The Effective Use of Demonstrations and Simulations in Class

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A Recurring Theme of Today's Discussion

I HEAR … AND I FORGET

I SEE … AND I REMEMBER

I DO … AND I UNDERSTAND

Confucius (Master Kong, or 孔子, or K'ung Fu-tzu)

Today

- A Brief Overview of Physics Education Research
- About Demonstrations and Simulations
- Facilitating Student-Student Interactions
  - Group Sizes
  - The Importance of Architecture
  - The Role of the Teacher

At 17h30 we will have a workshop in which we will show how the ideas of this talk can be implemented

A Brief Summary of Physics Education Research (PER)

Physics Teachers Have Suspected for a Long Time …

- That our beginning students have many wrong ideas and conceptual misunderstandings
- Over the past couple of decades a number of diagnostic instruments have been devised
  - Force Concept Inventory
  - Conceptual Survey of Electricity and Magnetism
  - etc.

Physics Teachers Have Suspected for a Long Time …

- That our beginning students have many wrong ideas and conceptual misunderstandings
- Over the past couple of decades a number of diagnostic instruments have been devised
- The results confirmed our suspicions
- **Good Idea**: Give the diagnostic instrument at the beginning and again at the end of the course/term/unit
- For conventional pedagogy, almost no increase

Physics Education Research (PER)

- Modify the method of teaching of a course
- Use the changes in the performance on the diagnostic instruments before and after instruction to quantify the effectiveness of the new pedagogy
- Note: this is applying Physics techniques to education

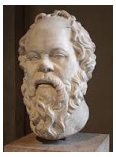
Some Key Results of PER

- Most students learn best by interacting with their peers
  - They do not learn best by being lectured to
- This has led many to reduce the amount of lecturing or abandoning lecturing entirely, replacing with
  - Peer Instruction
  - Clickers
  - Flipped Classrooms
  - Interactive demonstrations and simulations

"I've moved from being *the sage on the stage* to *the guide on the side*." – Eric Mazur, Harvard

About "Reformed" Research-Based Teaching

- Many of these results have been known to skilled educators for a long long time
  - Socrates certainly knew all this although he didn't have the technology that we do



- Physics Education Research lets us prove it!

The Origins of the Conventional Lecture (Middle Ages)

1. The professor reads the book to the students
2. A few days later the professor again reads the book to the students, perhaps adding some commentary
3. A few days after that the professor gives the book its "third reading" perhaps with even more commentary

What if anything has changed since the Middle Ages?

The students have the book too!

About Demonstrations and Simulations

Demonstrations and Simulations

- Students love demonstrations and simulations
- The research shows that they don't learn very much from them when they are used conventionally
  - Conventional use: just show it to the students
- Students do learn from them when they are used **interactively**

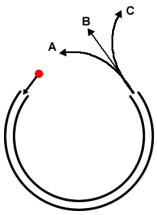
Making Demonstrations and Simulations in the Classroom **Interactive**

- Set it up, but don't do it
- Have the students discuss in small groups and predict the result
- Do the demonstration/simulation

This can be especially effective when many students predict the wrong result

An Example Using a Demonstration

A circular channel is mounted on a tabletop, and in the figure we are looking down at it from above.



A ball is rolled at high speed into the left side of the channel, goes around it, and emerges.

Which path is closest to the one the ball will follow?

Many students predict **A** The result is **B**

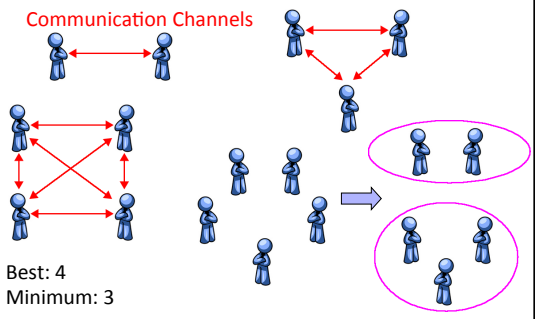
The Classroom

- The best learning occurs when students work together in small groups
- The learning is even more effective when it involves conceptually based activities
  - A "guided discovery" model often works best
  - Whenever possible, the activities should involve real apparatus or simulations

Facilitating Student-Student Interactions: Group Sizes

Student-Student Interactions: Best Group Size

Communication Channels



Best: 4
Minimum: 3

Facilitating Student-Student Interactions: The Importance of Architecture

You are hungry …

How do you get something to eat in a restaurant?

The Architecture Tells You:

- Go to the counter and order food
- Pay for food
- They give you food
- Take food to a table and eat

The Architecture Tells You:

- Sit down
- A server will come
- Order food
- The server will bring food
- Eat food
- Pay

Sometimes an (ethnic) restaurant gives mixed signals: How can I get something to eat here?

You want to learn …

How do you learn in a classroom?

The Architecture Tells You:

- Sit down
- Somebody at the front of the room will lecture to you
- Write it down
- Don't talk!

Even if the chairs can be moved, the room has already sent the students the message. Getting small group discussion to happen is difficult if not impossible.

The Architecture Tells You:

- Sit down at a "Pod"
- Talk with the other students who sit at your Pod
- Play with the apparatus or simulation
- Write on the whiteboard

One of our rooms

Getting small group discussion to happen is automatic

Facilitating Student-Student Interactions: The Role of the Teacher

The Goal: Have the Students Discover the Answer For Themselves

- Easier said than done!
  - Particularly if you are experienced in "lecturing"
- The process is not efficient: it takes time
  - It is time well spent
- Be Socratic: guide your students with questions, not answers
- Keep your hands in your pockets
  - Both your physical and your intellectual "hands"

Finally …

Our students will often tell us what their difficulties are … if we just stop talking to them and instead start listening to them.

Thank you!