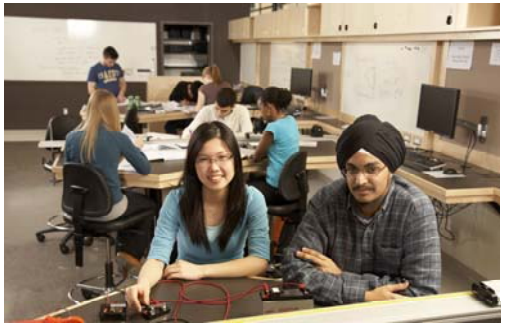
University of Toronto Physics Practicals

David M. Harrison



Please pick up a "clicker" at the front

University of Toronto Physics Practicals

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Larry Avramidis, David Bailey, Sarah Barrett (York University), Antony Chen, Behi Fatholahzadeh, Jason Harlow, Zahra Hazari (Harvard) , Peter Hitchcock, Chris Josephides, Lilian Leung, Mike Luke, Stephen Morris, Catherine Robin, David Rogerson, Kim Strong, Andrew Zasowski & *unit a* architects

University of Toronto Physics Practicals

I HEAR … AND I FORGET

I SEE … AND I REMEMBER

I DO … AND I UNDERSTAND

(Chinese Proverb)

University of Toronto Physics Practicals

- Combine tutorials and laboratories into a new entity: Physics Practicals
- Before
  - 1 hour tutorial every week
  - 3 hour laboratory every 2nd week
- Now: 2 hour Practical every week
- Our largest 1st year course: ~1000 students
- We still have 2 one hour classes per week

Outline

- Brief Summary of Physics Education Research
- Team Structure
- A Sample Activity
- The Importance of Architecture
- Computers
- Time Management
- About “Wrong” Ideas and Conceptual Misunderstandings
- Does This Pedagogy Work?

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 pedagogy 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 abandon or reduce the amount of lecturing, replacing with
  - Peer Instruction
  - Clickers
  - Interactive demonstrations
  - Variations of our Practicals

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

Some Key Results of PER

- Most students learn best by interacting with their peers
- These interactions are most effective when they involve conceptually-based guided-discovery activities
  - Knight's **Student Workbook** that accompanies his textbook
  - Harrison & Ellis, **Student Activity Workbook** that accompanies Ohanian & Markert's textbook
  - etc.

Some Key Results of PER

- Most students learn best by interacting with their peers
- These interactions are most effective when they involve conceptually-based guided-discovery activities
- The activities are most effective when they involve real apparatus
  - McDermott **Tutorials**, Laws **Workshop Physics**, University of Calgary *Labatorials*, M.I.T. *TEAL*, etc.

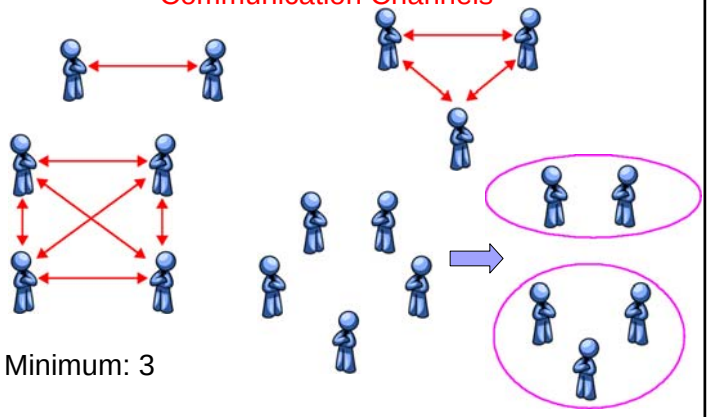
University of Toronto Physics Practicals

- Conceptually-based guided-discovery Activities, often involving real apparatus or simulations
- Students work in Teams on the Activities
- The pedagogical model is Socratic: Instructors keep their "hands in their pockets"
- Experimental physics and data analysis are interwoven into the Activities
- We have also developed Modules on Teamwork and on the Scientific Method

About Our Learning Teams

Team Size: 4

Communication Channels



Minimum: 3

Team Structure 1

Each team has

- **Facilitator**:
  - Different person each week
  - Keeps the team on track
  - When we have the whole class discuss something, the primary spokesperson for the team
- **Record Keeper**
  - Different person each week
  - Keeps the lab book

Team Structure 2

- Teams are shuffled every 6 weeks
- Each team ideally has a mixture of good and less strong students
  - The good students learn even more by teaching their teammates
  - Students learn more from discussion with their peers than by listening to us
- Avoid a team of three males and one female

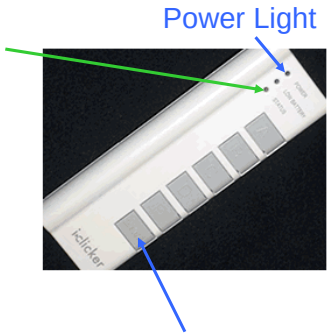
An Example Activity

The "Clickers"

Status Light

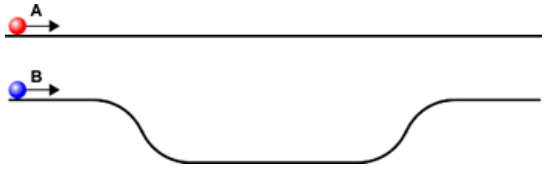
When we start asking you questions:

- Will flash green when your response is registered
- Will flash red if your response is not registered



Please turn on your clicker now

Racing Balls



Two balls are launched with equal initial speeds. Friction and air resistance are negligible. Which ball wins the race?

A. Ball A B. Ball B

C. The race ends in a tie

10% of our students get this correct

Racing Balls

- At U of T we do the demo in class
  - Having the students figure out where they went wrong is done in the Practicals
- Alternatives to the physical demo
  - We have a Flash animation
  - The University of Maryland has a video

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
- Write on the whiteboard

One of our rooms

Getting small group discussion to happen is automatic

Computers

We Use Computers For:

- Data acquisition and experiment control
- Computer vision
- Data analysis
- Flash animations
- Numerical approximation using *VPython*

Data Acquisition

- Pasco's *DataStudio* and Vernier's *LabPro* are good software choices for a high school context
  - Not really suitable for us
- We have reluctantly developed our own software
  - Based on *LabVIEW*
  - Open source
- Many of our sensors are from Pasco

Data Acquisition (DAQ) Hardware

- Original plan: use Pasco's *ScienceWorkshop* 750 USB interface
- The available drivers to use this interface with *LabVIEW* were unacceptably slow
- Designed and built our own hardware
  - The "heart" of the hardware is a National Instruments DAQ board
  - The design is open source

Computers Are Nice But Far From Essential

- The heart of the learning is students working collaboratively on guided-discovery Activities
- Many of our Activities use non-computerised apparatus
- Some don't have any apparatus at all

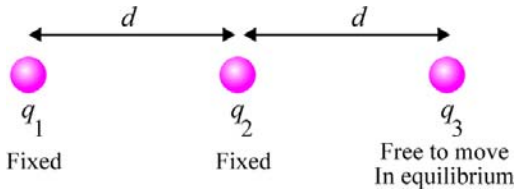
McDermott et al., **Tutorials In Introductory Physics** (Prentice-Hall): the apparatus can be bought for a few dollars at any hardware store

Time Management

Typical Two-Hour (110 Minute) Session

- 45 minutes: students work on Activities
- 20 minutes:
  - Questions from students
  - Multiple-choice quizzes
- 45 minutes: students work on Activities

Three-charge problem

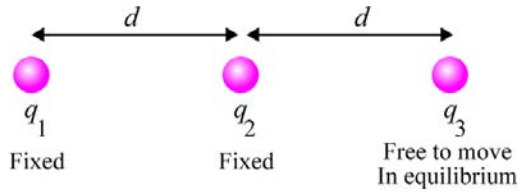


If $q_2 = Q$, what is q_1?

As you will see, this is usually not a good question to ask as a "clicker question" in class.

It is a good "clicker question" for you.

Three-charge problem



If $q_2 = Q$, what is q_1?

A. Q

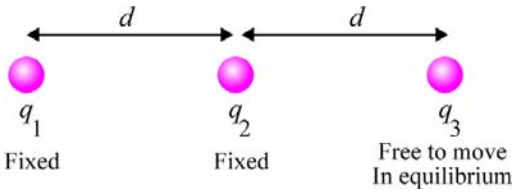
B. $-Q$

C. $-2Q$

D. $-4Q$

E. $-6Q$

Three-charge problem



You: solved in a minute or less.

Students: up to 45 minutes!

You: have "compiled" this sort of problem solving.

Students: don't have that fast running "binary" in their cognitive structures.

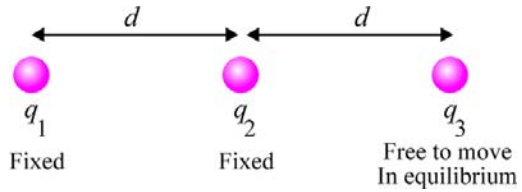
Three-charge problem: transcript fragment 1 (Tuminaro & Redish)

Darlene:	I'm thinking that the charge q_1 must have it's … negative Q
Alisa:	We thought it would be twice as much, because it can't repel q_2, because they're fixed. But it's repelling in such a way that it's keeping q_3 there.
Bonnie:	Yeah. It has to ----
Darlene:	Wait, say that.

Three-charge problem: transcript fragment 2 (Tuminaro & Redish)

Alisa:	So, we – we were thinking it was like negative two Q or something like that.
Bonnie:	Yeah. Cause it has to be like big enough to push away.
Darlene:	Push away q_3.
Bonnie:	Yeah, which we – which I figured out was negative two.
Darlene:	Cause its twice the distance away than q_2 is?

Three-charge problem



If $q_2 = Q$, what is q_1?

The point is: the up to 45 minutes the students spent was time well spent. Solving it for them is not as effective.

Student Teams Work At Different Rates

- In general, you will be surprised at how long it takes students to go through an Activity
  - It is time well spent!
- We assign enough required Activities to keep most Teams busy for the entire session
- We have some "if you have time" Activities for a small bonus

About "Wrong" Ideas and Conceptual Misunderstandings

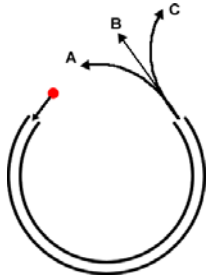
"Wrong" Ideas

- Based on a lifetime of experience
- Often deeply held

Deeply Held "Wrong" Ideas

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 channel, goes around it, and emerges.

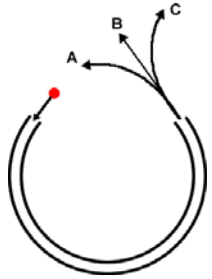


Which path is closest to the one the ball will follow?

Many students answer **A**

Deeply Held "Wrong" Ideas

Many students answer **A**



Do a demonstration

Some students claim to actually see the ball follow Path A!

Put a meter stick beside Path B

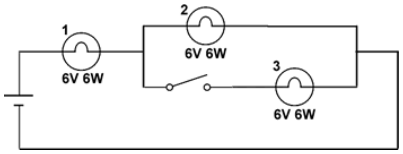
"There must be magnets or something in the meter stick that caused the ball to now follow Path B."

"Wrong" Ideas

- Based on a lifetime of experience
- Often deeply held
- To change such "wrong ideas" is for the student:
  - Difficult
  - Time consuming
  - Frightening

"What students really want is trouble-free knowledge." -- Ray Land

A Physical Apparatus Can Help the Students Confront Their "Wrong" Ideas and Conceptual Misunderstandings



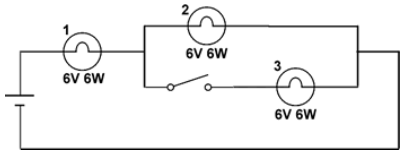
Without doing any calculations, *predict* what will happen to the brightness/dimness of Bulb 1 when the switch is closed.

A. Dimmer

B. Brighter

C. Stays the same

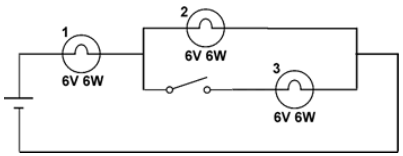
Some students predict the brightness of 1 will stay the same



Some students predict the brightness of 1 will stay the same.

Why do you predict that? "The switch is downstream from the bulb so can't affect its brightness." **Instantaneously this is sort of true!**

Further probing: "The charges are accumulating on the switch."



Some students predict the brightness of 1 will stay the same.

Not so good idea: tell the students they are wrong and explain the correct answer.

Better idea: have the students wire the circuit and *see* that they are wrong. Guide them to figuring out why the correct answer is correct.

Does This Pedagogy Work?

Using PER

- MIT, University of Maryland, University of Washington, Dickinson College, and others have used the standard PER pre/post test protocol
- Conclusion: yes it works!

This is measuring conceptual understanding with the standard diagnostic instruments. But what about performance in the course?

Direct Comparison With Traditional Instruction

- While developing the Practicals, we ran Pilots involving about 75 students
  - Chosen randomly
- The other 900 students had traditional tutorial/laboratory sessions
- The Pilot students' final mark in the course was almost ½ a letter grade higher

Observing/Listening

- Watching and listening to the students while they learn in this environment is breathtaking!
- Our observations are matched by others doing similar pedagogy at North Carolina State, MIT, Univ. of Maryland, etc. etc.
- Also by Chris Meyers for his Grade 12 Physics class at York Mills Collegiate, Toronto

The Students 1

Spring 2010 Evaluation: The heart of the learning in the Practicals is you working on the Activities with your Team. Was this an effective way of learning for you?

1. Definitely not
2. Probably not
3. I'm not sure
4. Probably
5. Definitely

73% answered "Probably" or "Definitely"

Students 2

"WHENEVER WE HAD TIME, YOU MAY HAVE NOTICED THAT MY GROUP LIKED TO EXPLORE THE TOPICS A LITTLE BIT MORE DEEPLY … WHICH HONESTLY HELPED ME DEVELOP A PHYSICAL CORRELATION AND THEREFORE AN INTUITION FOR THE MATERIAL."

At MIT, converting to this type of pedagogy had a role in reducing homework copying by a factor of 4

To Learn More …

- Every Workshop Session offers you an opportunity to come and play with some of the Activities from our Practicals
  - Forces, Motion & The Scientific Method: today 10:45 – noon, today 1:00 – 2:15, Saturday 9:00 – 10:15, Saturday 10:30 – 11:45
  - Electricity, Magnetism & Geometric Optics: today 2:30 – 3:45, Saturday 9:00 – 10:15, Saturday 10:30 – 11:45
- http://www.upscale.utoronto.ca/Practicals/

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Thank you! Please return your clicker