

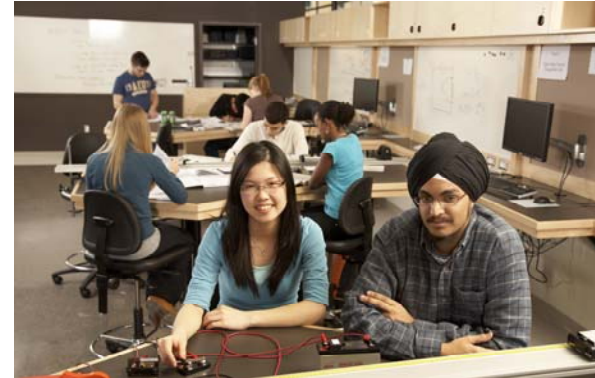
This is the PowerPoint of an invited talk given to the Physics Education section of the Canadian Association of Physicists annual Congress in Quebec City in July 2008

-- David Harrison, david.harrison@utoronto.ca

1



University of Toronto
Physics Practicals



2



University of Toronto
Physics Practicals

David M. Harrison
Department of Physics
University of Toronto

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

3



University of Toronto
Physics Practicals

I HEAR ... AND I FORGET
I SEE ... AND I REMEMBER
I DO ... AND I UNDERSTAND
(Chinese Proverb)

4



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: ~1300 students
- We still have 3 one hour classes per week

5



University of Toronto Physics Practicals

Outline:

- Brief summary of Physics Education Research
- The importance of architecture
- The Practical rooms
- Use of computers
- Pedagogy
- Teaching assistants

6

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.

7

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/unit
- For conventional pedagogy, almost no increase

8

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

9

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

“I’ve moved from being the *sage on the stage* to the *guide on the side*.” – Eric Mazur

10

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.

11

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**, SCALE-UP, TEAL, etc.

12

The Importance of Architecture

13

You are hungry ...

How do you get something to eat in a restaurant?

14

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



15

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?

16

You want to learn ...

How do you learn in a classroom?

17

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.

18

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



Getting small group discussion to happen is automatic

19

The Pods

- 3 or 4 students
- The 2.2 m Track determined the size
- Computer, Data Acquisition Board, Whiteboard, Web Cam
- Tabletop 92 cm high



Connected to a server via a private network.

Nothing can be stored on the local disc.

20

The Room

- 9 Pods
- Instructor Station at one end
- Projector and Screen
- Sound system, including hand held microphone
- Lighting control and motorized blinds
- Acoustic panels on the ceiling and walls
- AC power on the walls and the center of the hexagonal table



21

Number of Rooms

- For our 1200 students:
 - Five rooms
 - Two sessions / day
- First room completed: January 2008
 - A Pilot program with 70 students
- Two more rooms currently under construction
- Two final rooms Summer 2009, plus an area for the technologists and a student lounge

22

Computers

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

23

Data Acquisition Software

- Pasco's *DataStudio* and Vernier's *LabPro* are more suitable for High School than University level
 - Many of the details that are important for our purposes are hidden inside the software
- We use National Instruments *LabVIEW* and *SignalExpress*
 - A non-trivial programming effort
- Open source

24

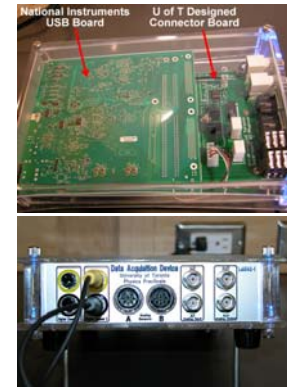
Data Acquisition (DAQ) Hardware

- 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

25

U of T Data Acquisition Device

- Clear plastic case
- Blue indicator lights
- Digital and analog inputs and outputs
- USB connection
- 1.2 M samples/sec
 - Pasco: ≤ 250 k S/s
- Cost: ~\$1200*
 - Pasco: ~\$1000



* This is a quantity price

26

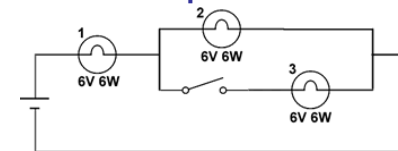
The Practicals

- **Conceptual:** concentrate on the concepts being discussed in class
 - Also introduce principles of experimental science and data analysis
 - Real apparatus, Flash animations, etc.
- **Discovery:** experimental investigations which may not relate to the topics of the class

We also have developed Modules on Teamwork and writing Formal Reports

27

A Conceptual Activity



- Without doing any calculations, *predict* what will happen to the brightness/dimness of Bulb 1 when the switch is closed. Explain your prediction without equations.
- Wire the circuit and check your prediction. Was your prediction correct? If not, describe what happened.

28

A Typical Session

- Introduce the Modules (5 minutes)
- Activities (45 minutes)
- Questions, homework problems (20 minutes)
- More activities (40 minutes)

Each Team of 3 – 4 students has:

- Facilitator: primary spokesperson for the Team
- Record keeper: primary person who records in the lab book

A different person every week

29

Audio-Visuals

- Can broadcast from any computer to every monitor and to the projection screen
- If a Team has something on the whiteboard, the web cam allows all students to see what is on it
- The hand held microphone allows students to hear each other during discussions

30

Teaching Assistants

- The Practicals are neutral in terms of required TA resources compared to the old tutorial / laboratory structure
- One full day of training
 - The Socratic teaching method in particular is difficult for some
- Two TAs present at each session
 - In the “steady state” we will pair experienced and inexperienced TAs

31

OUR STUDENTS SPEAK ...

“THANK YOU FOR A WONDERFUL SEMESTER! IT HAS BEEN DELIGHTFUL TO BE PART OF THE PILOT PRACTICAL - I FOUND IT IMMENSELY REWARDING AND MUCH MORE EXCITING AND HELPFUL THAN THE REGULAR TUTORIAL/LABS.”

“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.”

32

OUR STUDENTS SPEAK ...

“THE PILOT WAS A GREAT EXPERIENCE AND WAS CONDUCTED IN A GOOD ENVIRONMENT. IT WAS A GREAT SUCCESS, AND HONESTLY I ATTRIBUTE A LOT OF MY PHYSICS UNDERSTANDING TO THE PHYSICS PRACTICALS.”

“MY FIRST TWO TEST MARKS WERE PRETTY POOR, BUT WITH THE GUIDANCE I WAS PROVIDED IN THE PILOT, MY THIRD TERM TEST MARK WAS BOOSTED WELL OVER 20%.”

33



University of Toronto
Physics Practicals

I HEAR ...

AND I FORGET

I SEE ...

AND I REMEMBER

I DO ...

AND I UNDERSTAND



Thank you!

34