments to show how the productive parts could be built on and/or the problematic parts improved.

The idea that *something* must be zero at the turnaround is compelling and in some way makes sense. What might Victor be thinking about, and how could you help him refine his ideas?

Lab: *Research-based instructional sequence*

Activity III: Bouncy-ball motion

This activity addresses Learning Targets 1-3 in a somewhat more complicate scenario: a ball that falls freely to the ground and then bounces back up.

You will use the ultrasonic sensor to examine this motion. Set up the rod assembly and connect the motion sensor so that it is "looking downward" at the motion of the ball.

A. The prelab asked you to predict the motion graphs for the bouncy ball experiment. Before you carry out the experiment, review your prelab and discuss your predicted graphs with your partners. When you are ready, draw group consensus predictions on the axes below.

x

v

Lab: *Research-based instructional sequence*

Does the bounce happen instantaneously? If not, determine how much time the ball spends in contact with the ground and mark and label this interval on your velocity graph. Explain.

During the bounce, does the velocity of the ball change? If so, is the direction of the change in velocity vector *upward* or *downward*?

During the bounce, is the direction of the ball's acceleration vector *upward, downward,* or *zero?* Explain.

Lab: *Revisiting Initial Ideas*

Activity IV: Reflection

This activity asks you to reflect on your thinking and learning by comparing your original prelab explanations to your current understanding.

Obtain your prelab. Together with your partners, go over the questions and come to agreement on how to explain them. As you go, make annotations in colored pencil. Use green or blue to underline the parts of your reasoning that were productive, and red for parts that need revising. Add brief comments to identify where and how your initial ideas were problematic. Focus not just on whether you had the correct answers, but also on the quality of your explanations. Discuss your reflections with your partners.

When you are ready, check your annotated prelab with your instructor. Go over your understanding of the physics underlying the prelab questions, as well as any specific difficulties or misconceptions that you have identified in your initial ideas. Take this opportunity to discuss your ideas in detail with your lab partners and your instructor.

After participating in the checkout discussion, have your instructor initial your prelab.

Take your annotated prelab with you when you leave.

Video Clip 1: *"So that's something we all misunderstood"*

Discussion of acceleration during the bounce

Video Clip 1: *"So that's something we all misunderstood"*

Discussion of acceleration during the bounce

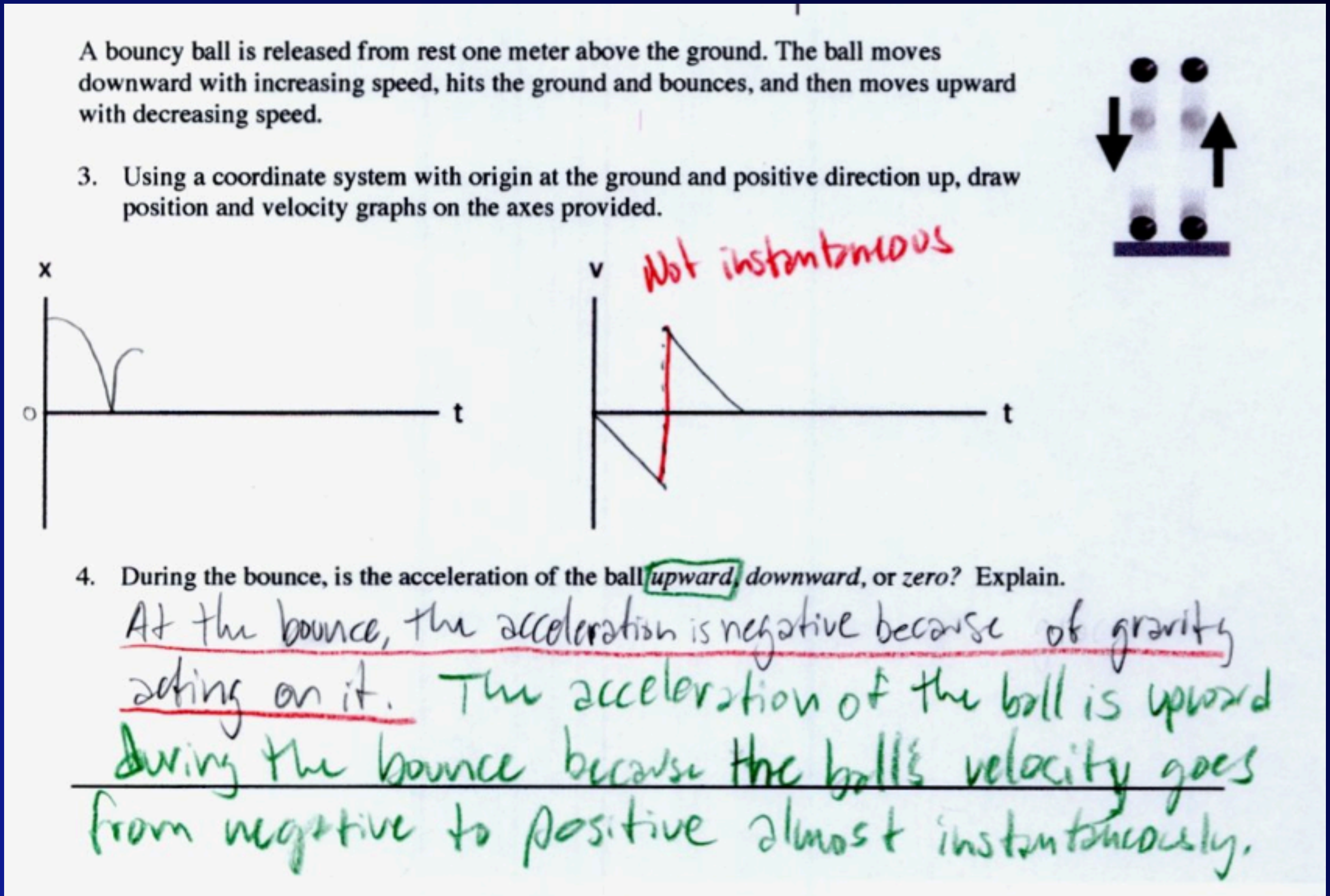
Video Clip 2: "*Why did we think that?*"

Discussion of bouncy ball vs sticky ball

Video Clip 2: “*Why did we think that?*”

Discussion of bouncy ball vs sticky ball

Lab: *Revisiting Initial Ideas*



A bouncy ball is released from rest one meter above the ground. The ball moves downward with increasing speed, hits the ground and bounces, and then moves upward with decreasing speed.

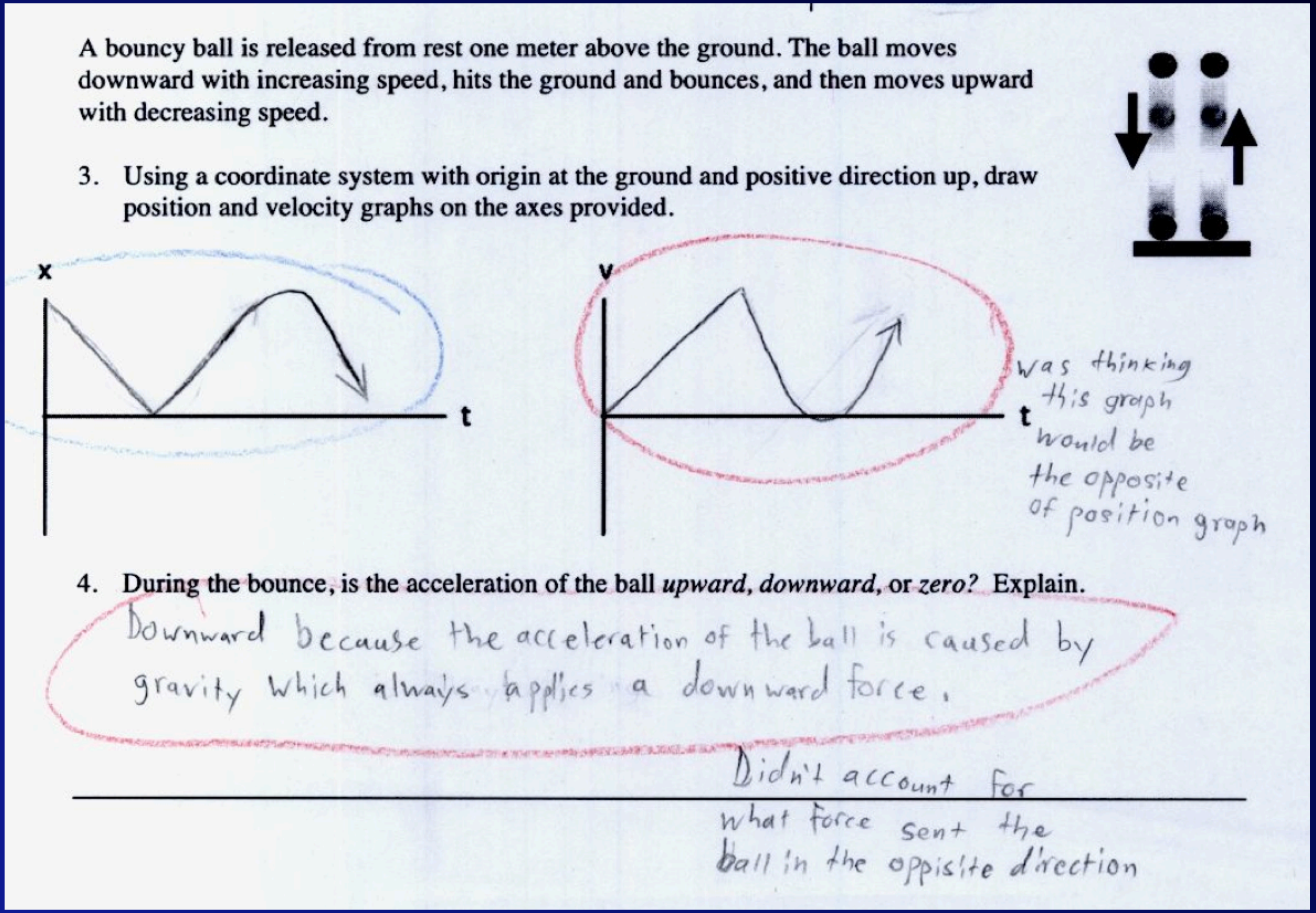
3. Using a coordinate system with origin at the ground and positive direction up, draw position and velocity graphs on the axes provided.

4. During the bounce, is the acceleration of the ball *upward*, *downward*, or *zero?* Explain.

At the bounce, the acceleration is negative because of gravity acting on it. The acceleration of the ball is upward during the bounce because the ball's velocity goes from negative to positive almost instantaneously.

Focus on current answers and reasoning

Lab: *Revisiting Initial Ideas*



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3. Using a coordinate system with origin at the ground and positive direction up, draw position and velocity graphs on the axes provided.

x

t

v

t

was thinking this graph would be the opposite of position graph

4. During the bounce, is the acceleration of the ball *upward, downward,* or *zero?* Explain.

Downward because the acceleration of the ball is caused by gravity which always applies a downward force.

Didn't account for what force sent the ball in the oppisite direction

Focus on initial ideas

Lab HW: *Postlab question*

A child's toy consists of an elastic band that connects a wooden paddle and a small rubber ball. The paddle is used to give the ball a quick downward whack, after which the ball moves downward with decreasing speed, comes to rest for an instant, and then moves upward with increasing speed.

During the different parts of the motion (*not* including the whack), is the acceleration of the ball *upward, downward,* or *zero?* Explain your reasoning, and make sure to discuss the turnaround point.

Culminating lab activity: *Synthesis Challenge*

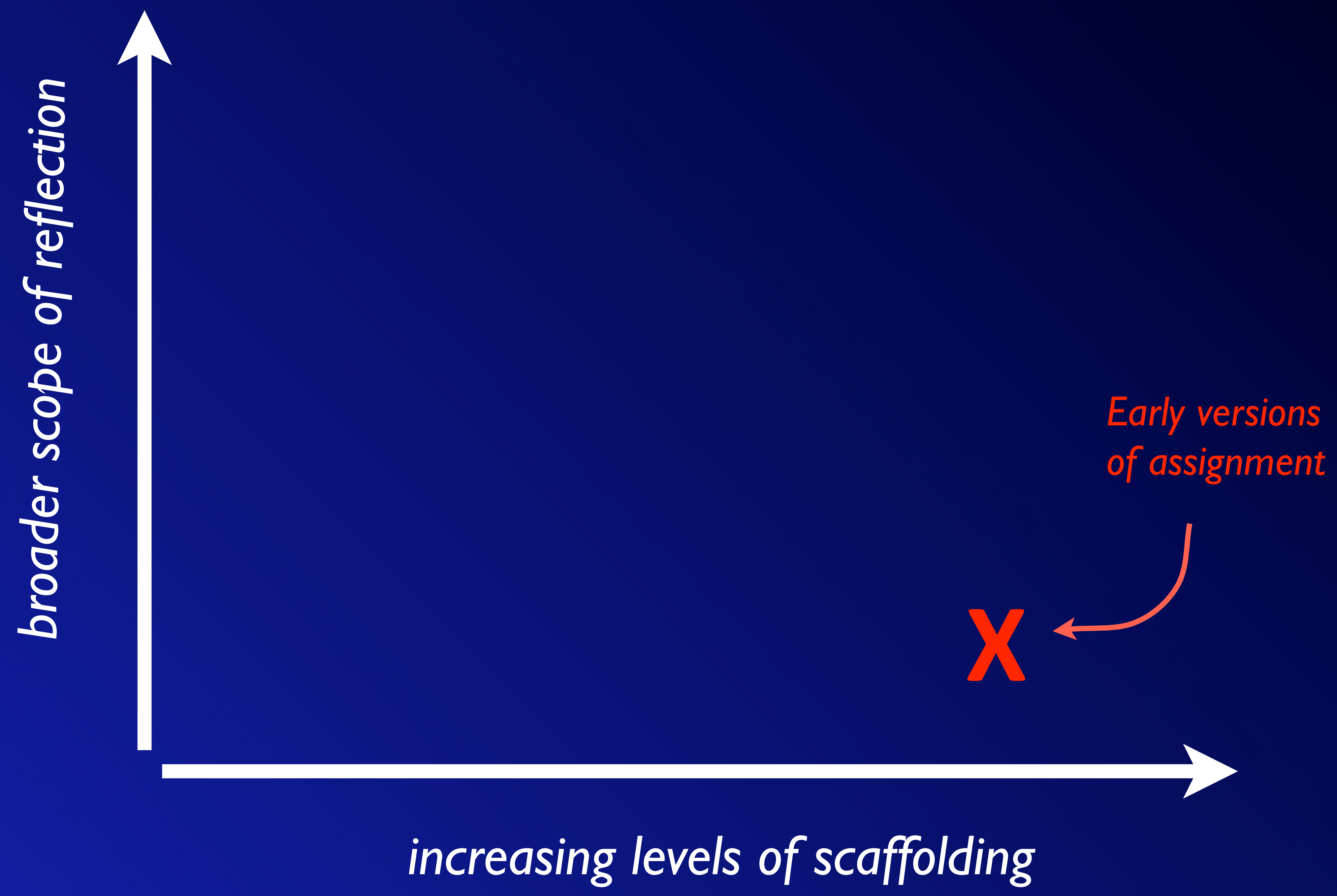
A roller coaster carries terrified patrons down a steep incline. On the way down, they go through an artificial "thunderstorm" that involves sprinklers. You're the technical consultant, and your boss gives you certain parameters the ride must fit into. She wants customers to be subjected to the "rain" for only 0.2 second; furthermore, the length of the water spraying device is fixed, providing a set distance along the track during which the spray comes down.

How far above the water sprayer should the roller coaster car start?
(Your lab group will model this scenario with a ball bearing rolling down an inclined track.)

Lab HW: *Narrative Reflection*

A written "learning commentary"
in which students discuss how their understanding of
specific physics concepts has changed.

Lab HW: *Narrative Reflection*



Lab HW: *Narrative Reflection*

An early version:

A. Collaborate with your partners and come to a consensus about the acceleration during the bounce.

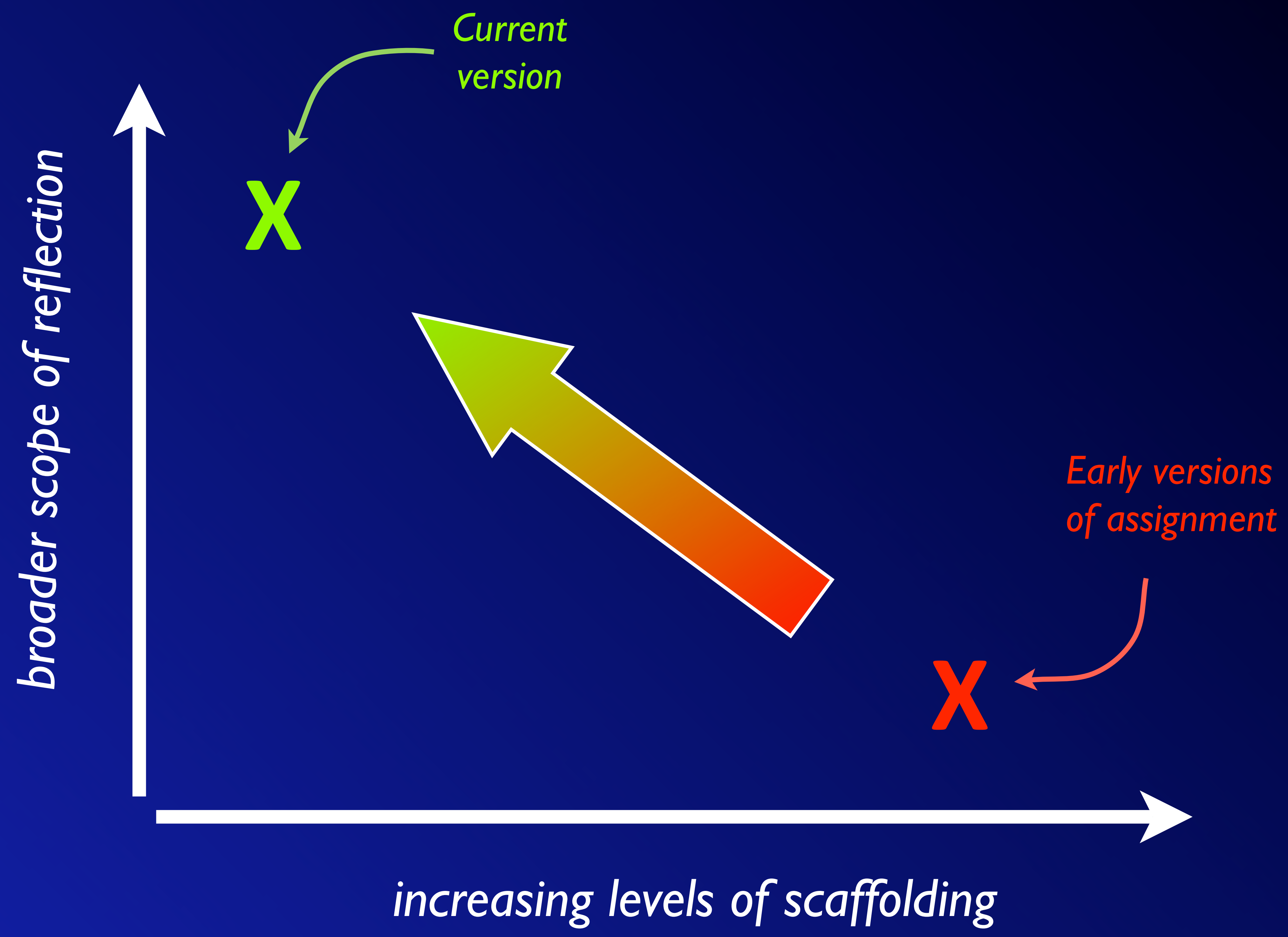
B. Obtain your prelabs and discuss how each group member was originally thinking about the question. Indentify specific areas where reasoning was incomplete or incorrect.

C. Compare your current understanding and your initial ideas (parts A and B) to describe how your thinking has changed.

Remember: Steps A-C are interrelated and we encourage you to bounce back and forth between them as needed. Also, try to fill in the table *during* your discussion to avoid repeating your explanations. Use notes and bullet points rather than full paragraphs.

A. Current consensus answer:	B. Incorrect group ideas:	C. Description of how your ideas have changed and what you have learned:

Lab HW: *Narrative Reflection*



Lab HW: *Narrative Reflection*

Current Version:

Lab 2 HW

4. Now write your own narrative reflection. It should be typed, between 1-3 paragraphs (but not more than a single page). Your narrative should include the following:

   - Select *one* of the learning targets. Pick the one for which you feel you made the most significant gains in understanding. Quote the selected learning target.
   - *Initial understanding*. What *specifically* did you understand about this learning target coming into the lab? What was unclear to you or misunderstood? Cite evidence from your written work.
   - *Current understanding*. Summarize your current understanding of the learning target. Highlight how your current understanding differs from your initial. Cite evidence from your written work.
   - *Learning "pathway."* Discuss what led to the changes in your understanding (e.g. a specific experiment, a computer simulation, *etc*.). Be more specific than just listing the activities. Discuss <u>what</u> you did and <u>how</u> it helped you change your idea.

Sample student narrative: *Glimpsing the realm of forces*

When I first came into the lab I did not have the proper understanding of learning target number 2. "Analyze the turnaround point of a one-dimensional accelerated motion." My initial understanding of the momentary acceleration at the turn around point was that the only acceleration the ball was feeling was that of gravity. When I started to experiment in lab and analyze what force propelled it back up (in what we designated the negative direction) I began to question my previous hypothesis. How could the ball change directions if the only acceleration it was experiencing was that of gravity? When interpreting the velocity vs. time graph I realized that the time the ball was on the ground was .05 seconds. Since acceleration reflects the change in velocity over the change in time, that there must be a momentary acceleration upward to propel the ball. That momentary acceleration is what we classify as a force. Tracking the balls velocity vs. time allowed me to change my preconceived notion that the only acceleration is due to gravity and allowed me to glimpse into the realm of forces.

Questions for research

To what extent are the quality and depth of student reflection associated with conceptual learning?

Do the quality and depth of student reflection improve over time with practice?

Can the quality and depth of student reflection be reliably measured?!

Metacognitive Elements Rubric (MER)

Need: A reliable measure of the amount, depth and quality of student reflection.

Response: Iterative development of a scheme for coding student writing.

Metacognitive Elements Rubric (MER)

Start "top down" with components of reflective thinking. Modifications based on analysis of student writing.

- Identify problematic/productive aspects of initial reasoning.
- Diagnose underlying learning difficulty.
- Describe differences in thinking *then* compared to *now*.
- Retrace my learning pathway:

  How did I come to know what I know?

Metacognitive Elements Rubric (MER)

13 codes in 4 code groups:

Cognition (Codes 1-4):
State initial and current answers and explanation.

Reflection on initial ideas (Codes 5-7):
Identify and describe problematic aspects of underlying ideas.

Reflection on current ideas (Codes 8-10):
Identify and describe newly understood ideas.

Metacognition (Codes 11-13):
Highlight changes in thinking and discuss "trigger events".

Non-Codes

"I learned a lot . . ."

"I don't have any questions . . ."

"There isn't anything I'm confused about . . ."

"My answer to question 2.b was wrong . . ."

"The lab didn't help me . . ."

"I got all of the prelab questions right . . ."

Applying the MER to students' reflective writing

Sample Narrative: *Glimpsing the realm of forces*

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Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

Sample Narrative: *Glimpsing the realm of forces*

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1,2

Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

1: Statement of initial answer

2: Statement of initial reasoning

Sample Narrative: *Glimpsing the realm of forces*

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Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

12: Identifies action or thought as a cause of or impetus for change in understanding

5: Identifies an idea as problematic

Sample Narrative: *Glimpsing the realm of forces*

When I first came into the lab I did not have the proper understanding of learning target number 2. "Analyze the turnaround point of a one-dimensional accelerated motion." My initial understanding of the momentary acceleration at the turn around point was that the only acceleration **1,2** the ball was feeling was that of gravity. When I started to experiment in lab and analyze **12** what force propelled it back up (in what we designated the negative direction) I began to question my previous hypothesis. **5** How could the ball change directions if the only acceleration it was experiencing **12** was that of gravity? When interpreting the velocity vs. time graph I realized that the time the ball was on the ground was .05 seconds. **12** Since acceleration reflects the change in velocity over the change in time, that there must be a momentary acceleration upward to propel the ball. That momentary acceleration is what we classify as a force. Tracking the balls velocity vs. time allowed me to change my preconceived notion that the only acceleration is due to gravity and allowed me to glimpse into the realm of forces.

Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

12: Identifies action or thought as a cause of or impetus for change in understanding

Sample Narrative: *Glimpsing the realm of forces*

When I first came into the lab I did not have the proper understanding of learning target number 2. "Analyze the turnaround point of a one-dimensional accelerated motion." My initial understanding of the momentary acceleration at the turn around point was that the only acceleration **1,2** the ball was feeling was that of gravity. When I started to experiment in lab and analyze **12** what force propelled it back up (in what we designated the negative direction) I began to question my previous hypothesis. **5** How could the ball change directions if the only acceleration it was experiencing **12** was that of gravity? When interpreting the velocity vs. time graph I realized that the time the ball was on the ground was .05 seconds. **12** Since acceleration reflects the change in velocity over the change in time **3,4** that there must be a momentary acceleration upward to propel the ball. That momentary acceleration is what we classify as a force. Tracking the balls velocity vs. time allowed me to change my preconceived notion that the only acceleration is due to gravity and allowed me to glimpse into the realm of forces.

Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

3: Statement of current answer

4: Statement of current reasoning

Sample Narrative: *Glimpsing the realm of forces*

When I first came into the lab I did not have the proper understanding of learning target number 2. "Analyze the turnaround point of a one-dimensional accelerated motion." My initial understanding of the momentary acceleration at the turn around point was that the only acceleration **1,2** the ball was feeling was that of gravity. When I started to experiment in lab and analyze **12** what force propelled it back up (in what we designated the negative direction) I began to question my previous hypothesis. **5** How could the ball change directions if the only acceleration it was experiencing **12** was that of gravity? When interpreting the velocity vs. time graph I realized that the time the ball was on the ground was .05 seconds. **12** Since acceleration reflects the change in velocity over the change in time **3,4** that there must be a momentary acceleration upward to propel the ball. That momentary acceleration is what we classify as a force. **10** Tracking the balls velocity vs. time allowed me to change my preconceived notion that the only acceleration is due to gravity and allowed me to glimpse into the realm of forces.

Code groups

- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

10: Illustrates or applies a new concept or idea

Sample Narrative: *Glimpsing the realm of forces*

When I first came into the lab I did not have the proper understanding of learning target number 2. "Analyze the turnaround point of a one-dimensional accelerated motion." My initial understanding of the momentary acceleration at the turn around point was that the only acceleration **1,2** the ball was feeling was that of gravity. When I started to experiment in lab and analyze **12** what force propelled it back up (in what we designated the negative direction) I began to question my previous hypothesis. **5** How could the ball change directions if the only acceleration it was experiencing **12** was that of gravity? When interpreting the velocity vs. time graph I realized that the time the ball was on the ground was .05 seconds. **12** Since acceleration reflects the change in velocity over the change in time **3,4** that there must be a momentary acceleration upward to propel the ball. That momentary acceleration is what we classify as a force. **10** Tracking the balls velocity vs. time allowed me to change my preconceived notion that the only acceleration is due to gravity and allowed me to glimpse into the realm **11** of forces.

Code groups

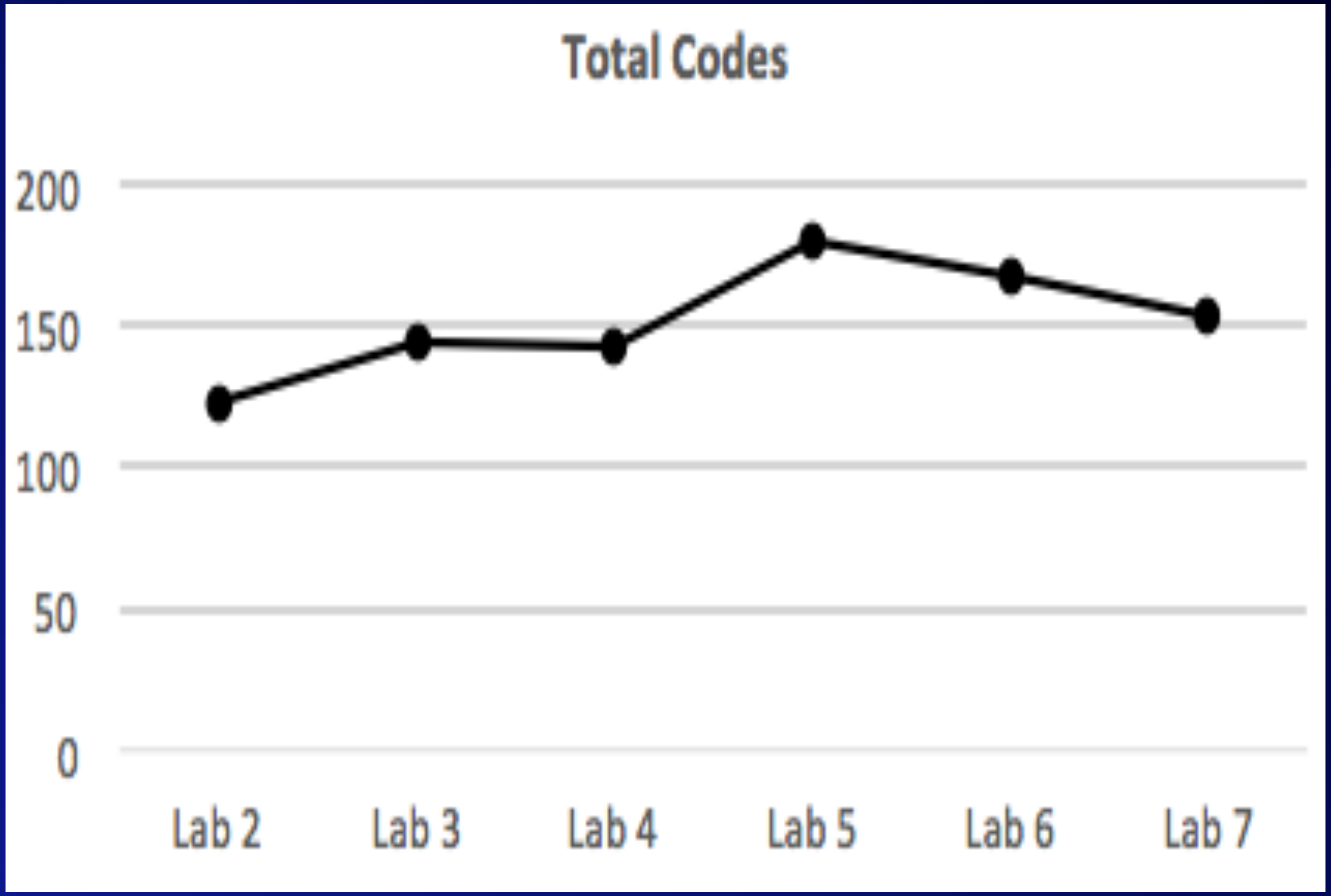
- *State answer/reasoning*
- *Reflect on initial ideas*
- *Reflect on current ideas*
- *Analyze change in thinking*

11: Compares, contrasts, or relates ideas from before and after learning episode

Preliminary Findings (N = 17)

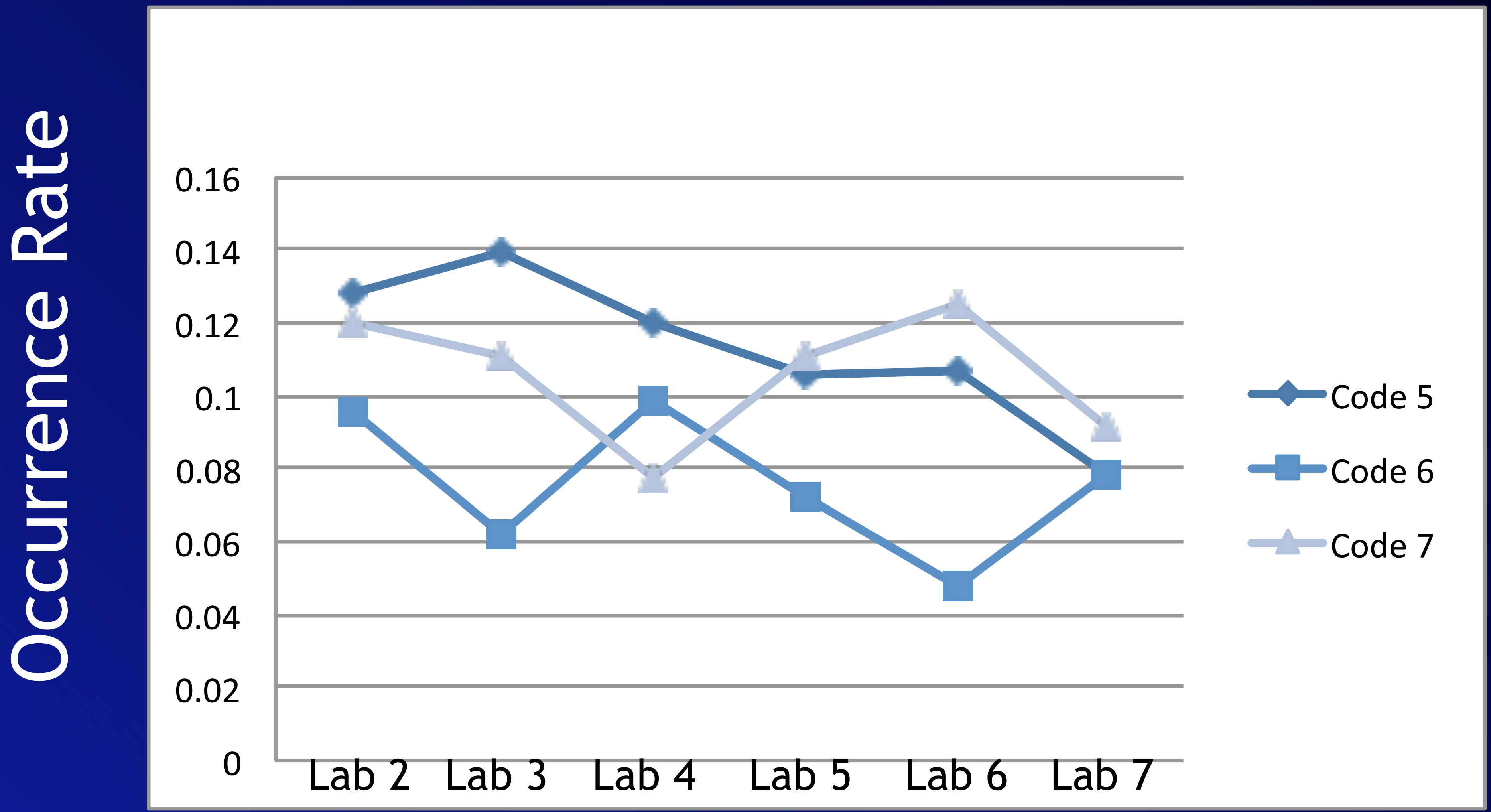
- Introductory calc-based mechanics, Fall 2012
- Single lecture section
- Criteria for inclusion:
  - *student completed narrative reflection assignment for all 7 labs*
  - *student completed FCI both pre- and post-course*

Study 1: Tracking student reflection over time



- Avg: 9 codes per student per lab; low 5, high 16.
- Labs 2, 3, and 4 have fewer total codes than the average of all 6 labs, while labs 5, 6, and 7 have more

Study 1: Tracking student reflection over time



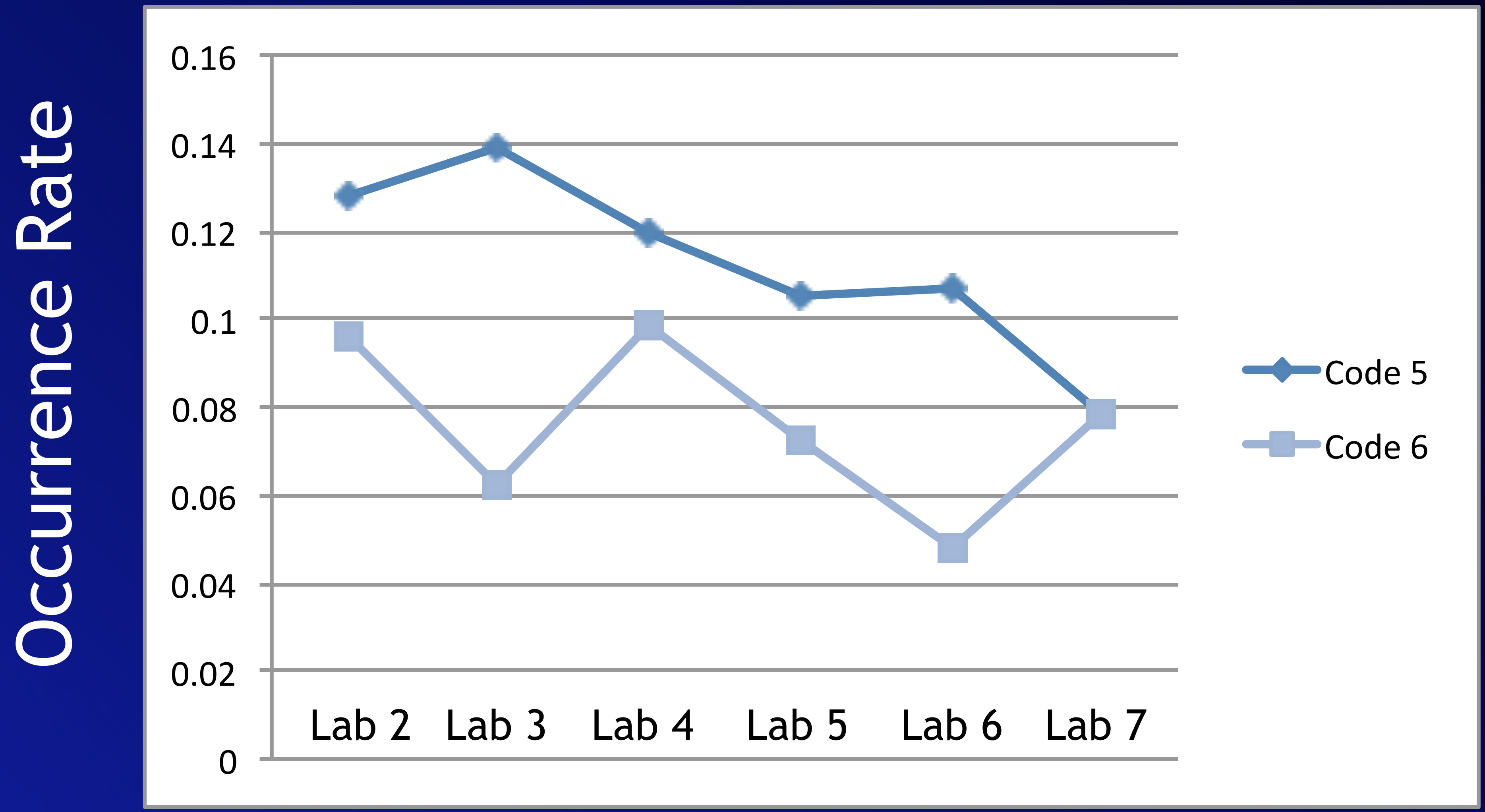
Initial ideas
Code Group

5: Student identifies statement/idea as problematic

6: Student explains *what* is problematic

7: Student reflects on what led them to/caused problematic idea

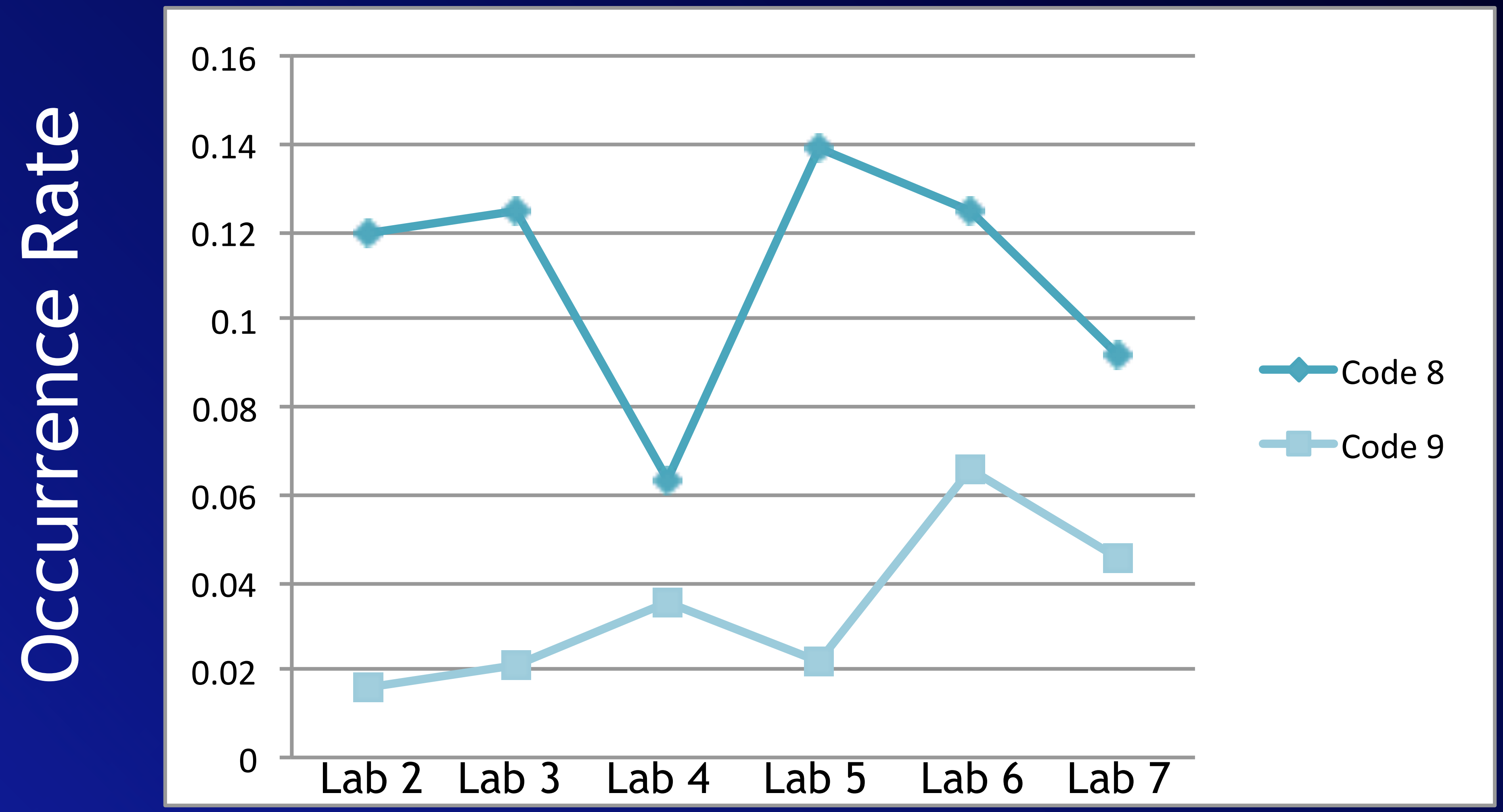
Study 1: Tracking student reflection over time



More 5's, fewer 6's:

More common for students to <u>identify</u> a response as problematic than to <u>analyze</u> specific flaws in their reasoning.

Study 1: Tracking student reflection over time

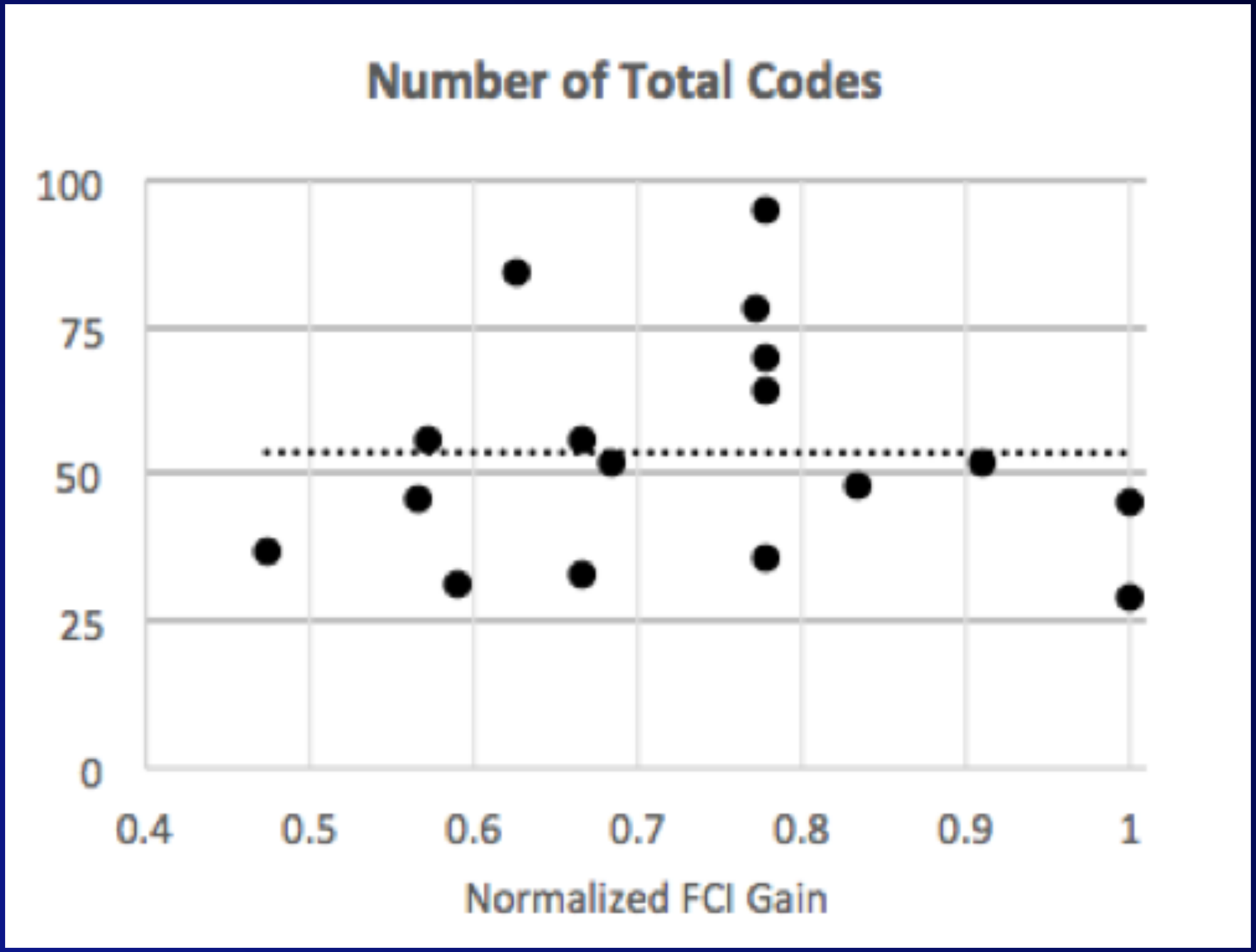


More 8's, fewer 9's and 10's:

More common for students to identify an idea they are now more comfortable with than to describe or illustrate their understanding of that idea.

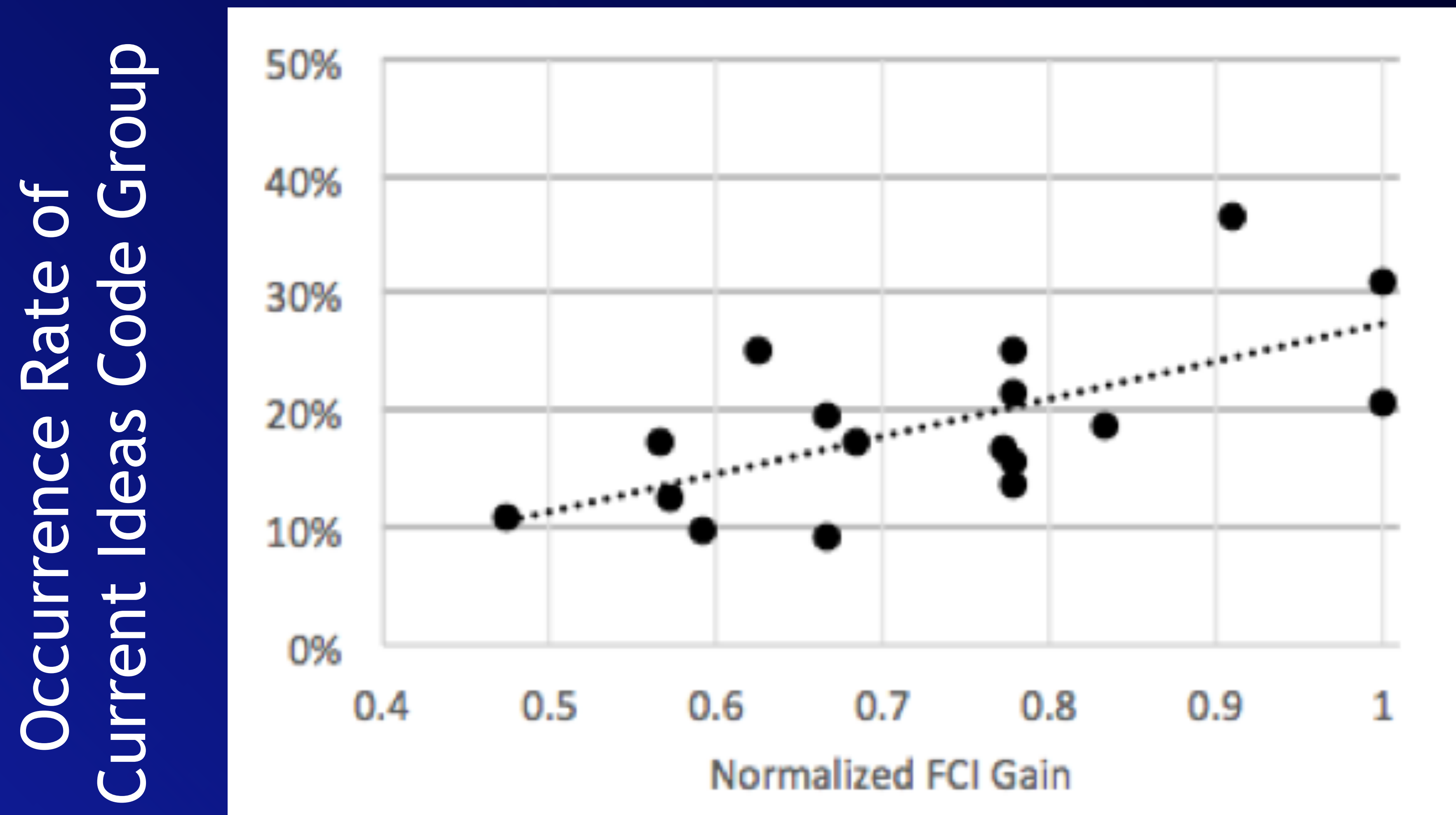
Study 2: Correlating reflection and conceptual learning

Number of Codes Vs FCI Gains



FCI gain independent of overall amount of reflection

Study 2: Correlating reflection and conceptual learning



Association between FCI gain and proportion of narrative devoted to reflection on current ideas

CONCLUSIONS

- We have developed a weekly, scaffolded writing assignment in which students reflect on how they came to understand a specific physics topic or idea.
- We have designed and tested a rubric for categorizing the types of reflective statements made by students in response to the assignment.
- Preliminary findings suggest that students do reflect in specific desirable ways on their own learning.
- Research is ongoing.

Thank you

For more, please visit Alistair's PERC poster:

McInerny, Boudreaux & Kryjevskaia;
Wednesday 7pm

Sample Narrative: *Should not override common sense*

Narrative Reflection Lab 2

My understanding of learning target number 2 ("analyze the turnaround point of a one-dimensional accelerated motion") did change in a sense during this lab, although most of the change was in my way of approaching this type of problem. Initially, I assumed the change in the ball's velocity was going to be instantaneous when it bounced, and that the velocity graph would have discontinuities when the ball bounced. When I saw the graph generated by the computer of the ball's velocity, I quickly realized that this was an unrealistic assumption based on differential calculus, and that while calculus describes physical observations really well, the assumption of instantaneous change should not override common sense assumption (which is that nothing happens instantaneously).

The measured acceleration of the ball during the bounce was about 3 g's, which makes sense if the ball is going to move upward with the same velocity because something (the normal force) had the cancel the acceleration due to gravity, and then another force had to make the ball go back up. This is what my lab partners and I discussed. This also means that technically the "corners" drawn on the ball's position graph should actually be really small parabolas. However, if the ball truly changed its velocity instantaneously, my initial prediction would be correct.