1 ❑ Discovery Based Labs for Calculus-Based Introductory Physics

Dawn C. Meredith

Robert E. Simpson

Physics Department

University Of New Hampshire

Supported in part by NSF grant # DUE-9750830

2 ❑ Motivation

- Several years ago I became aware of curricular materials (e.g. Tutorials from University of Washington; Workshop Physics, Tools for Scientific Thinking and Real Time Physics by Thorton, Sokoloff and Laws) that were based on "McDermott's Wheel": research on student understanding leading to curriculum development which is then assessed, and the cycle starts again.
- These are wonderful new pedagogical resources that I wanted to use these materials in my class but none was a perfect fit to my needs.

3 ❑ Why Tutorials?

I choose to use the tutorials because they developed student reasoning and understanding of physics concepts, gave hints of calculus, and could be done in 50 minutes.

However, most of the tutorials were pencil and paper activities. My goal was to create discovery-based activities that compliment the University of Washington Tutorials (McDermott, Shaffer, *et al.*).

These activities include

- Microcomputer based lab (MBL) experiments
- More connections to calculus
- Kinesthetic experiences
- Computer simulations

4 ❑ Institutional Context

- Approximately 250-300 students each semester in the calculus-based introductory physics courses.
- We have three kinds of calculus-based introductory physics (not all at the same time):
  - Standard large lecture class with lab and recitation
  - Studio format with less lecturing and more group learning using discovery-based activities
  - Studio format combined with calculus

5 ❑ Outline of talk

- 4 labs:
  - RC circuit (calculus and MBL)
  - Electric Field (computer simulation)

- Moment of Inertia (MBL)
- Torque (Kinesthetic)

- 3 parts
  - Goals
  - Lab Design
  - Assessment (all are initially assessed by listening as students go through the lab)

6 ❑ RC circuit - goals

- Given a circuit with a combination of resistors and capacitors students can qualitatively predict the time evolution of the circuit.
- Given the differential equation $dq/dt = a\, q$, students predict exponential time evolution.

7 ❑ RC Circuit - lab design

- Predict time evolution of a charging/discharging circuit using conceptual understanding of circuits.
- Use calculus to make the same prediction.
- Verify the predictions using MBL equipment and a buffer amp to allow for a larger resistor and smaller capacitor.
- Run with two resistors or capacitors in series or parallel.

8 ❑ RC circuit - assessment

- 95% (19/20) of students correctly identified the *q(t)* plot (out of five choices) for a charging capacitor. In the comparison group 81% (52/64) correctly identified *q(t)* .
- In fall, compare pre and post-test scores on Electric Circuit concept inventory for test class and compare to data bank.

9 ❑ Electric Field Lines - goals

- Given a set of charges and corresponding electric field lines, students can identify incorrectly drawn field lines and explain why the lines so drawn are incorrect.
- Given a small set of charges students can qualitatively sketch correct field lines.
- Given a set of field lines and a charged test particle and its initial velocity, students can qualitatively sketch the path of the particle

10 ❑ Electric Field lines - lab design

- Given the rules for drawing field lines, find errors in a set of field lines.
- Gain knowledge of near and far limits for charge distributions; use this knowledge to sketch field lines for simple charge distributions. Check field lines with those drawn by *EM Field.*
- Predict motion of charged particle near an electric dipole; check prediction with *Electric Field Hockey*.

11 ❑ Electric Field lines - assessment

- Pre and post test given to assess student understanding of E field lines - can they point out physically impossible situations and give reason for impossibility?
- Initially 17/37 students say Electric field lines cannot be closed circles, but none give correct reasoning.
- Finally 31/37 give correct reasoning for disallowing closed circles; 18/37 give correct reasoning for disallowing kinks.

12 ❑ Moment of Inertia - goals

- Given a setup that includes pulleys and weights, students can correctly calculate the acceleration of the system.
- Given the physical dimensions of two pulleys made of the same material, students can estimate the relative moments of inertia

13 ❑ Moment of Inertia - design

- Students develop their own procedure to measure the moment of inertia of a large metal pulley.
- They are given two weeks to do the lab; the first week is often spent floundering, the second week they get down to business.
- This lab occurs late in the first semester after students have experience with the MBL equipment.

14 ❑ Moment of Inertia -assessment

- Anecdotal feedback
  - One student switched her major to physics because of this lab - it made her think!
- We compared the performance of two groups - one group had the full two weeks to do the lab; the other group had only one week (due to short summer session) and was given more hints on how to do the problem. In the first group 20% (21/107) of students correctly answered a question about the tension in an Atwood machine, in the second group only 3% (1/29) got the correct answer. (Overall test averages were 7.9 and 8.0 respectively.)

15 ❑ Torque - goals

- Given a rotating object and an impressed force students can predict the motion of the object.

16 ❑ Torque - design

- Students apply $\tau = dL/dt$ to a falling bicycle wheel in order to understand precession.

17 ❑ Torque - assessment

- We compared the performance of two groups. One group did the activity, the other group did not. Of the students who did the activity (n=16) 62% correctly answered a question on precession. Of the control group (n=134) 18% correctly answered the question.

18 ❑ Other activities under development

- Vector addition
- Projectile Motion with Videopoint
- Kinesthetic experiences with Newton's three laws
- Force table and addition of forces.
- Drag force, coffee filters and slope fields
- 1 and 2-dim collisions with Videopoint
- Wave speed lab
- Newton's law of cooling
- Heat capacity
- Gauss' Law, symmetry and Styrofoam
- Inductance walk-around lab

19 ❑ Future Evaluation Plans

- Use FCI, SAT's and Real-Time Physics Electric Circuit Concept Test to characterize students from regular class and studio class.
- Listen to students as they go through the labs.
- Give pre and post questions to evaluate efficacy of each lab.
- Compare performance of students with and without lab. Use analysis of variance to take initial state of students into account.

20 ❑ Dissemination Plans

- All labs will be available on the web as pdf files. Perhaps also as LaTex files and/or MS Word files to allow for adoption/adaptation.
- Summaries of assessment will also be on the web.