Engaging Students in Large, Introductory Courses

The Intro Physics Story

Rebecca L. Trousil

ITeach Symposium

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Intro Physics Lectures

Large Classroom

100-150 Students
Intro Physics Lectures

Large Classroom

One Captivating Instructor

100-150 Students

Despite our best intentions...

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The Experiment

Develop a new introductory physics course that actively engages students in and out of class.
The Experiment

- Develop a new introductory physics course that actively engages students in and out of class
- Constraints:
  - Large class size
  - Classroom is a large lecture hall
  - Cover sufficient content in a two semester sequence

Goals for the New Course

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

How to engage students?

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How to engage students?

- Instructor talks less. Students talk more.

A Typical Class Period

- Mini-Lectures
- Two Minute Problems
- Interactive Problem Solving
- Demonstrations
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.)

Student Response Systems
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
Crucial Elements for Successful Engagement

- A non-threatening environment
- Reward desired behavior
- Class participation is 5% of grade
- Exams contain qualitative and quantitative reasoning elements like those practiced in class

How to engage students?

- Instructor talks less. Students talk more.
- Keep it “real” and/or make it fun.

“Real World” Problems
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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.
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... maintains student interest despite a demanding homework schedule

Example: Shoemaker-Levy Comet Crashing into Jupiter

In July 1994, about 20 fragments of comet Shoemaker-Levy struck the planet Jupiter, each traveling at a speed of roughly 60 kms. These impacts were closely studied because they promised to be the most cataclysmic impacts ever witnessed. No one knew exactly how cataclysmic, though, because the fragments' sizes (and thus masses) were too small to measure. One estimate of the total energy released by fragment G's impact was $4 \times 10^{17}$ J (equivalent to the detonation of roughly 100 million typical atomic bombs). Use this to estimate fragment G's mass, first assuming that it was solid rock and then that it was solid ice, which have densities of about 3000 kg/m$^3$ and 920 kg/m$^3$, respectively. Don’t worry about being excessively precise. This illustrates how even a little knowledge about kinetic energy can help answer questions about objects that can barely be seen by the best telescopes!

Translation:

Earth-based telescope image from Keck observatory in Hawaii after Fragment G of comet Shoemaker-Levy struck Jupiter.

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Earth-based telescope image from Keck observatory in Hawaii after Fragment G of comet Shoemaker-Levy struck Jupiter.
Wow! I can do this!

Physics 107 - Section 01 (Touzard)
Exam #2 - November 1, 2007

2 (19 Points) Knowing that you are doing physics, a friend of yours brings you a toy that was given to him as a gift, because he cannot figure out how it works. It is a dumbbell shaped object with a string wrapped around the central axis. It is similar to a yo-yo, but when you pull on the string, the toy begins to rotate and translate on a horizontal surface rather than in the vertical direction. Your friend is perplexed, because the resulting motion of the toy depends on how you pull the string.

(a) (9 Points) Clearly, you begin to play with the toy. If you pull the string to the right from underneath the center and as shown in the figure, the toy begins to translate slowly to the right and rotate slowly in a counterclockwise direction. The free body diagram shows all the forces acting on the toy. Place the tails of the force vectors at the location on the toy where the forces act. Now draw your free body diagram to consistent with the translational and rotational motion that you observed.

(b) (10 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 looks 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.

Everyone knows learning must be serious and difficult and you must remain seated at all times. No fun allowed.
How to engage students?

- Instructor talks less. Students talk more.
- Keep it “real” and/or make it fun.
- Pose counterintuitive questions and problems that will generate debate.
- Incorporate “hot” topics in current research/popular science into class
Six Ideas That Shaped Physics

- Novel introductory physics text that organizes curriculum around six underlying themes in physics
- Seamlessly integrates modern physics into curriculum

<table>
<thead>
<tr>
<th>Six Ideas Text</th>
<th>Unit C: Conservation laws constrain interactions</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Unit N: The laws of physics are universal</td>
</tr>
<tr>
<td></td>
<td>Unit R: The laws of physics are frame independent</td>
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<td>Unit E: Electric and magnetic fields are unified</td>
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<td>Unit Q: Particles behave like waves</td>
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<td>Unit T: Some processes are irreversible</td>
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- Let them know you are watching!

Keep them on their toes!

- Learn names and use them with reckless abandon!
- Solicit participation from all parts of the classroom.
- Ensure all students have an opportunity to contribute.

The Cost of an “Active Learning” Classroom...
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- Extensive self-study on part of students is crucial.
- Students must prepare for every class period in order to benefit from and contribute to the discussion.
- Unpredictable class sessions!

A Paradigm Shift

**Traditional Lecture**
- Instructor is gatekeeper of information.
- Goal of students is to acquire information.

**Active Learning Classroom**
A Paradigm Shift

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- Instructor is a coach, facilitator, traffic cop...

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**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

What have we learned?

• Students like the ability to talk during class.
What have we learned?

- Students like the ability to talk during class.
- They initially resist the idea that there may be more than one “right” answer or way to approach a problem, but with time and practice students 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.

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 WU.