The Introductory Course: Innovations & Implications

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Setting the Stage...

- Approximately 6000 undergraduates at WU
- ~ 500 students take calculus-based introductory physics each semester
  - freshmen engineers
  - upperclassmen pre-health students
  - physics majors
  - other A&S students

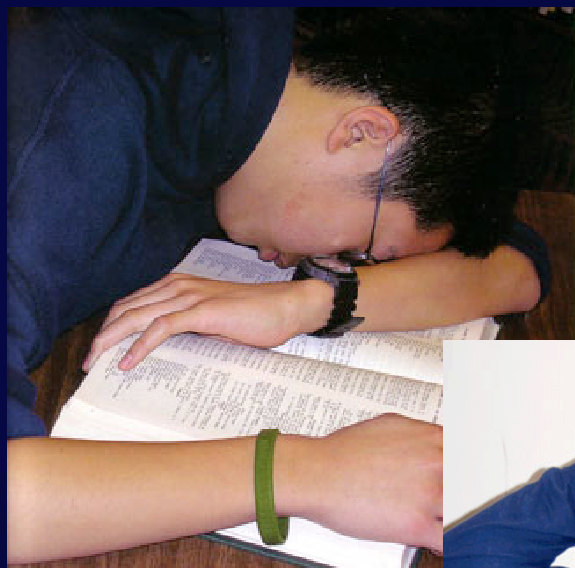
Intro Physics Classes at WU

Large Classroom

One Captivating Instructor

100-150 Students

Despite our best intentions...



The Experiment

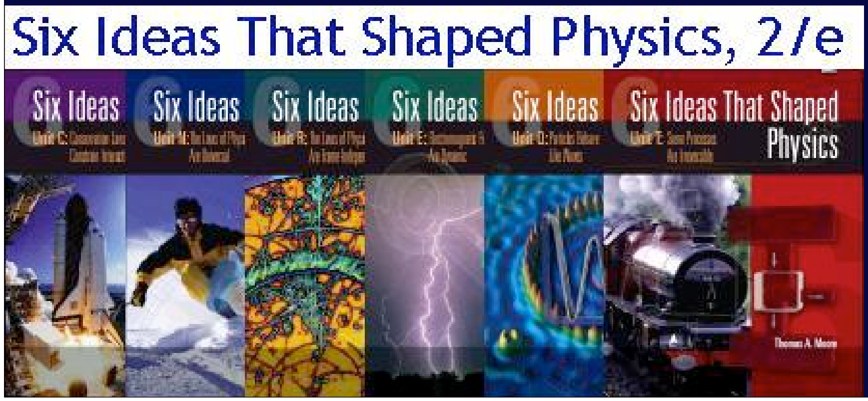
- Develop a new introductory physics sequence that ***actively*** engages students in and out of class
- Constraints:
  - Large class size
  - Classroom is a large lecture hall
  - Two semester sequence

Goals for the New Course

- Actively engage students during class
- Curriculum perceived as interesting and relevant to students
- Hone qualitative reasoning skills as well as quantitative problem solving skills
- Develop approximation and estimation skills necessary for "real world" problem solving
- Integrate modern physics into the curriculum

Six Ideas That Shaped Physics

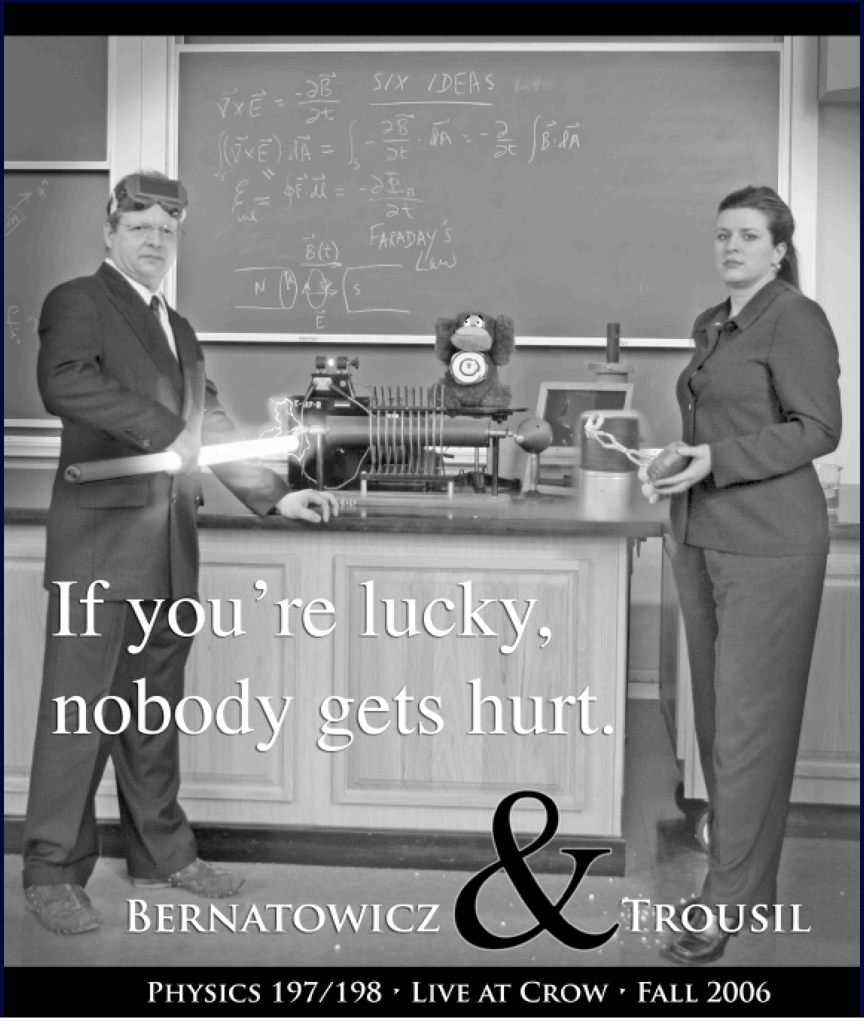
- Novel introductory physics text that organizes curriculum around six underlying themes in physics
- Integrates modern physics into curriculum
- Instructor resources for engaging students
- "Rich content" examples and problems



Six Ideas Text

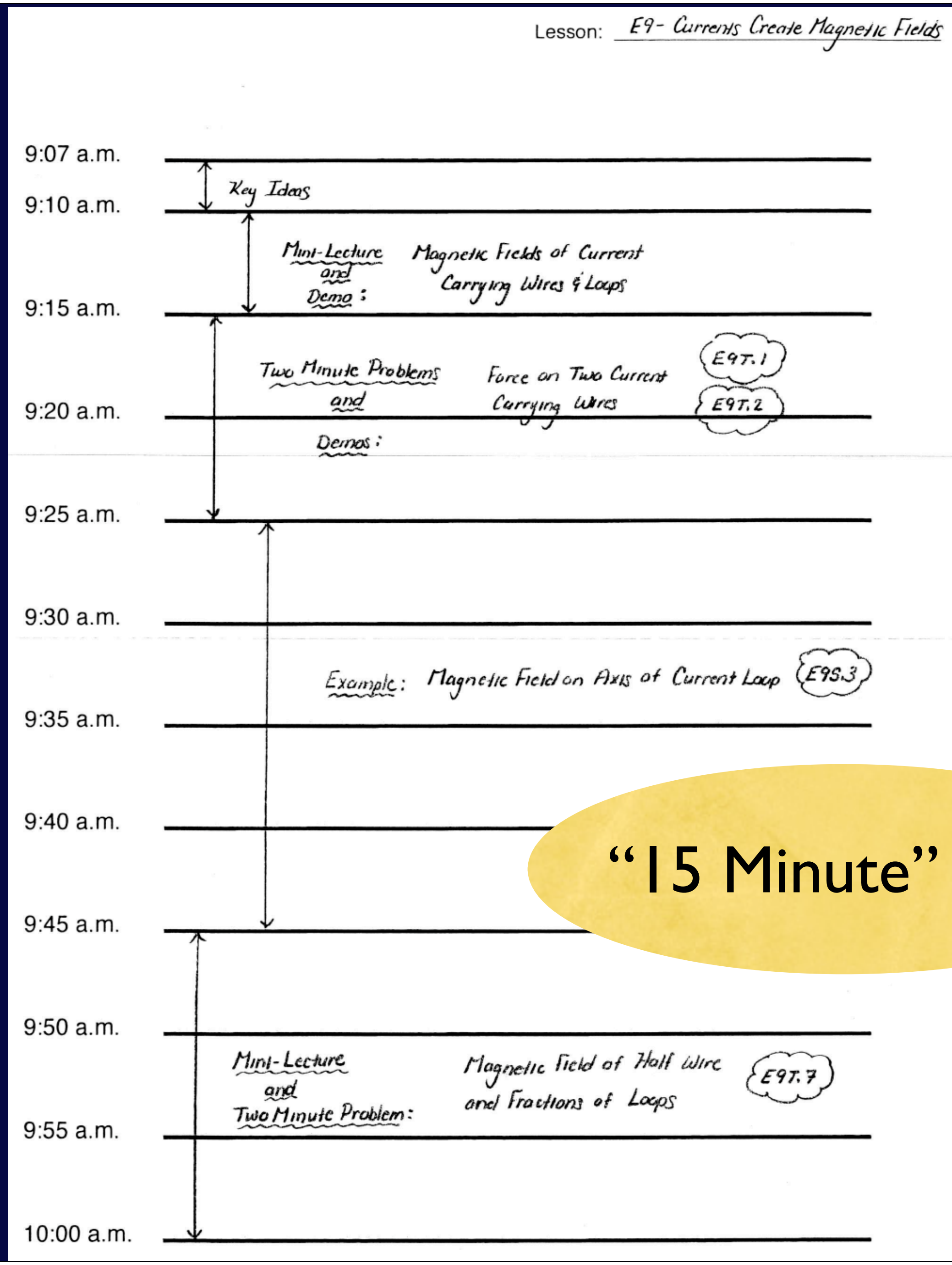
Unit C:	Conservation laws constrain interactions
Unit N:	The laws of physics are universal
Unit R:	The laws of physics are frame independent
Unit E:	Electric and magnetic fields are unified
Unit Q:	Particles behave like waves
Unit T:	Some processes are irreversible

What does an interactive physics class look like at WU?



A Typical 53 Minute Interactive Class Period

- Mini-Lectures
- Two Minute Problems / Concept Questions
- Interactive Problem Solving
- Prediction-based Demonstrations



Lesson: E9- Currents Create Magnetic Fields

9:07 a.m.	Key Ideas
9:10 a.m.	Mini-Lecture and Demo: Magnetic Fields of Current Carrying Wires & Loops
9:15 a.m.	Two Minute Problems and Demos: Force on Two Current Carrying Wires (E9T.1, E9T.2)
9:20 a.m.	
9:25 a.m.	Example: Magnetic Field on Axis of Current Loop (E9S.3)
9:30 a.m.	
9:35 a.m.	
9:40 a.m.	
9:45 a.m.	Mini-Lecture and Two Minute Problem: Magnetic Field of Half Wire and Fractions of Loops (E9T.7)
9:50 a.m.	
9:55 a.m.	
10:00 a.m.	

“15 Minute” Rule

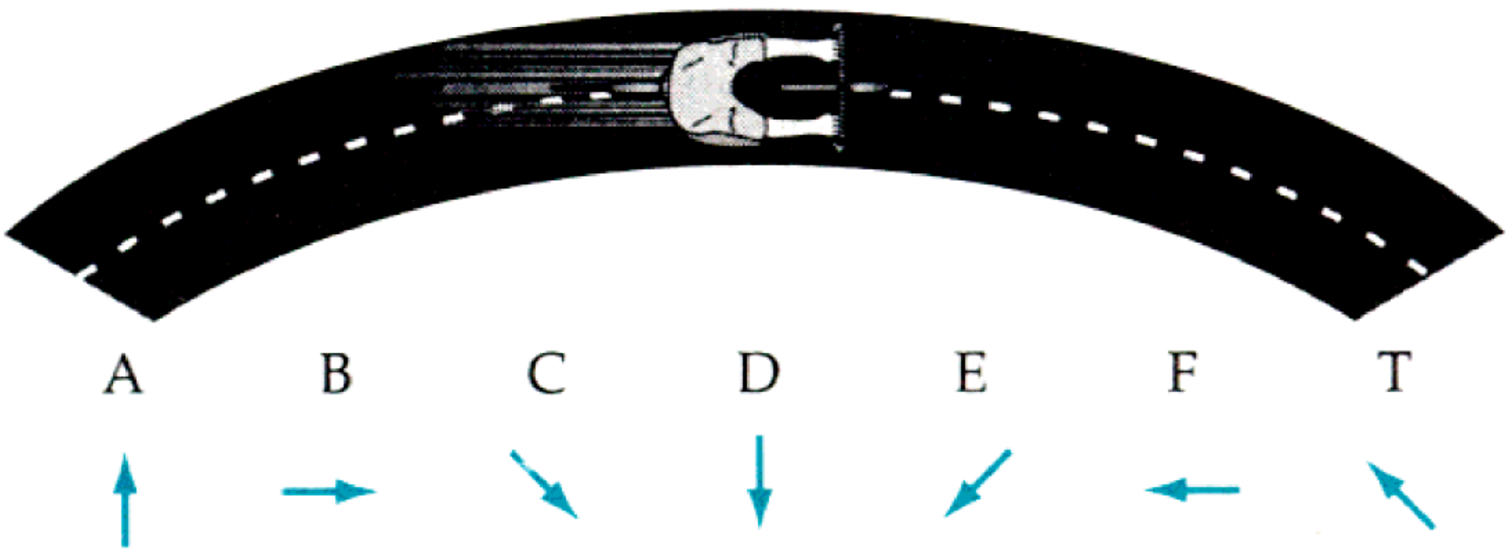
Two Minute Problems

- Multiple choice or True/False conceptual questions posed to entire class
- Students discuss the problems with nearest neighbors and build a group consensus

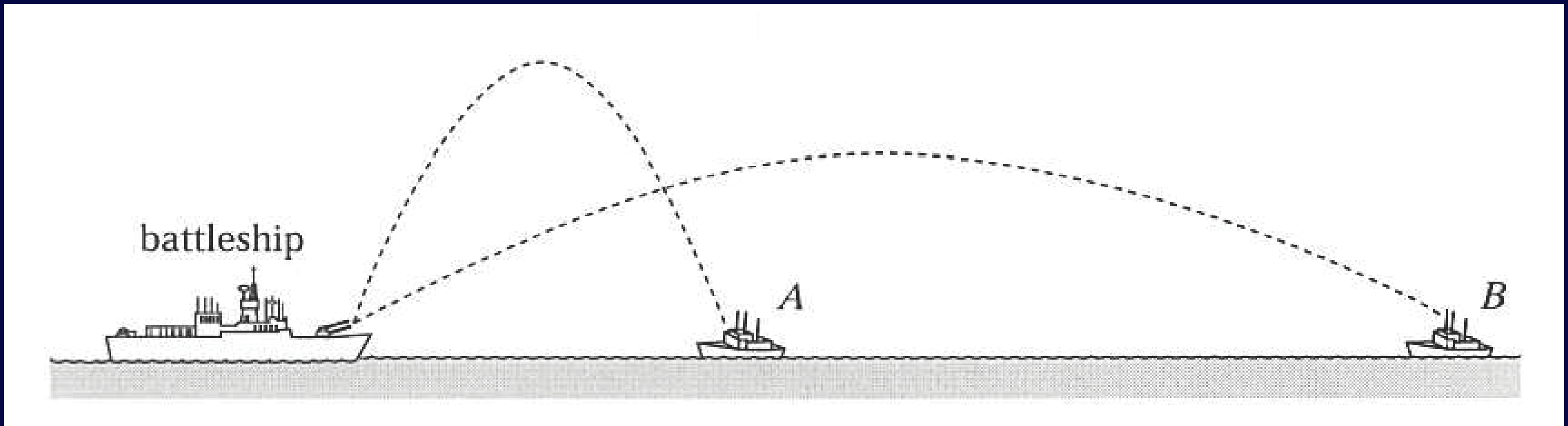
Two Minute Problem N2T.11

A bike (shown in a top view in the diagram) travels around a curve with its brakes on, so that it is constantly slowing down.

Which of the arrows shown below most closely approximates the direction of its acceleration at the instant that it is at the position shown? (Hint: Draw a motion diagram).



A battleship simultaneously fires two shells with the same muzzle speed at enemy ships. If the shells follow the parabolic trajectories shown, which ship gets hit first?



A) Ship A
B) Both ships get hit at the same time.
C) Ship B
D) Need more information
Z) ???

^ Student Response Systems

Old School

Interactive Examples

- Sophisticated quantitative and conceptual reasoning problems that illustrate key principles and applications of fundamental ideas
- Problems are broken into digestible pieces, so that students can formulate a problem solving framework in a few minutes
- Small and large group discussion elements

Example: How much does it cost to make popsicles?

Freezers and refrigerators have electric compressors and motors which transport heat from the cold compartments to the outside environment. Thus, electrical energy is required to maintain your freezer or refrigerator at a constant temperature. Consider, for example, the cost of making popsicles...

As kids we made popsicles in molds similar to the ones shown in the figure to the right. Let's figure out how much it would cost to make one tray of 6 popsicles out of fruit juice...

a) Each popsicle is about 4" long with a round cross-section that is about 1.5" in diameter. What is the total mass of our six popsicles?

b) Using energy conservation, determine how much electrical energy will be needed to make these popsicles if the fruit juice is initially at 22° C. My freezer's ambient temperature is 6.5° F (-14.2 °C). State any assumptions you make.

c) If electrical energy costs ~ \$1/25 MJ of electricity, how much will it cost us to make our popsicles?

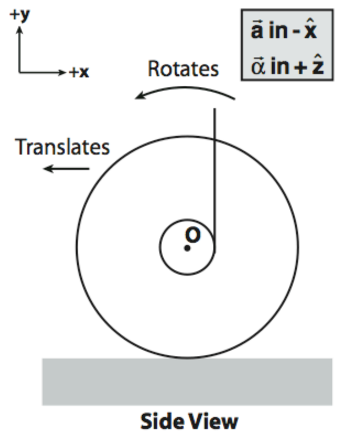
“Real World” Problems

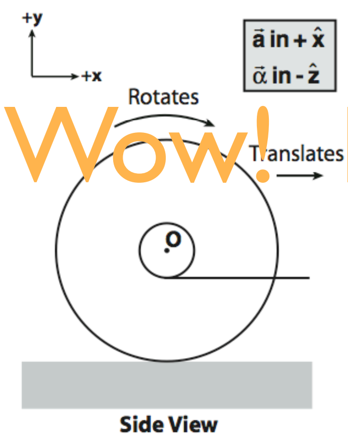
- Often we idealize our problems so much that students do not see relevance to the real world.

- Encouraging students to grapple with non-idealized problems...
  - ... develops high level problem solving skills (approximation, estimation, synthesis)
  - ... gives students confidence that they are capable of analyzing the world around them
  - ... maintains student interest despite a demanding homework schedule
  - ... develops ability to work in groups

Physics 197 - Section 01 (Trousil) Name: ______________________________
Exam #2 - November 1, 2007

(d) [4 Points] Feeling quite proud of yourself for understanding the motion of the toy when you pull the string to the right, your buddy tells you to try pulling upward on the string from the right side of the central axis as shown in the figure below. The ensuing motion is indeed different. This time the toy begins to translate slowly to the left and begins to rotate counterclockwise without slipping. Your friend, looking smug, thinks he has stumped you, but you are up to the challenge. To get yourself started, draw a free body diagram for the toy on the figure below, and label all the forces acting on the toy. Again place the tail of each force vector at the point on the toy where the force acts.





Wow! I can do this!


Everyone knows learning must be serious and difficult and you must remain seated at all times. No fun allowed.

Example: BBQ Ribs Anyone?

When Dr. Trousil was in college she waitressed during the summers at Billy's Bar & Grill in her home town of Anoka, MN. On Friday nights, the dinner special was a rack of baby back bbq ribs. On one particularly busy Friday, she learned a memorable lesson about static and kinetic friction. As she walked out of the kitchen carrying a large tray of food, including a platter of ribs, she remembered that she had forgot to bring a dinner sald to another customer, so she quickly stopped to grab a salad before heading out to the dining room. The sudden deceleration caused the platter of ribs to slide off the tray and launched them into the air, where they proceeded to crash loudly to the floor in the middle of a packed dining room. Mortification ensued...

a) To help Dr. Trousil understand what went awry, consider a tray supporting a plate of ribs. Her hand provides a contact force on the bottom of the tray to support the tray and food. Dr. Trousil is initially moving to the right when she suddenly stops. Draw free body and free particle diagrams for the tray and the ribs for the case when the platter does not slide relative to the tray. Circle any third law force pairs.

b) Identify the forces responsible for the following actions:

Force responsible for bringing the tray to rest:

Force responsible for bringing the ribs to rest:

c) Determine the maximum horizontal force that Dr. Trousil's hand can exert on the tray so that the plate of ribs does not slide relative to the tray. The plate of ribs has a mass of 1.0 kg, and the tray is approximately twice the mass of the platter of ribs. The coefficients of friction between the plate of ribs and the tray are $\mu_s = 0.4$ and $\mu_k = 0.25$. You may assume that the tray does not slip with respect to her hand.

d) If the horiztonal force exerted by her hand on the tray exceeds this maximum value, the platter of ribs will move relative to the tray. Will the magnitude of the acceleration for the platter of ribs be less than, greater than, or equal to the magnitude of the tray's acceleration? Which was does the kinetic friction force on the ribs (due to the tray) act? Relative to the tray, which way does the plate of ribs move?

Ingredients for Success...

- Extensive self-study on part of students is crucial.
  - Interactive class sessions are time consuming
  - Successful class periods are tightly coupled to student preparation
    - Daily Reading, Daily Homework, Weekly Homework
    - Rich content homework problems
- Textbook must be readable by students

Ingredients for Success...

- Students must be willing to take intellectual risks
  - Non-threatening classroom environment
  - Class participation is 5% of course grade
  - Homework is a significant portion of course grade and may be revised
- Instructor willing to adapt on the fly

A Paradigm Shift

Traditional Lecture

- Instructor is gatekeeper of information.
- Goal of students is to acquire information.

Active Learning Classroom

- Instructor is a coach, facilitator, traffic cop...
- Goal of students is to wrestle with new ideas, practice conceptual and quantitative problem solving, and give their own voice to the topics being studied

Colorado Learning Attitudes about Science Survey (CLASS)

- Assesses student attitudes about physics and learning physics
- Respond to 42 statements on a 5-Point Likert scale (strongly agree to strongly disagree)
- Student responses are compared to beliefs of experts

CLASS Categories

Real World Connection	Applied Conceptual Understanding
Personal Interest	Problem Solving General
Sense Making/Effort	Problem Solving Confidence
Conceptual Connections	Problem Solving Sophistication

- Questions are grouped according to these categories
- Each question belongs to 1 to 4 categories

WU Survey Background

- All (N = 457) introductory physics students invited to participate in a non-mandatory, web-based survey
- 94 students responded to the survey
  - 58 from traditional course (21%)
  - 36 from active-learning course (19%)
- Characteristics of the two populations very similar
  - Gender and ethnicity
  - Comparable math/physics high school preparation
  - Distribution of majors
  - Year in college

Real World Connection

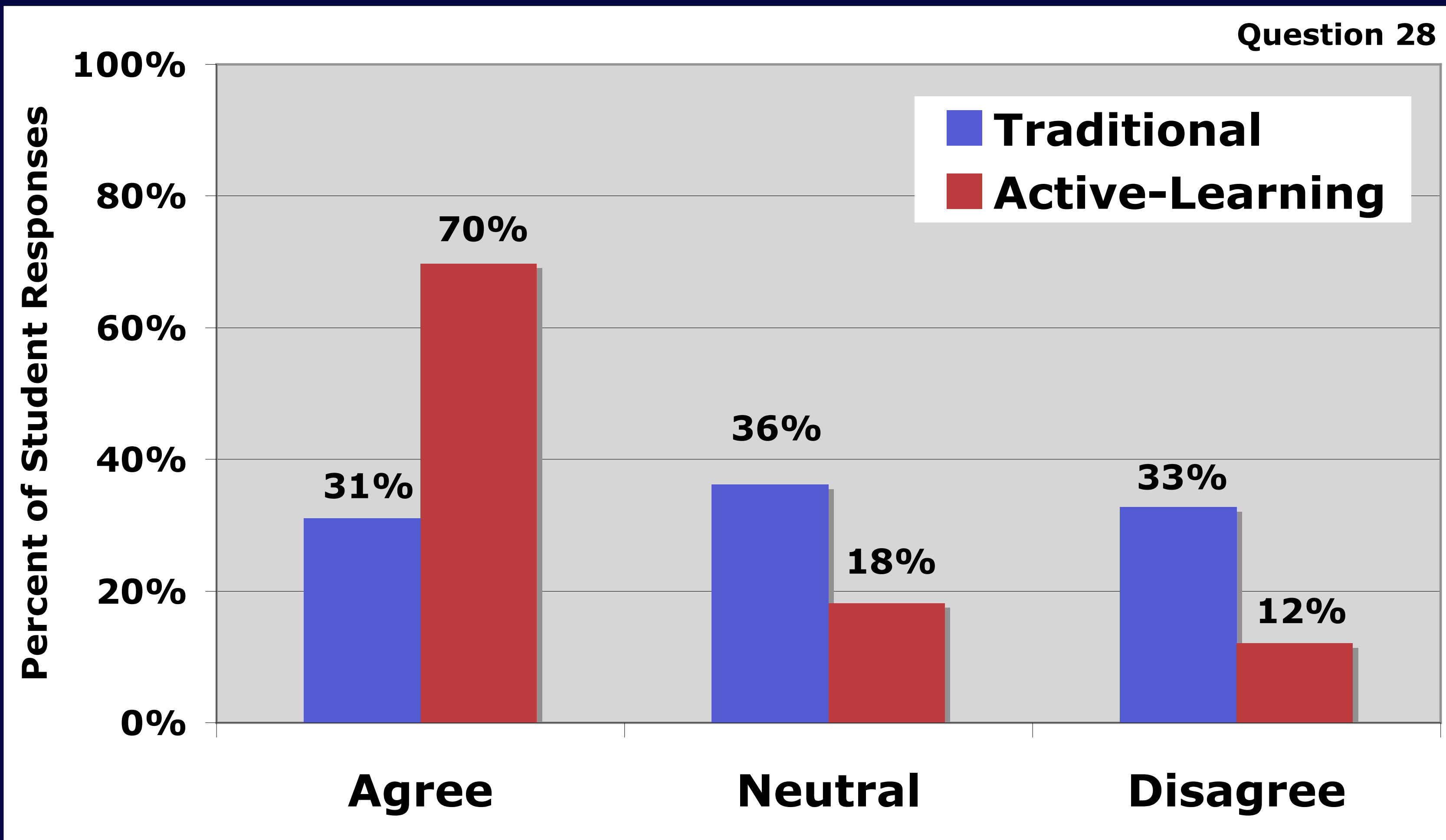
#28: Learning physics changes my ideas about how the world works.

#30: Reasoning skills used to understand physics can be helpful to me in my everyday life.

#35: The subject of physics has little relation to what I experience in the real world.

#37: To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

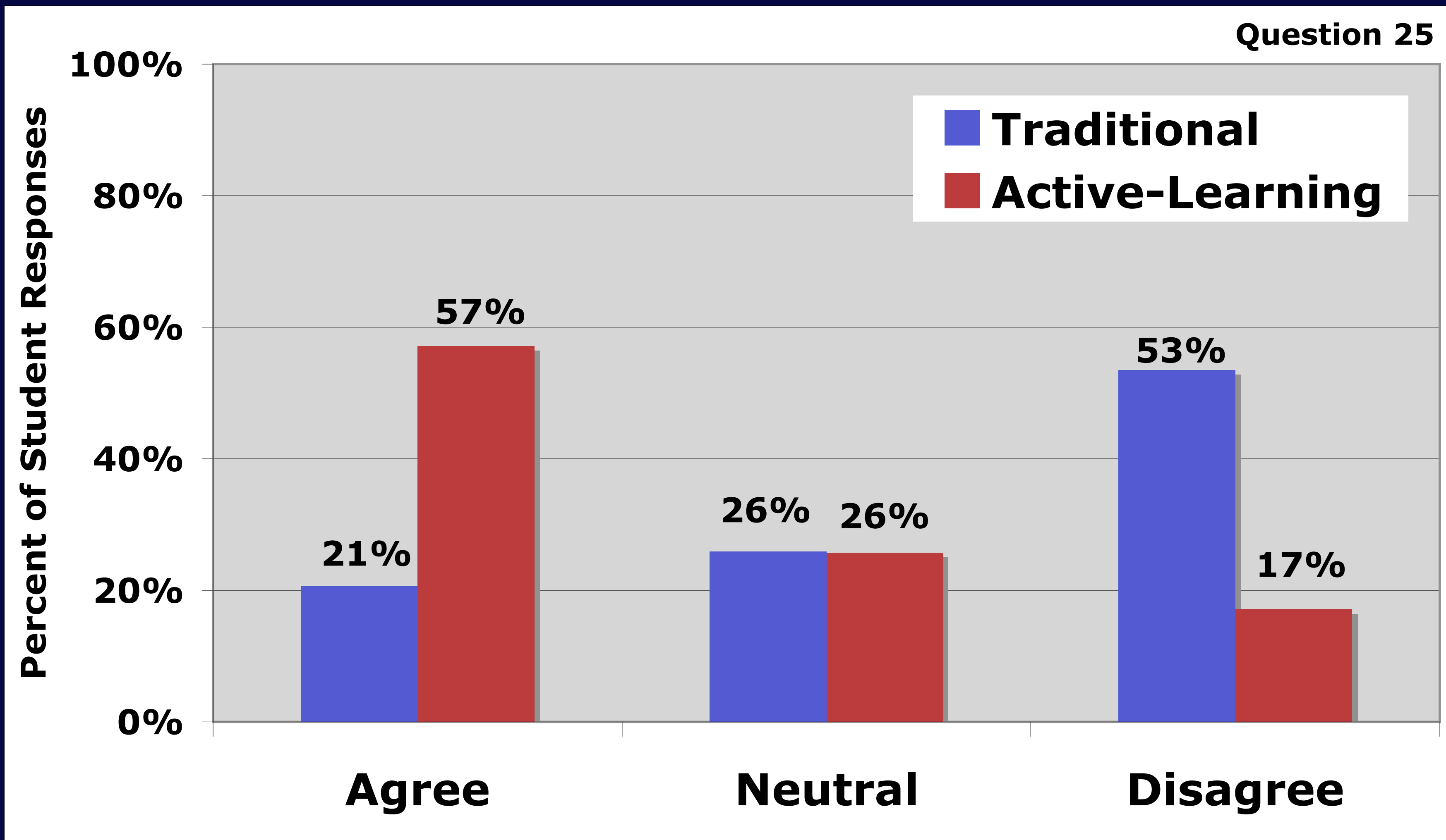
Q28: Learning physics changes my ideas about how the world works.



Personal Interest

- #03: I think about the physics I experience in every day life.
- #11: I am not satisfied until I understand why something works the way it does.
- #14: I study physics to learn knowledge that will be useful in my life outside of school.
- #25: I enjoy solving physics problems.
- #28: Learning physics changes my ideas about how the world works.
- #30: Reasoning skills used to understand physics can be helpful to me in my everyday life.

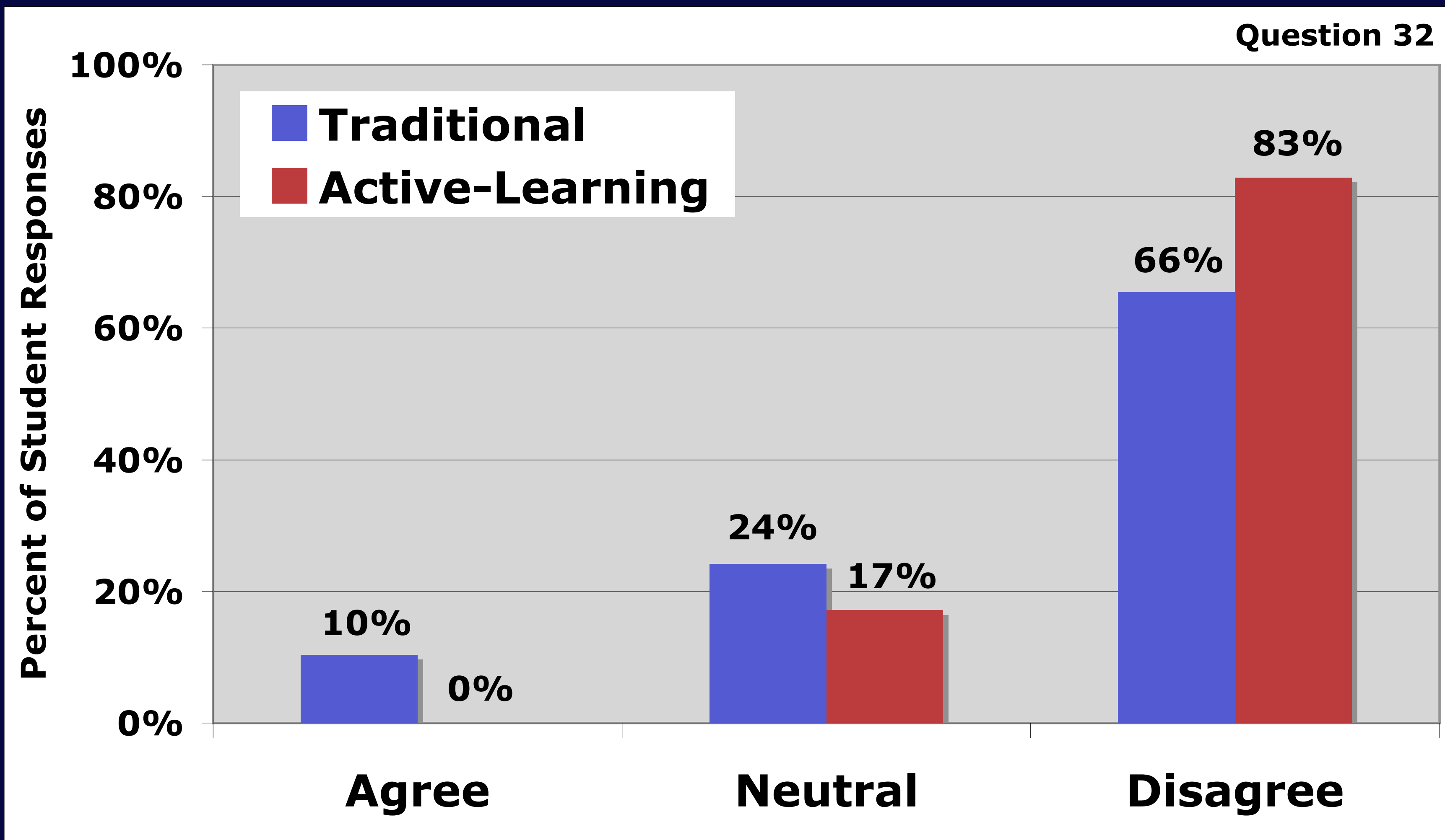
Q25: I enjoy solving physics problems.



Sense Making / Effort

- #11: I am not satisfied until I understand why something works the way it does.
- #23: In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.
- #24: In physics, it is important for me to make sense out of formulas before I can use them correctly.
- #32: Spending a lot of time understanding where formulas come from is a waste of time.
- #36: There are times I solve a physics problem more than one way to help my understanding.
- #39: When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.
- #42: When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

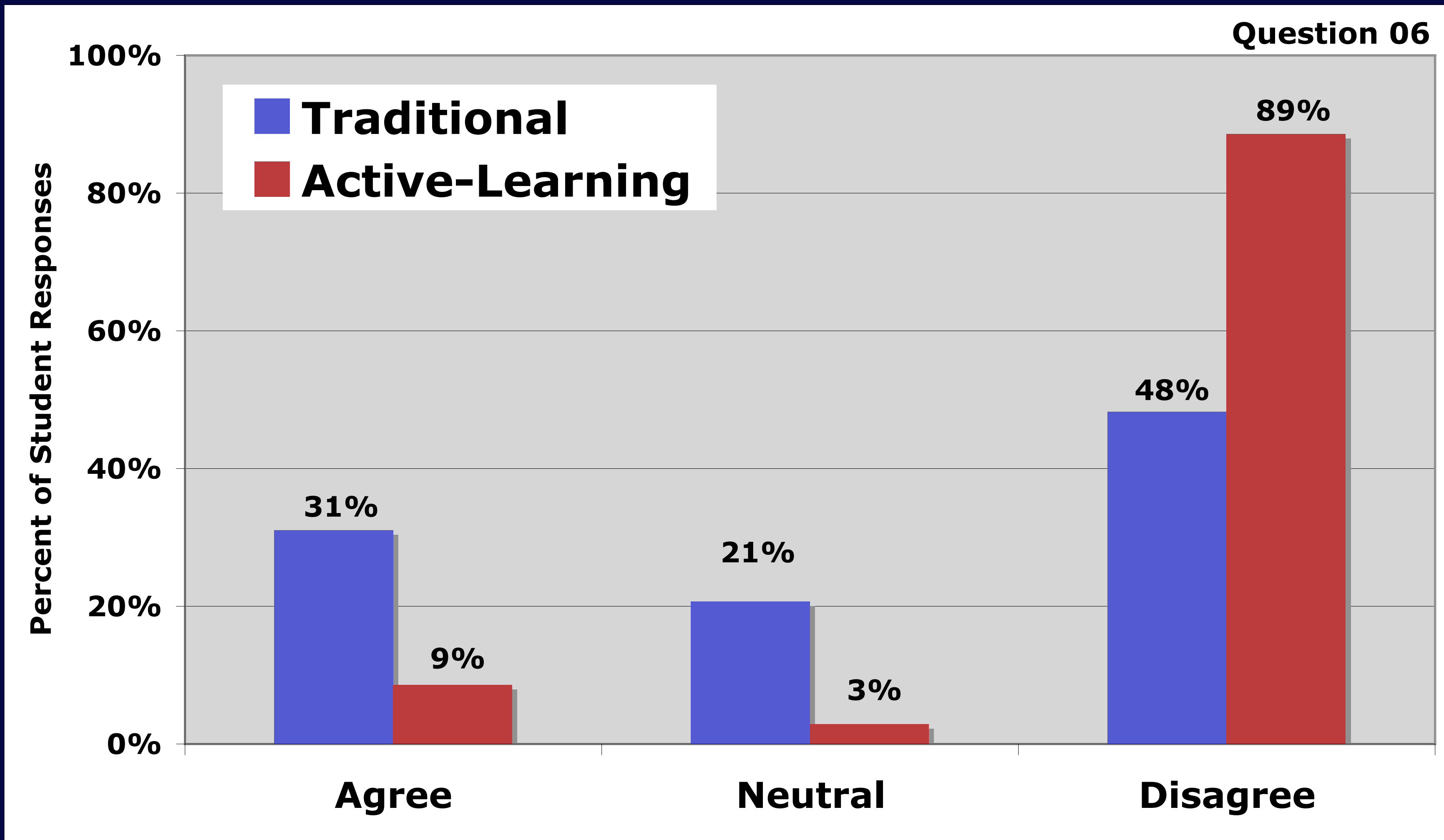
Q32: Spending a lot of time understanding where formulas come from is a waste of time.



Conceptual Connections

- #01: A significant problem in learning physics is being able to memorize all the information I need to know.
- #05: After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
- #06: Knowledge in physics consists of many disconnected topics.
- #13: I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
- #21: If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.
- #32: Spending a lot of time understanding where formulas come from is a waste of time.

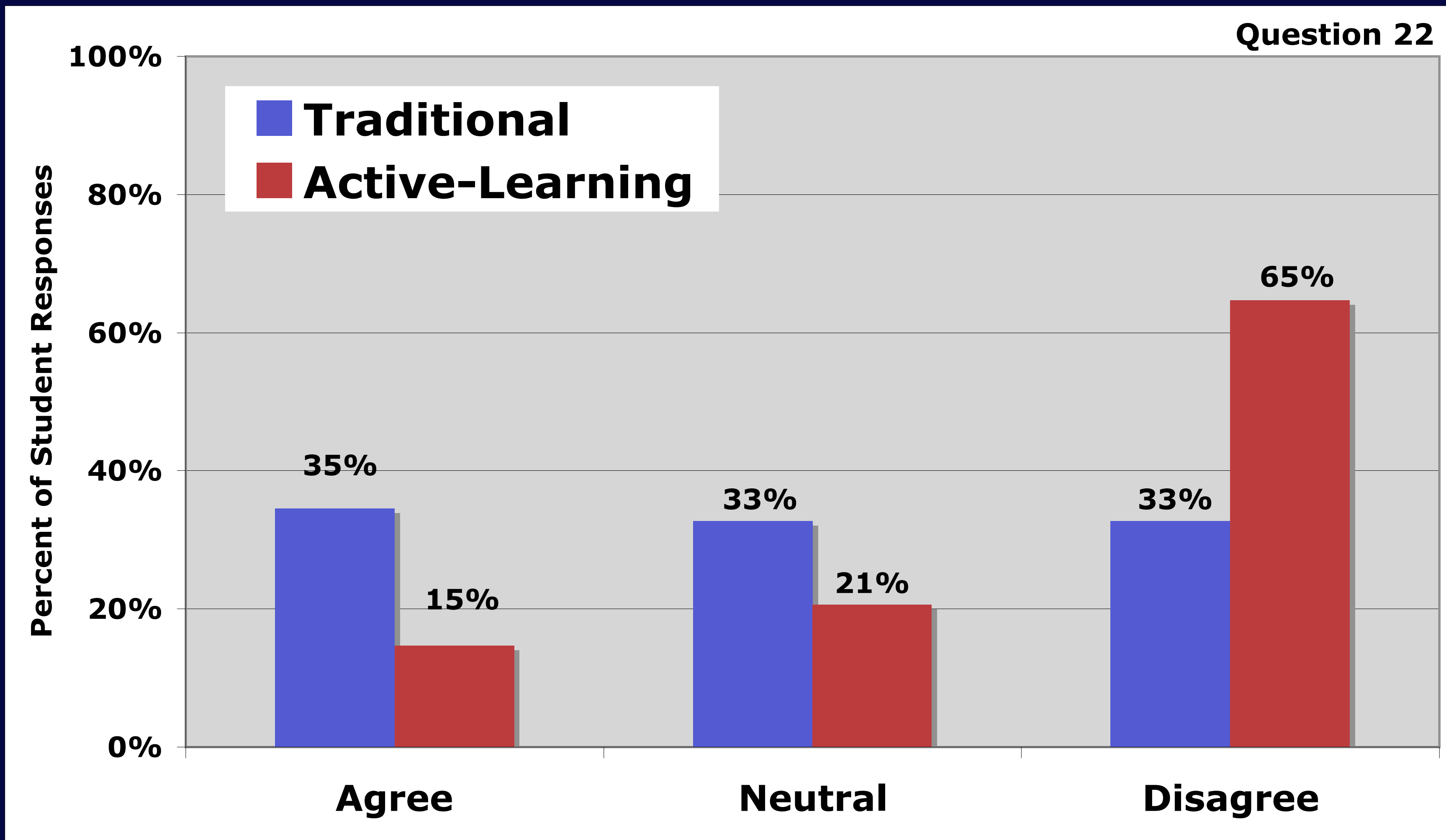
Q6: Knowledge in physics consists of many disconnected topics.



Applied Conceptual Understanding

- #01: A significant problem in learning physics is being able to memorize all the information I need to know.
- #05: After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
- #06: Knowledge in physics consists of many disconnected topics.
- #08: When I solve a physics problem, I locate an equation that uses the variable given in the problem and plug in the values.
- #21: If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.
- #22: If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
- #40: If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

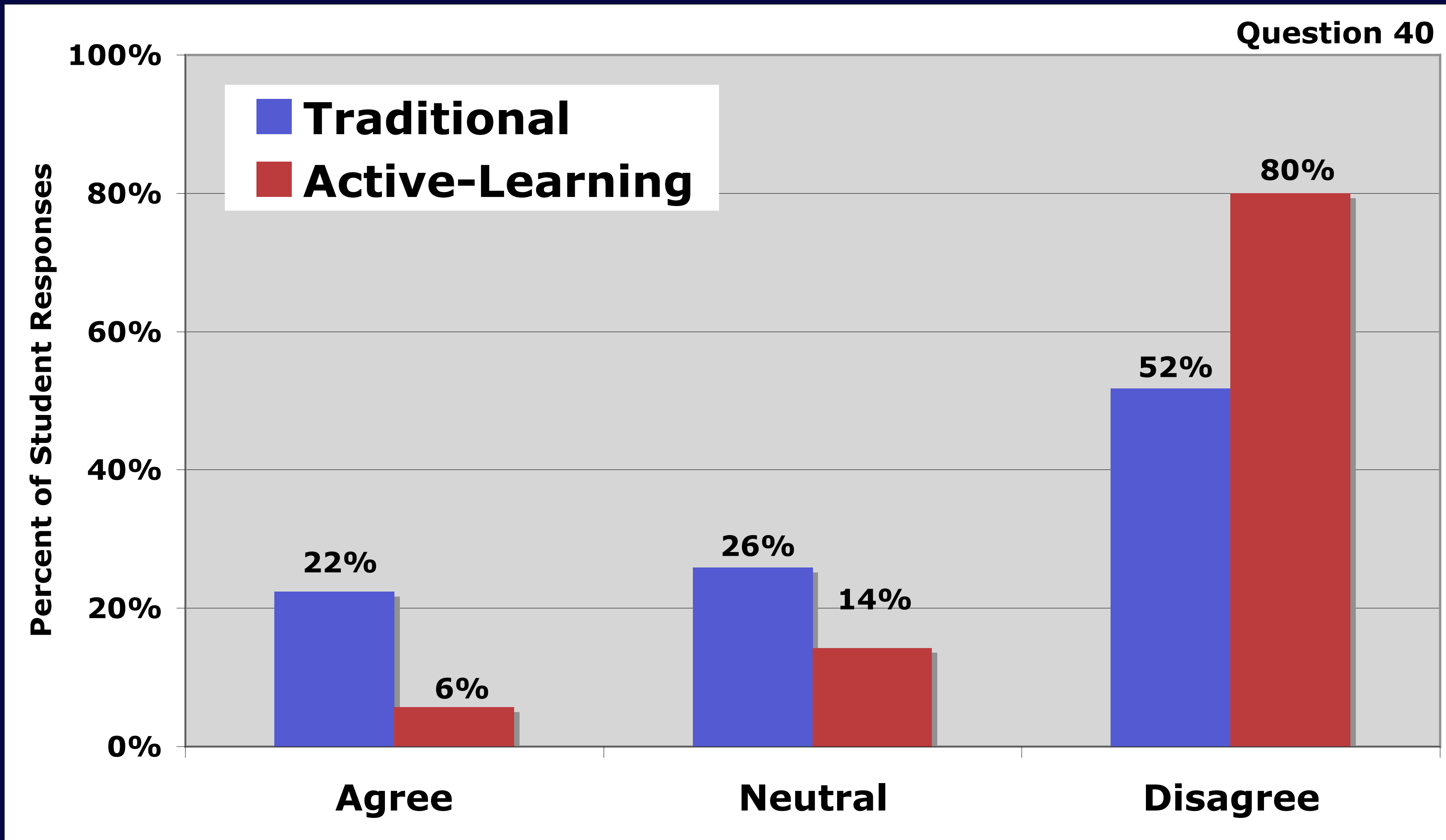
Q22: If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.



Problem Solving General

- #13: I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.
- #15: If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.
- #16: Nearly everyone is capable of understanding physics if they work at it.
- #25: I enjoy solving physics problems.
- #26: In physics, mathematical formulas express meaningful relationships among measurable quantities.
- #34: I can usually figure out a way to solve physics problems.
- #40: If I get stuck on a physics problem, there is no chance I'll figure it out on my own.
- #42: When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

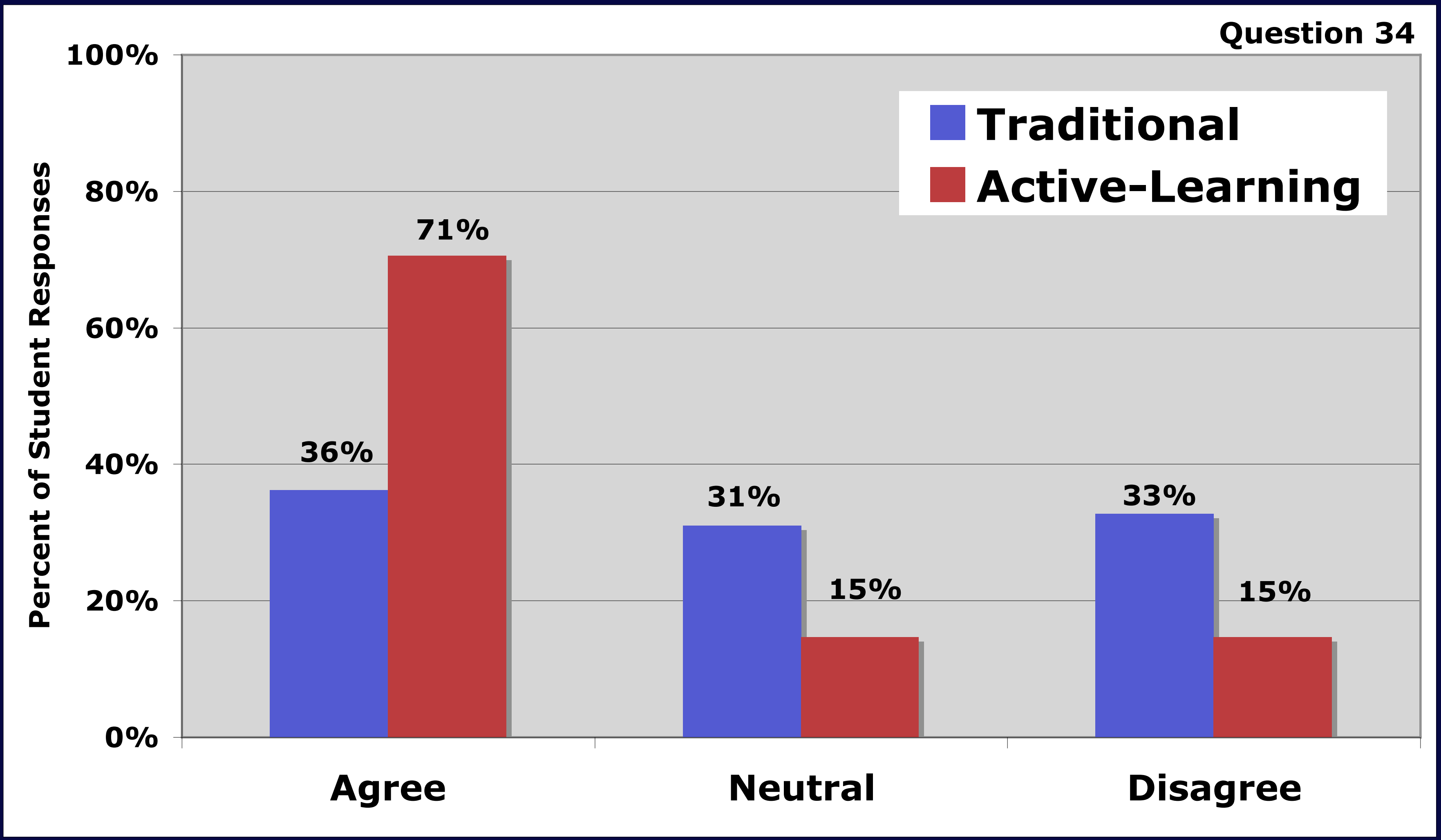
Q40: If I get stuck on a physics problem, there is no chance I'll figure it out on my own.



Problem Solving Confidence

- #15: If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.
- #16: Nearly everyone is capable of understanding physics if they work at it.
- #34: I can usually figure out a way to solve physics problems.
- #40: If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

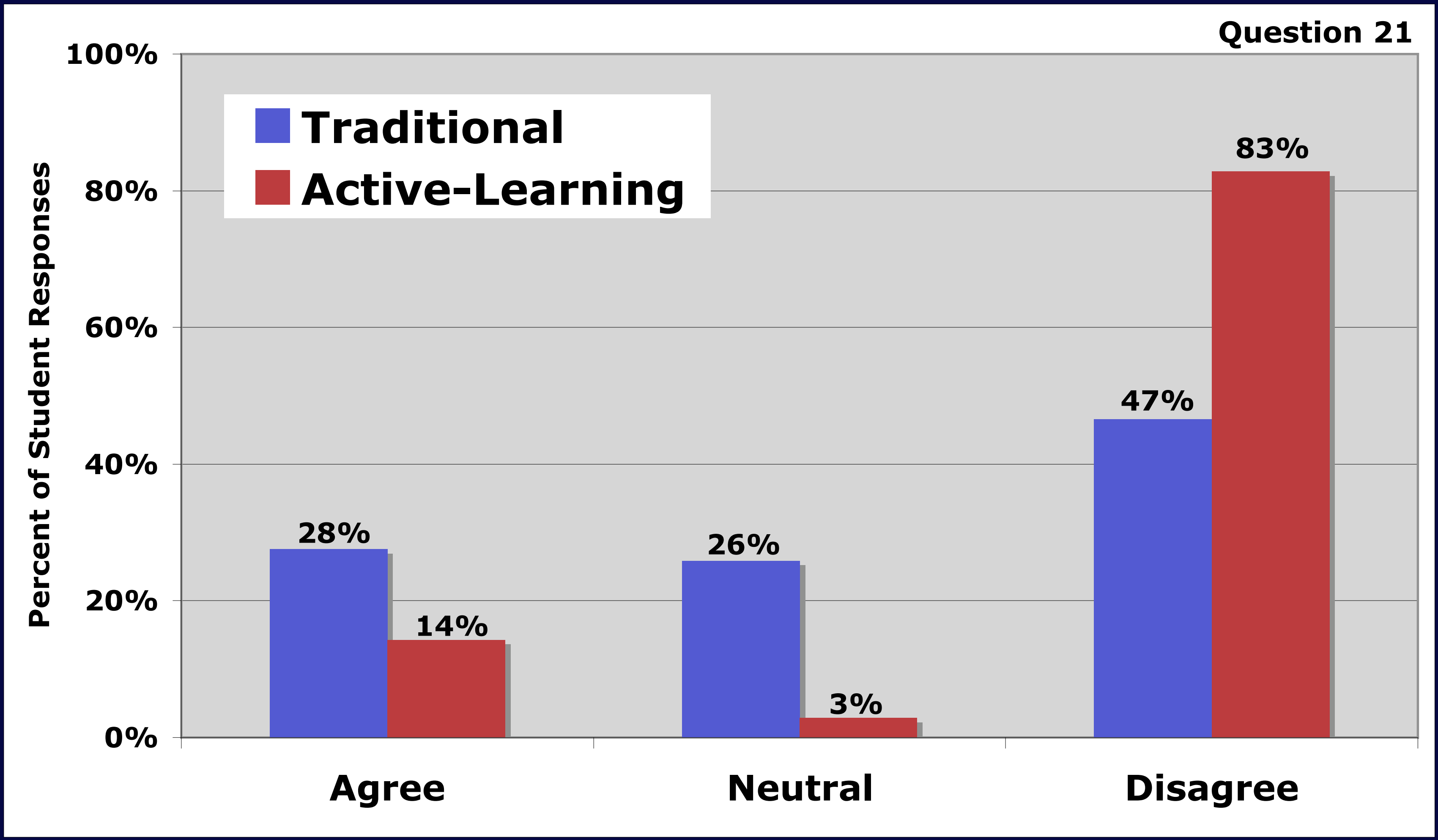
Q34: I can usually figure out a way to solve physics problems.



Problem Solving Sophistication

- #05: After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
- #21: If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.
- #22: If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
- #25: I enjoy solving physics problems.
- #34: I can usually figure out a way to solve physics problems.
- #40: If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

Q21: If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.



CLASS Summary
Percent of Students with Expert Beliefs

Scale	*Traditional*	*Active-Learning*	*Difference*
Overall	53.4%	68.7%	+15.3%
All categories	48.3%	68.0%	+19.6%
Real World Connection	47.0%	71.4%	+24.4%
Personal Interest	41.7%	65.0%	+23.3%
Sense-making/Effort	60.8%	69.7%	+8.8%
Conceptual Connections	51.4%	79.0%	+27.6%
Applied Conceptual Understanding	40.5%	66.5%	+26.0%
Problem Solving - General	49.1%	72.4%	+23.3%
Problem Solving - Confidence	38.0%	69.0%	+31.0%
Problem Solving - Sophistication	46.6%	69.8%	+23.2%

The Next Steps...

- Analyze our conceptual reasoning and quantitative problem solving post-instruction assessment that was piloted in Spring 2009
- Learn from our mistakes and revise assessments for a pre- and post-instruction survey in Fall 2009.

Some (Anecdotal) Lessons Learned in the First Five Years...

From Instructors and Students...

- Students really enjoy not being lectured at!
- At least 80% of students in our 100+ student sections are typically engaged in class activities.
- Students resist the idea that there may be more than one "right" answer or approach, but with time and practice they become more comfortable with a world filled with many shades of gray.
- Students perceive this course to be easier than the traditional lecture-based class.

What about the MCAT?

- Six Ideas curriculum leaves out some standard intro physics topics that do not fit neatly under the "Six Ideas" umbrella
- According to our students who took the MCAT after our active-learning course...
  - Everyone takes an MCAT prep course where they can learn/brush up on specific topics if necessary. Don't need a lot of content depth for the exam.
  - The problem solving skills developed in this intro physics course serve them very well when taking the MCAT!

Why do Students Like the Course?

- Pre-health students love that conceptual reasoning is given as much weight as quantitative problem solving.
- Engineers and physics majors are exposed to new (sexy) topics and are challenged to approach problems in different ways than they have before.
- It is a warmer, fuzzier intro physics experience with a tremendous amount of faculty interaction.

Unsolicited email to the Dean of Arts and Sciences...
10/08/08

Hello! My name is Priya Sury. I am a junior in Arts and Sciences. I am unsure to whom I should address this type of message, and hope you are or can get this to the appropriate recipient. I think that too often, professors and administrators hear complaints but not of students' positive experiences. For a while now, I have wanted to share the tremendously positive academic experience I had last year in Professor Bernatowicz's class.

I started Professor Bernatowicz's Physics 197 class last year very apprehensively. My previous experiences with physics were never great, and I considered myself a weak student in the subject. However, within the week I quickly became engaged in the lectures and class format, which were different from any class I had seen before or since. Ideas from the book were presented in a different and obviously incredibly well thought out way and students were always encouraged to participate and be an active part of class. I think any student would agree that Professor Bernatowicz is completely approachable and will spend any amount of time and will explain a concept as many different ways as necessary for a student to understand a concept. This, in combination with the test and assign format, abundant office hours, and classroom discussion style, completely removed the psychological intimidation factor of the difficult subject.

The class has completely changed the way I think about the world and view academics. Professor Bernatowicz continually challenges students to think deeply about problems, and has no patience for "plug and chug" methodology. This overarching concept has been invaluable in my other science classes, as well as humanities courses requiring critical thinking. If one thing has sunken in, it is to break down a problem to its simplest essence, then to fill in the details, a concept that has wide application. I described the course last year to my father, a professor at the University of Minnesota, and he was so impressed and interested that he still asks questions about it even last week. You probably do not get a lot of emails without a specific purpose or request, but I just wanted to let you know how this unique course has impacted me and made me very happy to be at WashU.

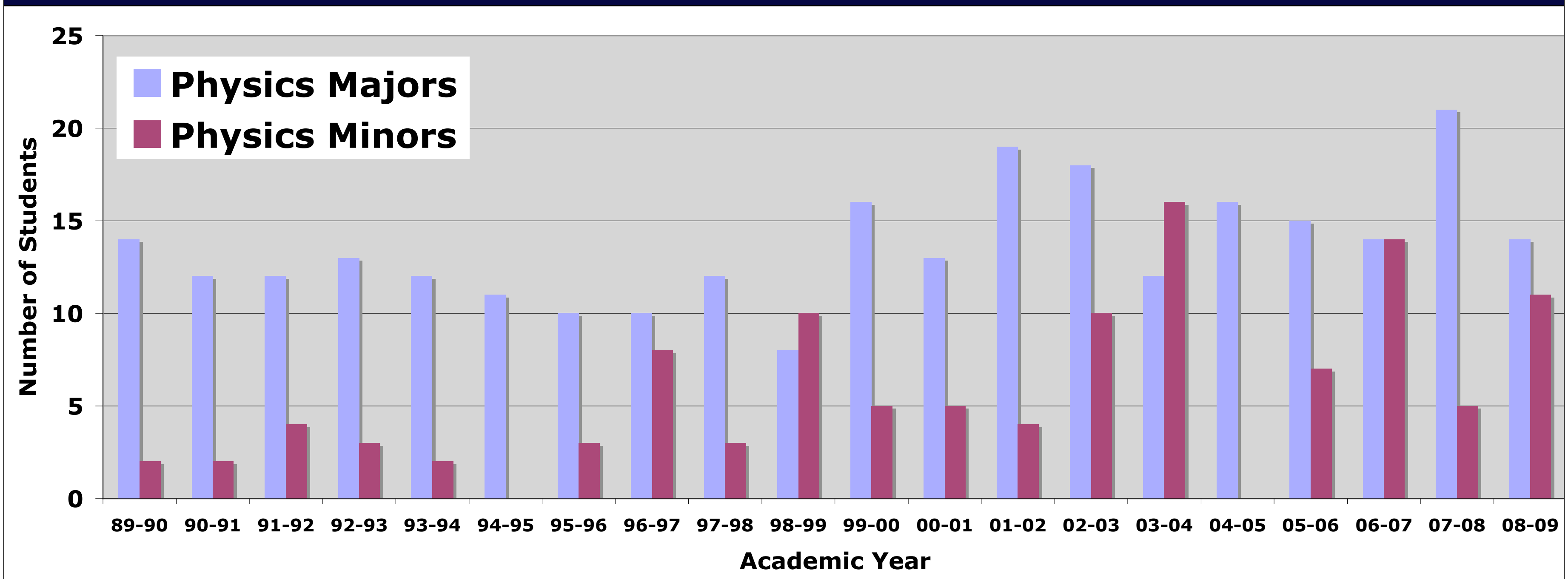
Warmly,

Priya Sury

Benefits for Physics Majors

- Develop a sense of community in their freshman year
- Foster personal interactions with physics faculty upon first arrival at WU
- Challenge them to develop their ability to talk about physics not just think and write about physics
- Foster the development of their conceptual reasoning skills in addition to their quantitative problem solving skills

Does Active-Learning Intro Physics Course Improve Number of Majors/Minors?



Too soon to tell...

First Freshmen Take Six Ideas Course

Acknowledgements

Thanks to...

- Tom Moore, author of the Six Ideas text, who makes this all possible.
- Tom Bernatowicz, the trail blazer for active learning in introductory physics at Washington University.