A Computerized Problem Solving Laboratory for Introductory Physics

Pat Heller, Charles Henderson, Vince Kuo
Department of Curriculum and Instruction
University of Minnesota

Ken Heller
School of Physics and Astronomy
University of Minnesota

Details at

http://www.spa.umn.edu/groups/physed/

Supported in part by NSF,
and the University of Minnesota

Thanks to University of San Diego

Task

❶ **Write down 3 things that you want to get out of this workshop.**

❷ **In groups of 3 introduce yourselves (your field, what you teach, …), compare lists and decide on the one most important thing you want to get out of this workshop..**

TIME ALLOTTED

2 minutes for individual list, 5 minutes for group list.

PROCEDURES

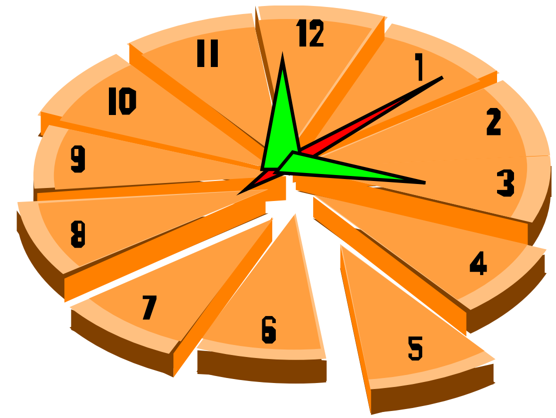
Formulate **a response individually.**

Discuss **your response with your partners.**

Listen **to your partners' responses.**

Create **a new group response through discussion.**

AGENDA
A Guide for Discussion

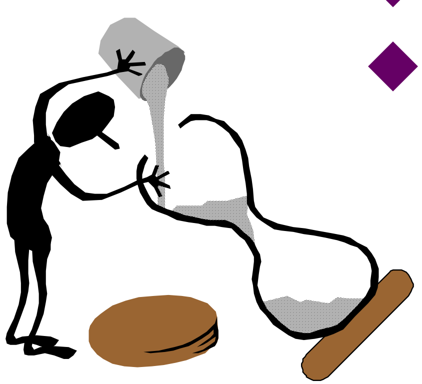


❶ **Problem Solving** (≈ 1/2 hour)

- Why emphasize problem solving ?
- What is problem solving ?

❷ **Problem Solving Laboratory** (≈ 1 hour)

- Principles
- Example - Magnetic Field
- Discussion



❸ **Computers in the Laboratory** (≈ 1/2 hour)

- Principles
- Execution

❹ Motion Data with Video (≈ 1 hour)

- How to do it - a demonstration
- Analysis of a video
- Discussion

❺ Optimal Apparatus (≈ 1/2 hour)

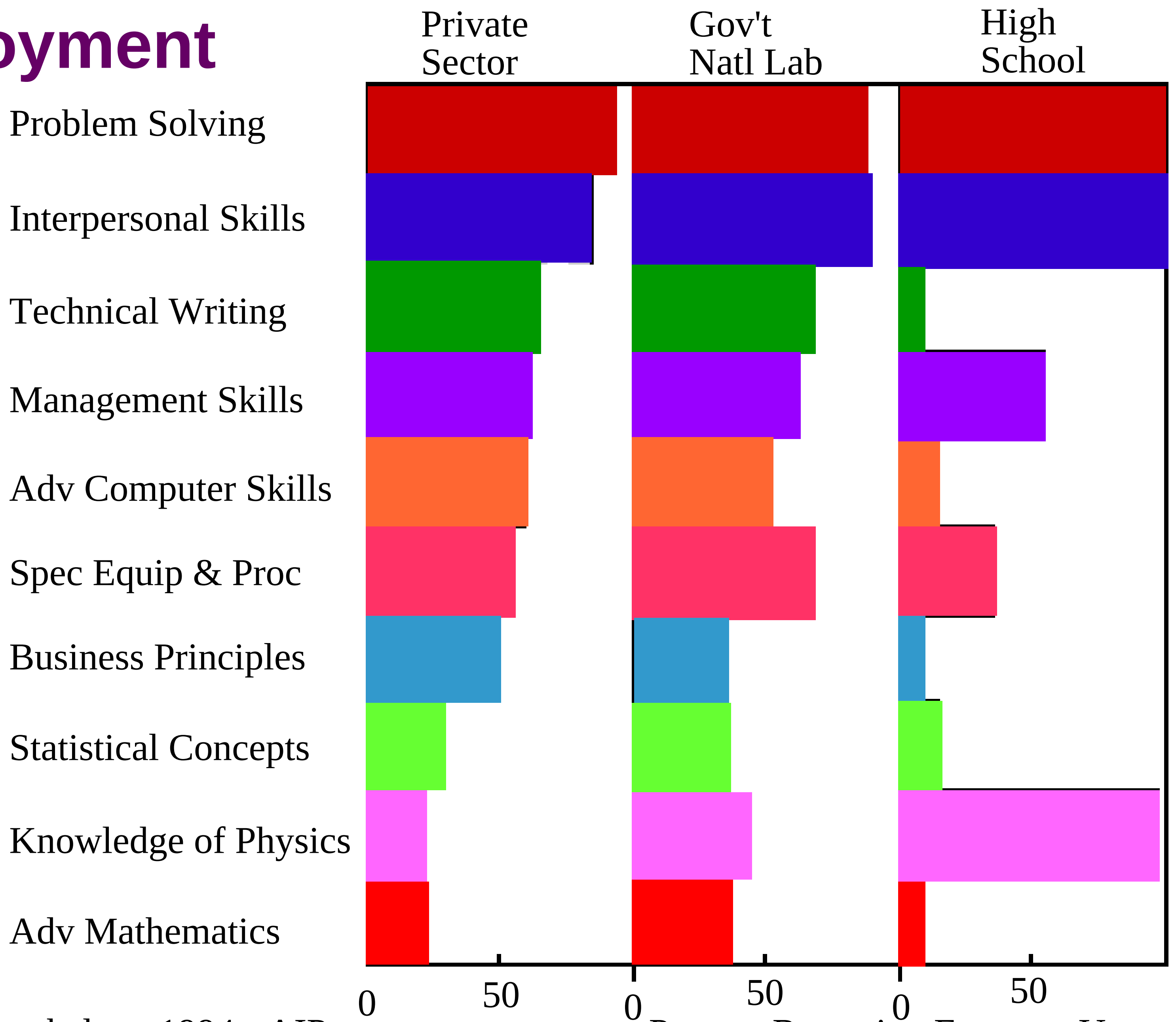
- Magnetism
- Forces
- Discussion

❻ Assessment (≈ 1/2 hour)

- Students - Lab reports
- Course

❼ Concluding Discussion

Employment



Survey of Physics Batchelors, 1994 - AIP

What Do Departments Want?

Goals: Calculus-based Course (88% engineering majors)

- 4.5 Basic principles behind all physics
- 4.5 General qualitative problem solving skills
- 4.4 General quantitative problem solving skills
- 4.2 Apply physics topics covered to new situations
- 4.2 Use with confidence

Goals: Algebra-based Course (24 different majors)

- 4.7 Basic principles behind all physics
- 4.2 General qualitative problem solving skills
- 4.2 Overcome misconceptions about physical world
- 4.0 General quantitative problem solving skills

What Is Problem Solving?

- "Process of Moving Toward a Goal When Path is Uncertain"
  - If you know how to do it, its not a problem.
  - A problem for your student is not a problem for you
    - Exercise vs Problem
- Problems are solved using tools

  General Purpose Heuristics

  Not algorithms

- Problem Solving Involves Uncertainty and Mistakes

M. Martinez, Phi Beta Kappan, April, 1998

Some Heuristics

Means - Ends Analysis

identifying goals and subgoals

Working Backwards

step by step planning from desired result

Successive Approximations

range of applicability and evaluation

External Representations

pictures, diagrams, mathematics

General Principles of Physics

Teaching Students to Solve Problems

Solving Problems Requires Conceptual Knowledge:

From Situations to Decisions

- Visualize situation
- Determine goal
- Choose relevant information
- Choose applicable principles
- Construct a plan
- Arrive at an answer
- Evaluate the solution

Students must be taught *explicitly*

The difficulty -- major misconceptions, no heuristics, lack of metacognitive skills

Metacognative Skills

- Managing time and direction
- Determining next step
- Monitoring understanding
- Asking skeptical questions
- Reflecting on own learning process

Explicit Problem-solving Framework

Used by experts in all fields

STEP 1 — **Recognize the Problem**

What's going on?

STEP 2 — **Describe the problem in terms of the field**

What does this have to do with ...... ?

STEP 3 — **Plan a solution**

How do I get out of this?

STEP 4 — **Execute the plan**

Let's get an answer

STEP 4 — **Evaluate the solution**

Can this be true?

Why Labs?

Laboratory environment can help students:

- **visualize** physical situations
- learn to **talk physics** in a “natural” situation
- connect physics to **reality**
- develop their **physical intuition**
- create necessary **disequilibrium**

Qualitative feedback (written lab reports):

Uncovers “misknowledge”

Extended time for coaching (peer & TA):

Cooperative Groups

Accommodates diversity of pace & style:

Guided “self-paced”

Why Not Labs

- Expensive
- Time consuming for students
- Faculty don’t pay attention to them
  - Student activity is enough
  - TA’s can monitor them
- TA’ don’t like them
  - Not “teaching” (lecturing)
- Students don’t like them
  - Waste of time

Traditional Laboratories Do Not Work

- Disconnected from lecture
- Different goals from lecture
- No modeling requires either

Cookbook

Discovery

Neither effective for learning physics

Use Laboratory for Coaching (Modeling in Lecture)

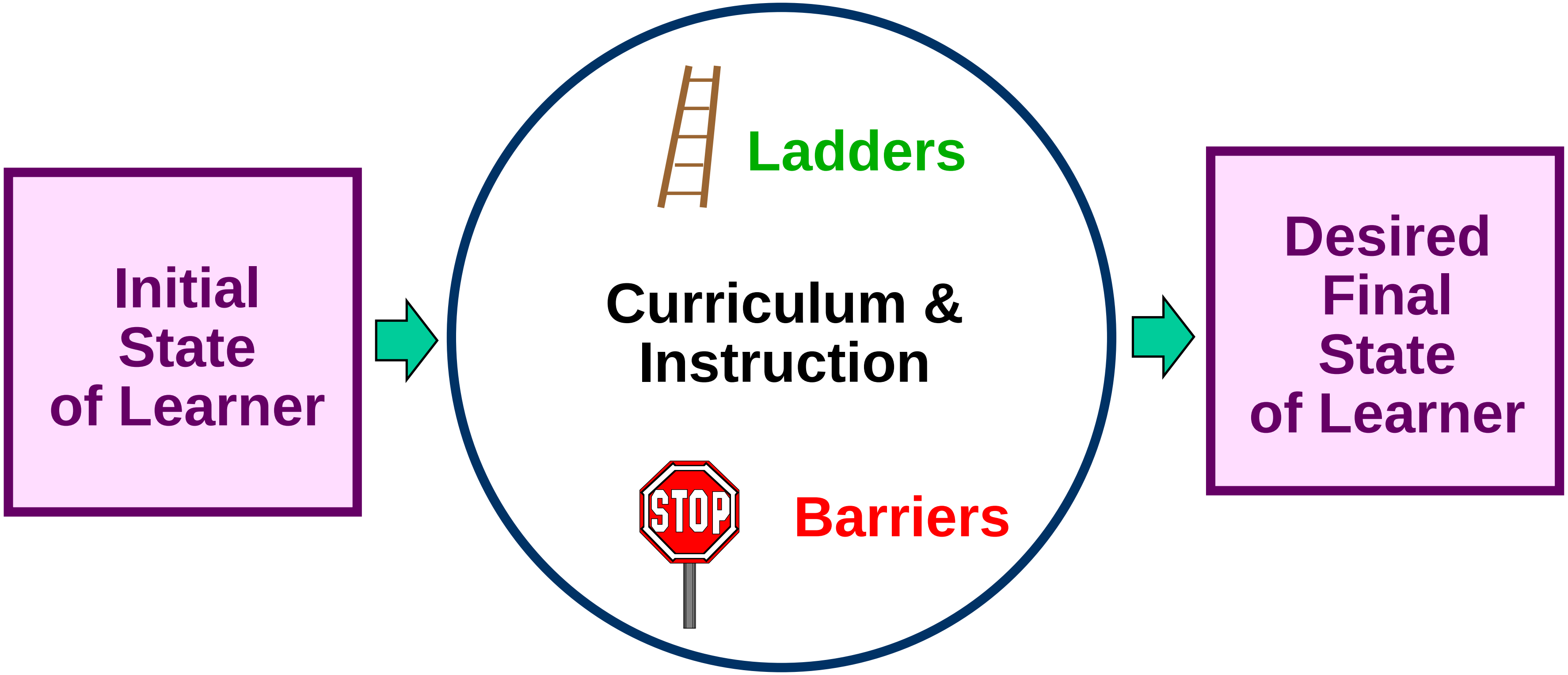
Students work on an appropriate task

- In small groups (peer coaching)
- Intervention by instructor (expert coaching)

Need

- Appropriate task
- Group structure
- Intervention tactics

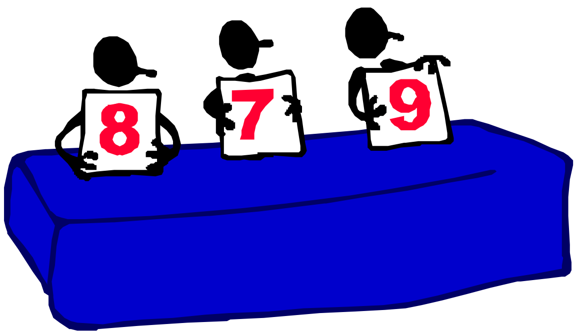
A Systematic Approach to Instructional Design



Transformation Process

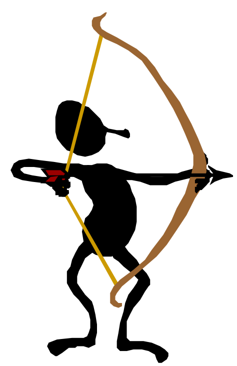
F. Reif (1986)
***Phys. Today* 39**

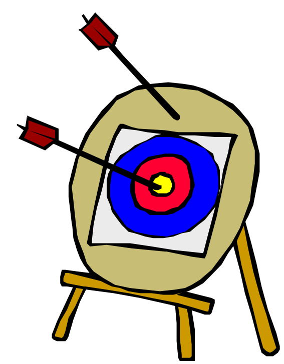
“Laws” of Instruction



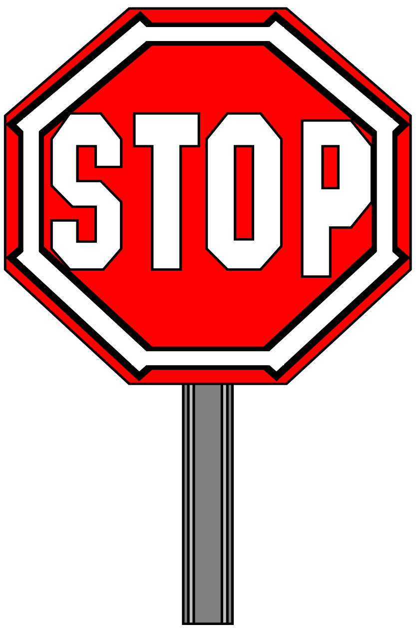
Zeroth Law: If you don't grade for it, students won't do it.

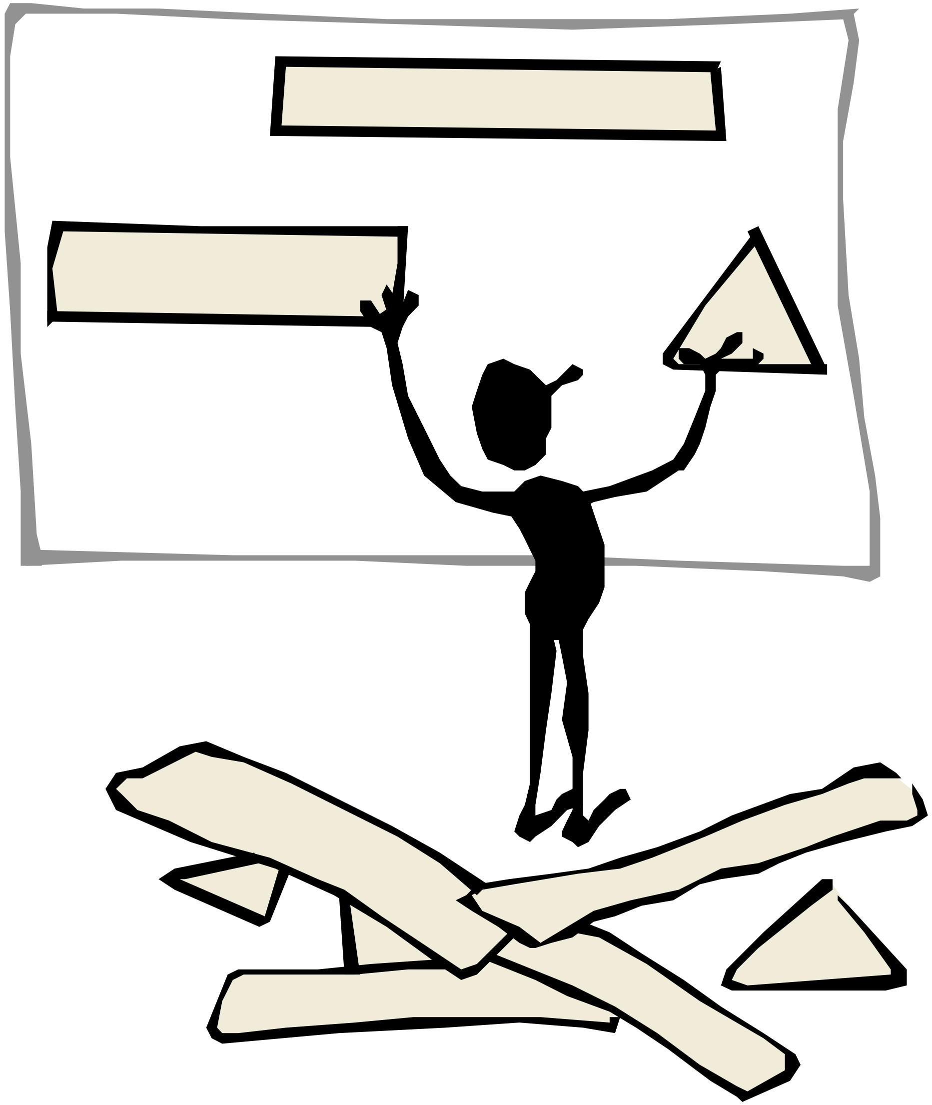
1st Law: Doing something once is not enough.



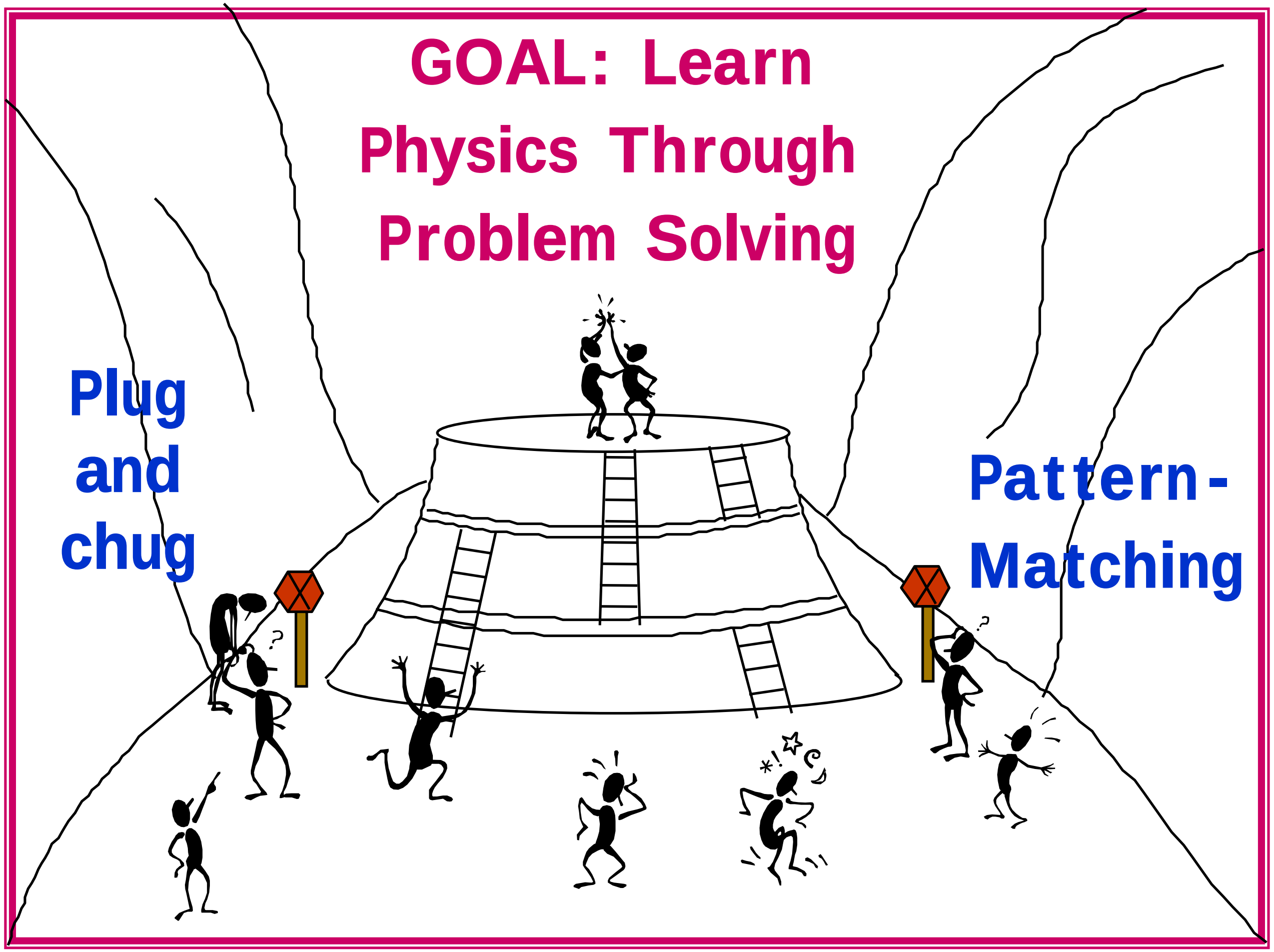


2nd Law: Don't change course in midstream!





3rd Law: Make it easier for students to do what you want them to do and difficult to do what you don't want .



Goals for Problem-solving Labs
Same as the Goals for the Cours

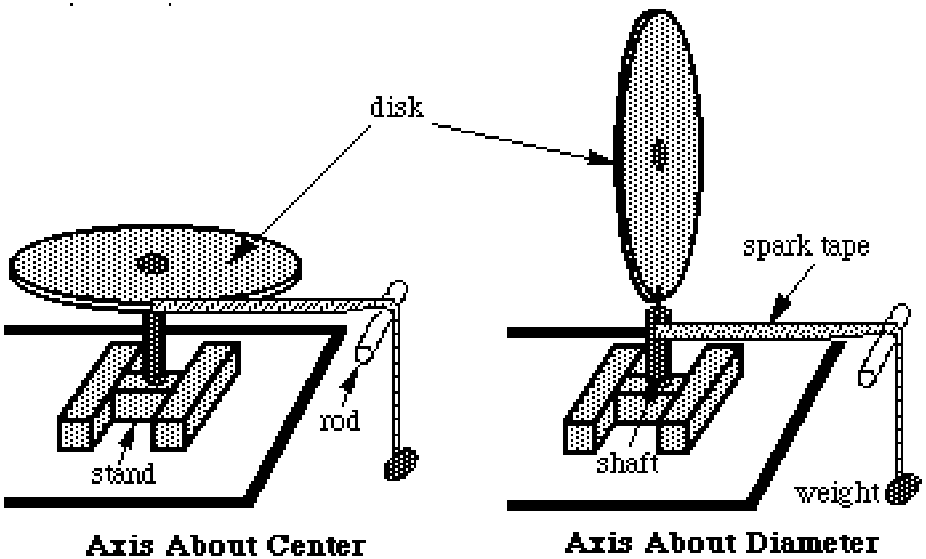
Know the ***basic principles*** of physics.

Solve problems using general ***qualitative*** logical reasoning and ***quantitative*** problem-solving skills within the context of physics.

Apply the physics topics covered to ***new situations*** not explicitly taught by the course.

Problem Solving Laboratories

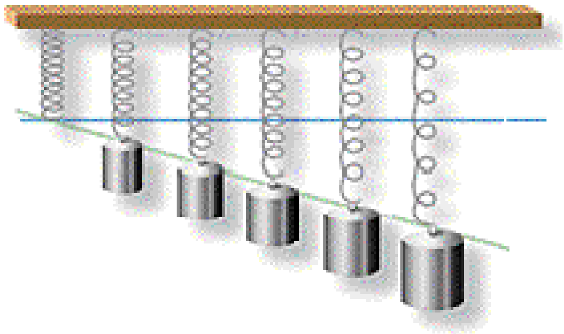
- **Closely integrated with lecture & recitation**
- **Always context-rich problems**
- **Emphasize modeling real systems**
- **Embody misconceptions**
- **Use problem solving strategy**
- **Work in Cooperative Groups**



Laboratory Design
Guiding Principles

- Connection between the physics and the apparatus must be simple and direct to the students.
- Correct physics predictions must agree with simple measurements to within 10%.
- Equipment must be simple enough for students to manipulate with minimal instructions.
- Minimize the amount of equipment used in the course
  (New Physics ≠ New Equipment)
  - Equipment must be robust.
  - Equipment available for more than one week.

Problem Solving Labs



- A "Lab" lasts 2 - 3 weeks, and consists of several related problems in a topic area.
- Each problem takes 1 - 2 hours to complete in a lab session..
- There are more problems than the typical group can complete in the time allotted
  - teaching team choose a preferred order and minimum number of problems to match the emphasis of the lectures;
  - instructor can select additional problems to meet the needs of individual groups.
- Theory is given only in the text to emphasize that the lab is an integral part of the course.

Teaching Problem Solving Labs

Preparation

↓

Group Predictions

↓

Class Discussion

↓

Measurement & Analysis

↓

Closing Discussion

Prelab Computer Checkout

Designed to make sure students have read relevant text material before they come to lab.

1. Available on the web.

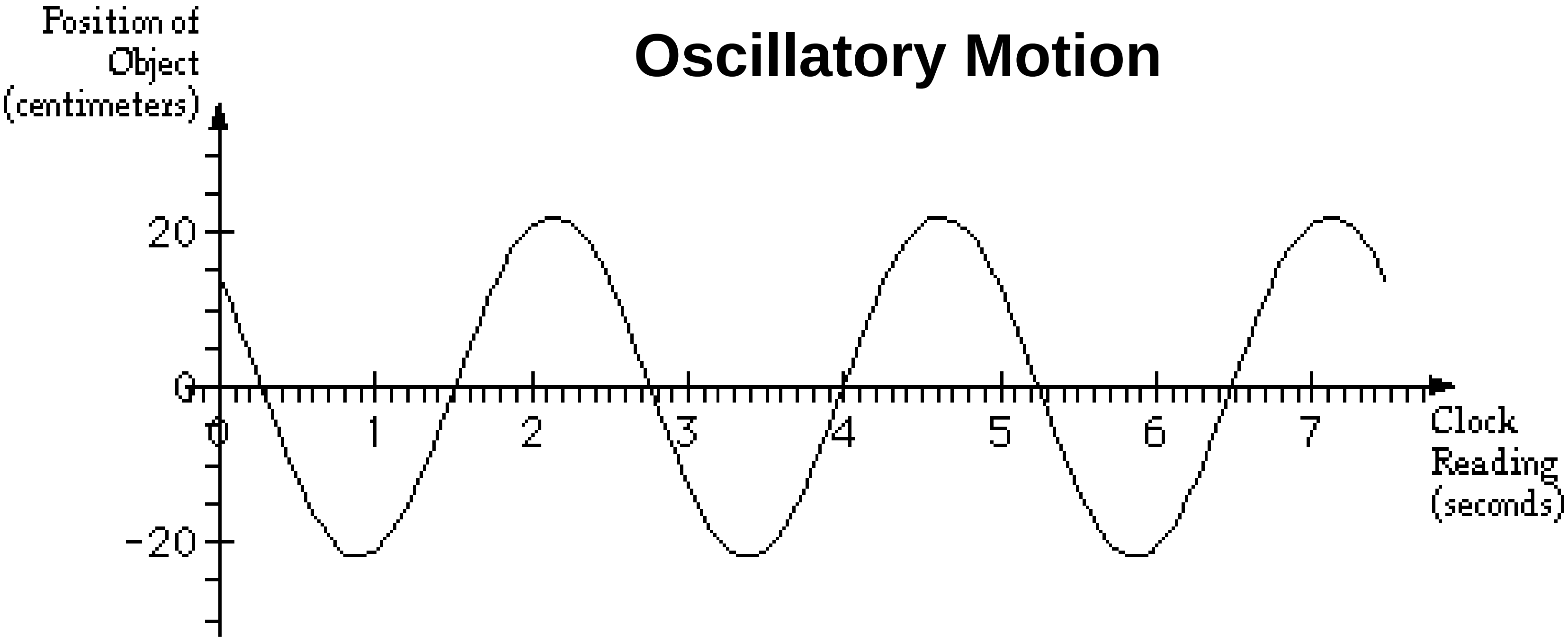
2. Students can take as many times as they wish, using textbook, notes, and other students.

3. Computer randomly changes question order, numbers and vector orientations in questions.

4. Questions require minimal understanding of concepts.

- about 4 questions (multiple choice, numbers with units, or drawings).
- if student misses a question, test expanded to give student another chance at similar question.
- 70% to pass.

Lab Prep Quiz

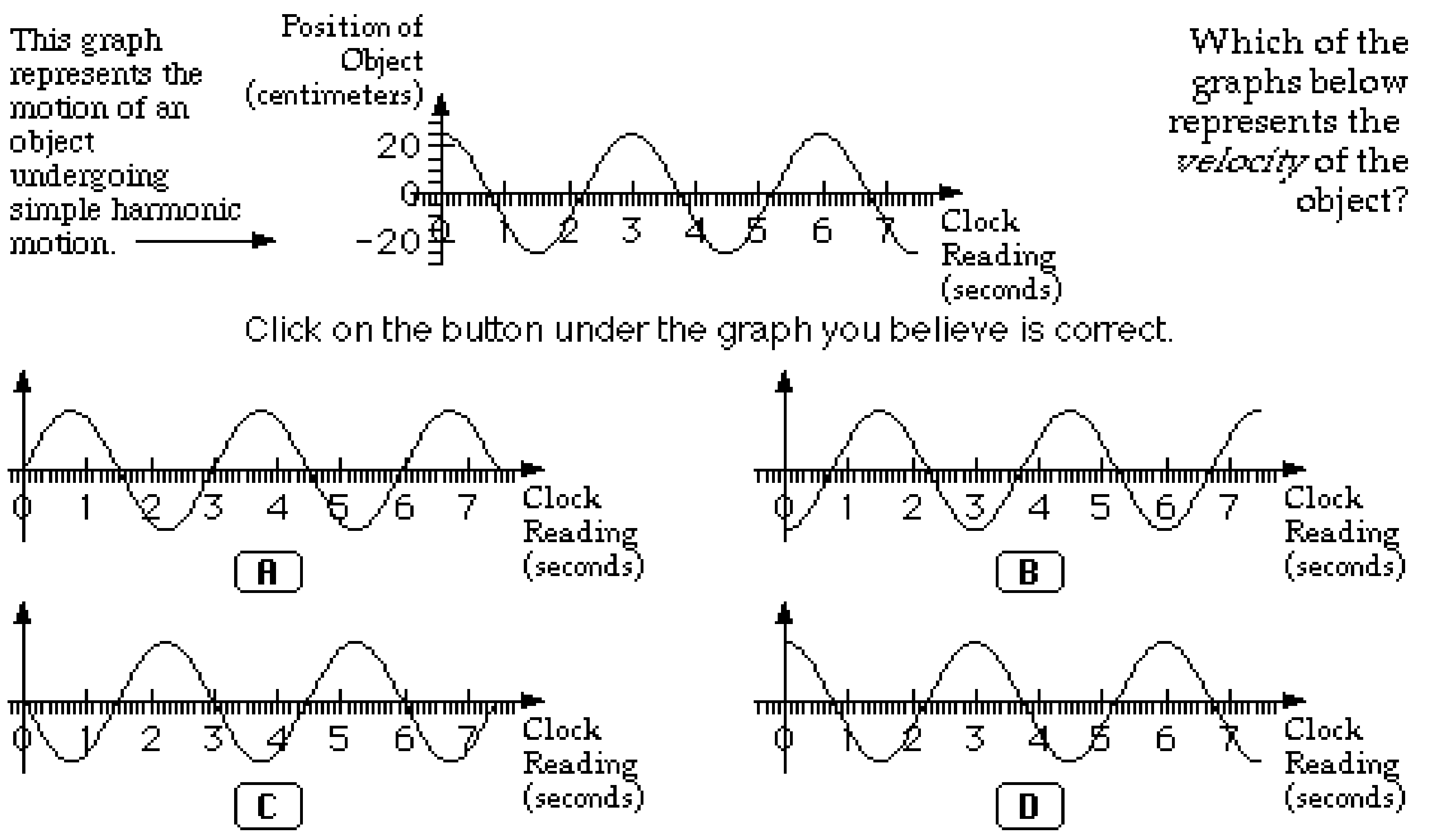


Consider the acceleration of the ball. On the graph, place an arrow at a point where the magnitude of the acceleration of the ball was *zero*. Click on the OK button when you are satisfied with the location of your arrow.

amplitude = 22 cm
angular frequency = 2.53 /s
mass = 0.21 kg

Lab Prep Quiz

Oscillations



A Lab Problem

You have been hired as part of a team to design new port facilities for Duluth. Your assignment is to evaluate a new crane for lifting containers from the hold of a ship. The crane is a boom (a steel bar of uniform thickness) with one end attached to the ground by a hinge that allows it to rotate in the vertical plane. Near the other end of the boom is a motor driven cable that lifts a container straight up at a constant speed. The boom is supported at an angle to the horizontal by another cable. One end of the support cable is attached to the boom and goes horizontally to a pulley. The other end goes over a pulley and is attached to a counterweight that hangs straight down.

The Problem

The pulley is supported by a mechanism that adjusts its height so the support cable is always horizontal. Your task is to determine how the angle of the boom to the horizontal changes as a function of the weight of the container being lifted. The mass of the boom, the mass of the counterweight, the attachment point of the support cable, and the attachment point of the lifting cable have all been specified by the engineers.

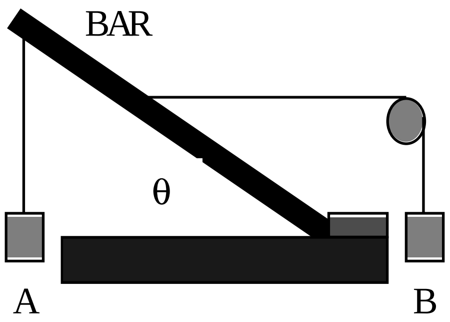
?

How does the angle of the boom to the horizontal depend on the weight to be lifted?

You decide to solve this problem with a laboratory model of a crane.

Equipment

You will have a bar, a pulley, some string, and two objects (A and B) of different mass.



Prediction

Calculate the angle of the bar from the horizontal as a function of the weight of object A (with everything else fixed.)

Make a graph of the bar’s angle as a function of the weight of object A.

Methods Questions (Coaching Problem Solving)

To complete your prediction, apply a problem-solving strategy.

1. Make a sketch of the situation (similar to the diagram in the Equipment section). Identify and label the known (measurable) and unknown quantities. On your sketch, show the direction of all relevant forces and accelerations.
2. What object(s) are of interest to you? Describe their motion? What principle(s) of physics relates the forces on each object to its motion?
3. Draw a free body diagram of each object of interest. Label all forces. Determine a useful coordinate system. Write down the equations determined by each diagram. Does any equation contain your target quantity?

Exploration

Collect the necessary parts of your crane. Find a convenient place to build it.

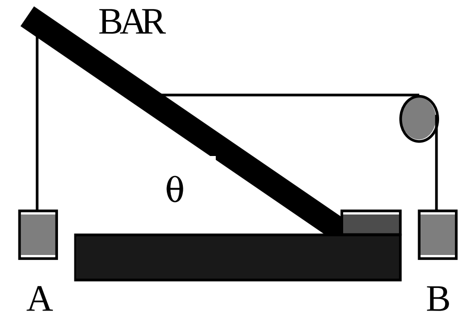
Decide on the easiest way to determine where the center of mass is located on the bar.

Determine where to attach the lifting cable and the support cable so that the crane is in equilibrium for the weights you want to hang. Try several possibilities. If your crane tends to lean to one side or the other, try putting a vertical rod near the end of the crane to keep it from moving in that direction. If you do this, what effect will this vertical rod have on your calculations?

Do you think that the length of the strings for the hanging weights will affect the balance of the crane? Why or why not?

Outline your measurement plan.

Measurement



Build your crane.

Make all necessary measurements of the configuration. Change the mass of object A and determine the angle of the bar when the system is in equilibrium. Remember to adjust the height of the pulley to keep the support string horizontal.

Is there another configuration of the three objects that also results in a stable configuration?

Analysis

Make a graph of the bar's angle as a function of the weight of object A.
What happens to that graph if you change the mass of object B? The position of the attachment of the support cable to the bar?

Conclusion

Did your crane balance as designed?

What corrections did you need to make to get it to balance? Were these corrections a result of some systematic error, or was there a mistake in your prediction?

In your opinion, what is the best way to construct a crane that will allow you to quickly adjust the setup so as to meet the demands of carrying various loads? Justify your answer.

Why Computerize Labs?

STUDENT'S NEEDS AND EXPECTATIONS

- **computers are already an integral part of technological fields.**
- **computers are part of their every day world -- they EXPECT the labs to be computerized**

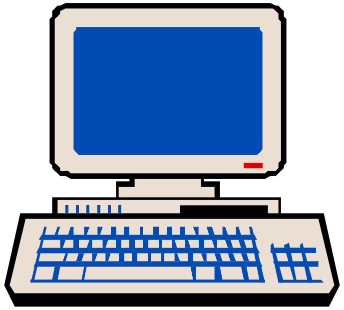
PRACTICAL

- **computer labs have fewer "pieces" -- easier to maintain, save money in the long run**
- **computers are an improving technology**

IMPROVED LEARNING

- **improved visualization**
- **save time doing repetitive, tedious measurements, so more time to learn physics**

What Do We Know About Computerizing Labs?



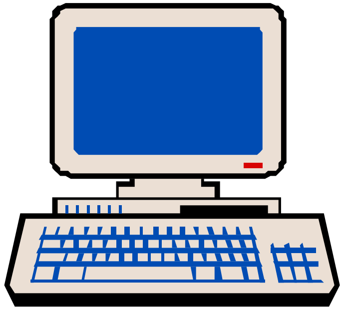
General Outcomes:

- **Traditional labs have no effect on general achievement.**
- **TIMSS data: classrooms with technology have lower achievement scores**
  - **technology poorly integrated with content**

Physics Labs:

- **Carefully designed, well implemented technology in labs can lead to higher achievement scores (e.g. Priscilla Laws, Ron Thornton, Bob Beichner)**
- **"Teachers must thoroughly integrate software into their instruction and not just tack it on." (Beichner, AJP, 1996)**

Software Rationale



- **Use National Instruments (LabVIEW) software to program measurement and analysis tools**
  - **Can program to match pedagogy for problem solving labs**
  - **Instructors can make revisions and extensions to change lab problems and pedagogy**
  - **Can use same software for all computer tools**

    - Practice Fit, Video analysis, Hall Probe, Oscilloscope
  - **Software available and updated to match new processors and operating systems**

Choices

Mechanics - Video for motion measurements

- More direct connection to reality for students
- More versatile - one technique to do all measurements
  - 1 D and 2 D motion
  - Linear and Rotations
- Technology will improve - driven by industry

Electricity and Magnetism - Vernier ULI interface

- Reasonably inexpensive
- Software controls are public to allow program changes by instructor

User Interface

3rd Law: **Make it easier for students to do what you want them to do and difficult to do what you don't want .**

It should be impossible (very difficult) to make progress

- **If students don't know what they are doing and why**
- **If students don't understand the physics**

It should be easy to make measurements and do analysis

- **If students know what they are doing and why**
- **If students understand the physics**

User Interface

Make a prediction of the object's motion along the X-axis. Select an equation and variables to match the motion along the horizontal axis. Select "Accept X Prediction" when satisfied.

Guide Box

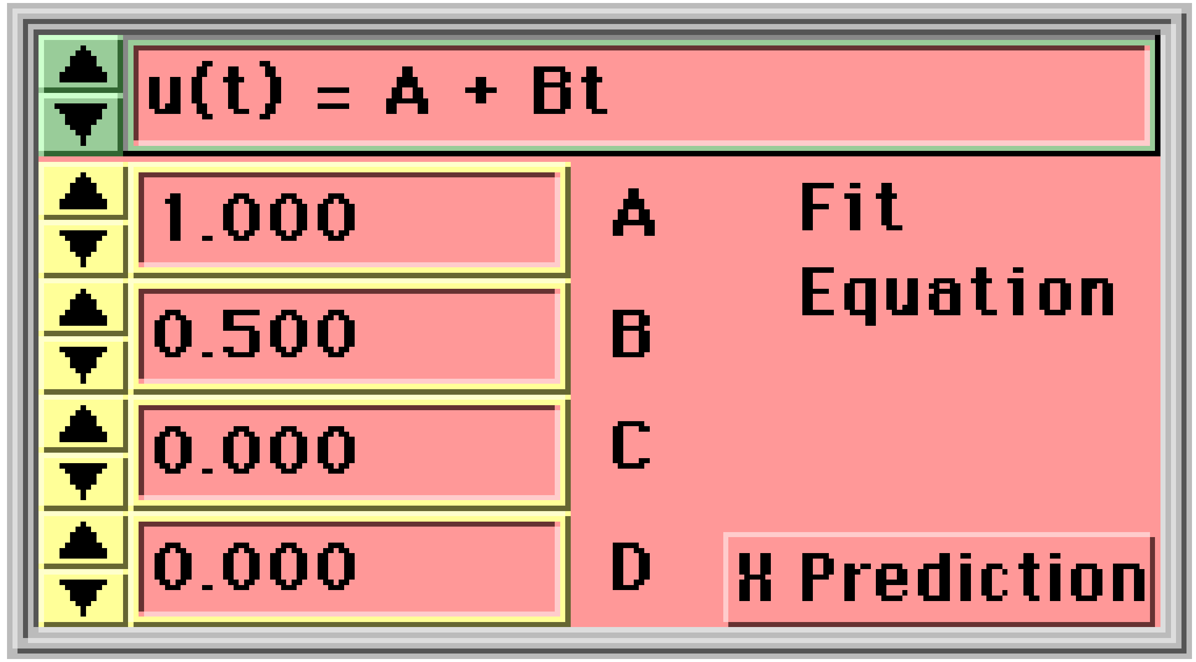
- Accept X Prediction
- Accept Y Prediction
- Open Movie
- Calibrate Movie
- Erase Data Points
- Analyze Data
- Accept X Fit
- Accept Y Fit
- Accept Vx Prediction
- Accept Vy Prediction
- Accept Vx Fit
- Accept Vy Fit

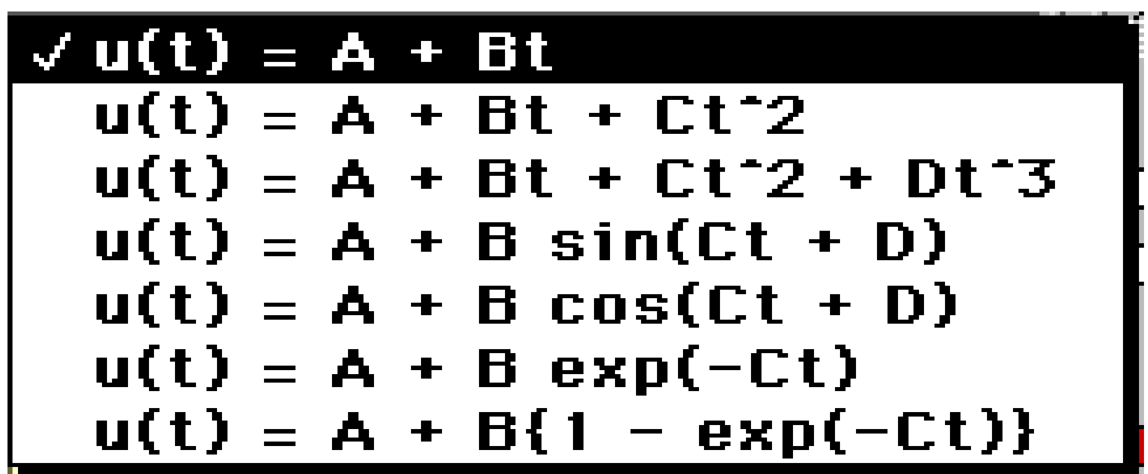
- Import Data
- Export Data
- Export Data Table

- Print Results on Close
- Close Movie / Abort

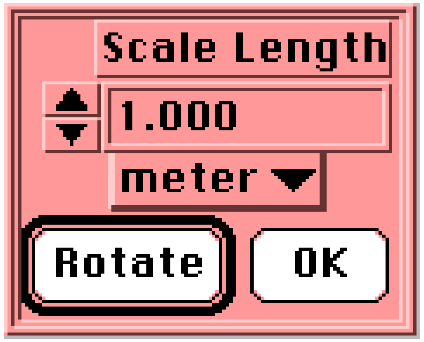
- Quit Program

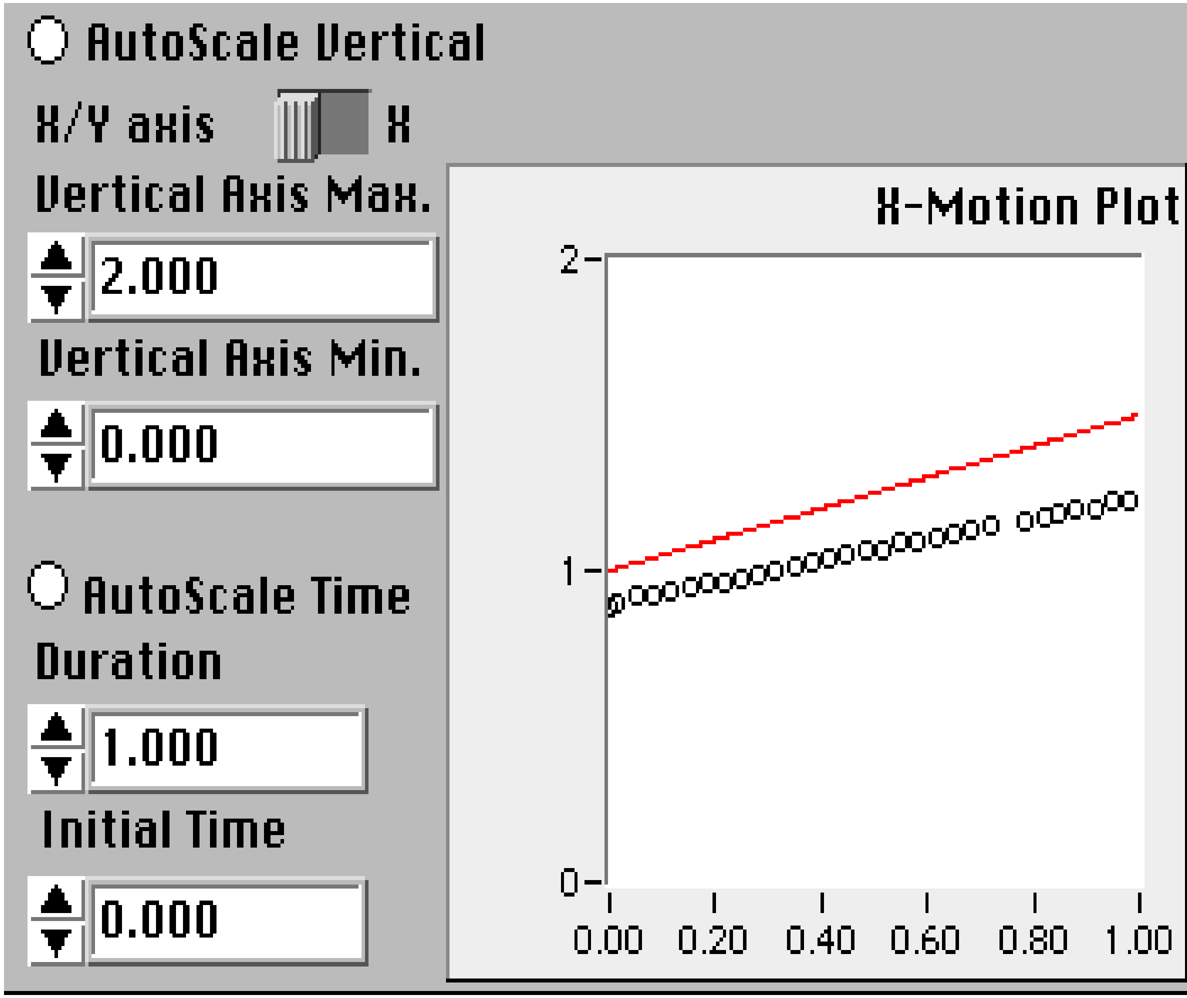
Predicted Graph



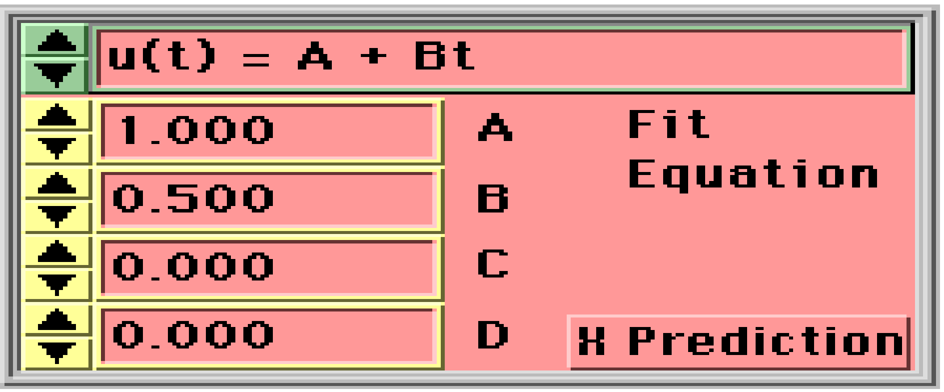


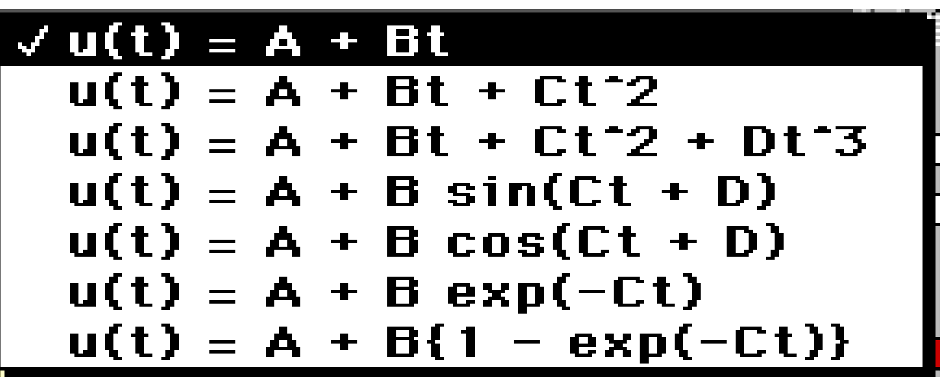
Graphing Data

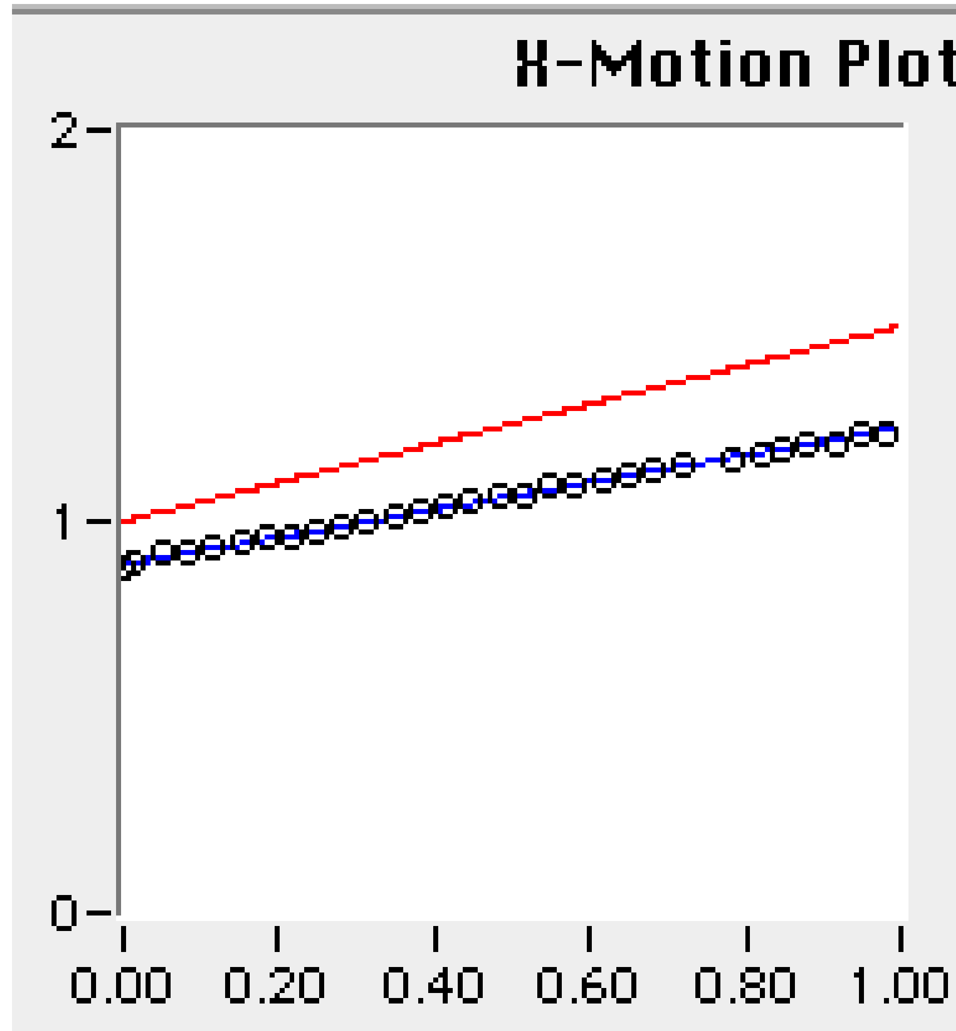




Fitting Data to Equation







Optimal Apparatus - Magnetism

One Apparatus for the entire topic of magnetism

- **~ 5 out of 15 weeks of course time**

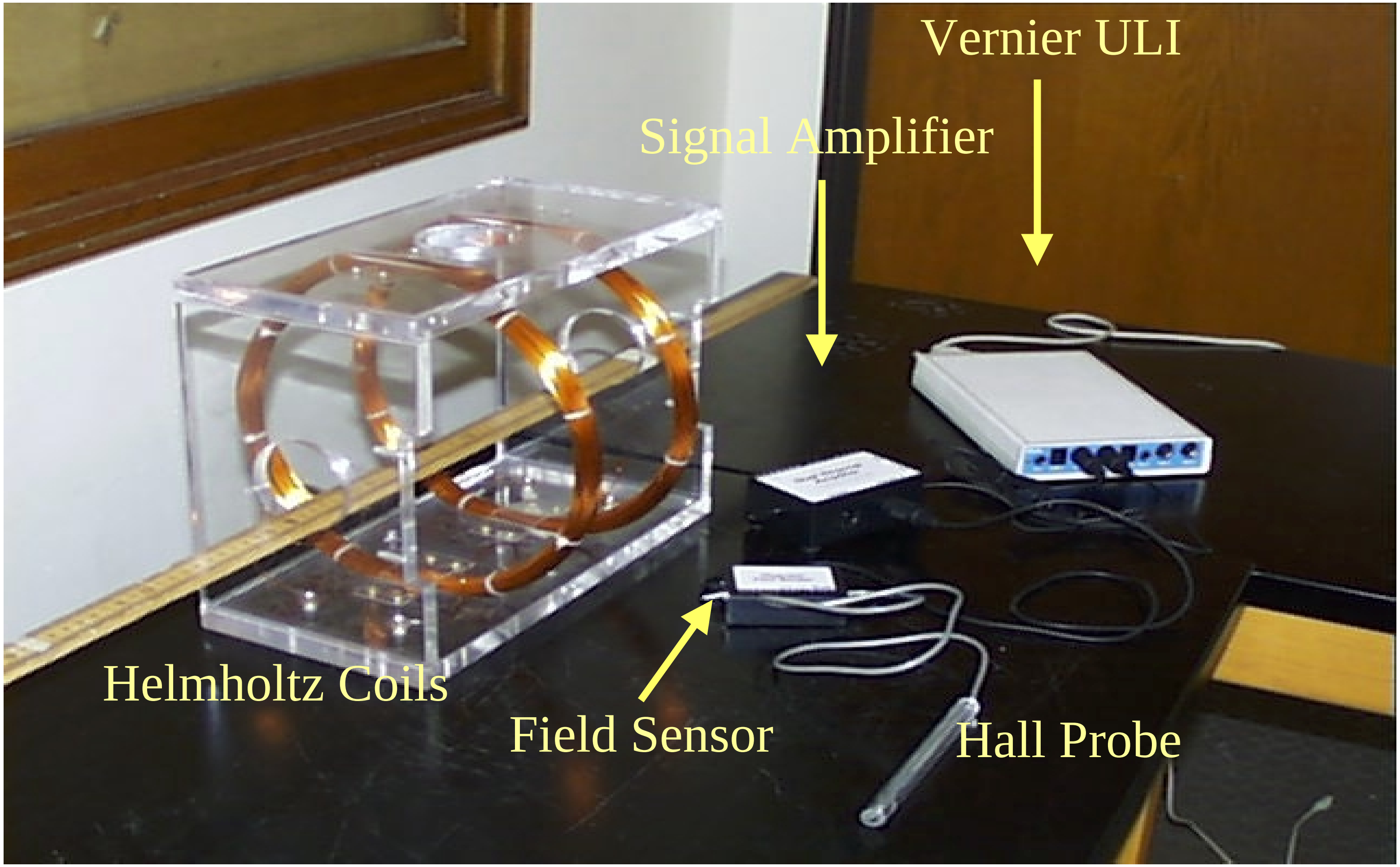
- **3 chapters from the textbook**
  - **magnetic fields**
  - **magnetic fields due to current**
  - **induction and inductance**

- **Context rich" laboratory problems**
  - 8 on fields and forces
  - 6 on flux and induction

Design Criteria

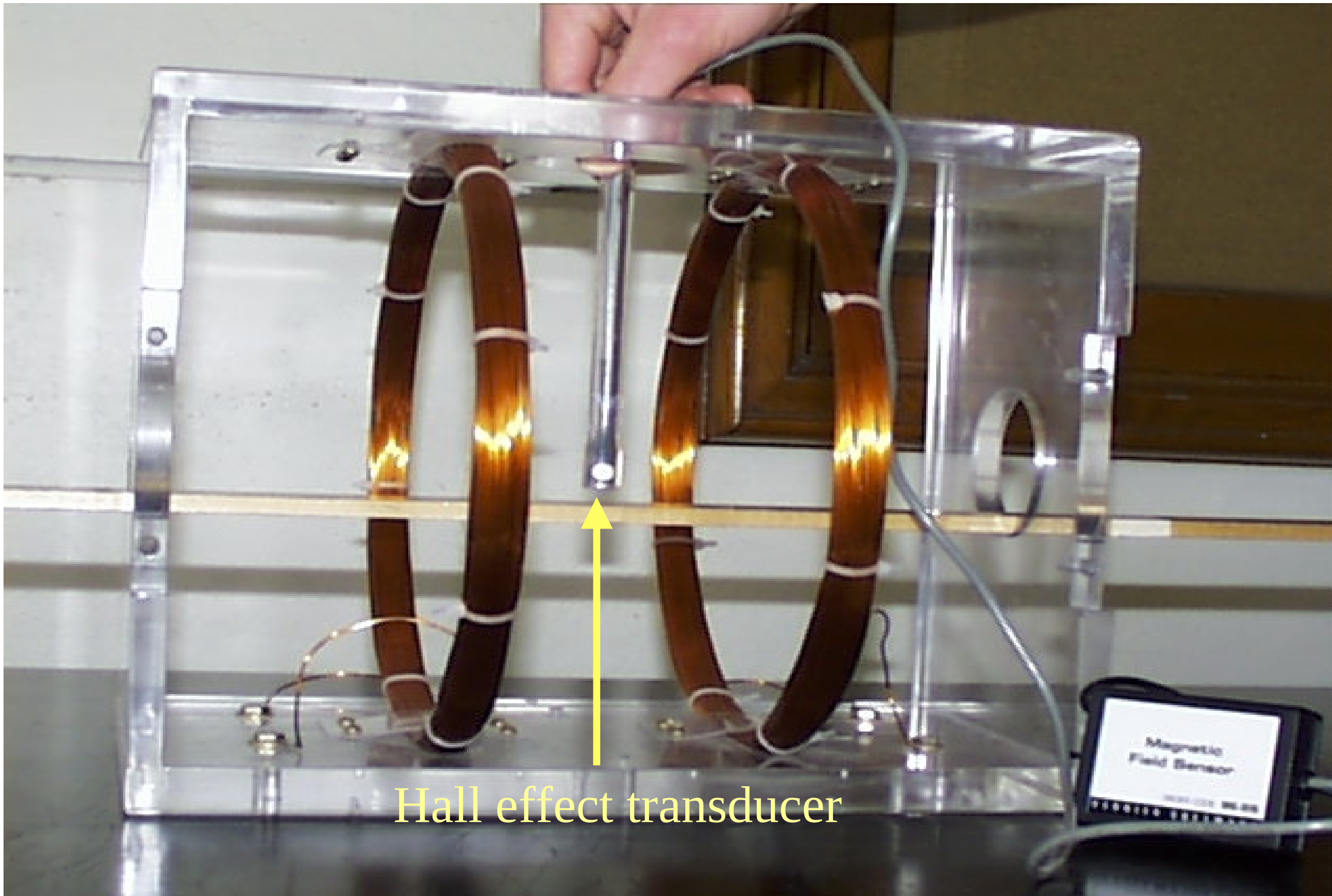
- Pedagogical - easy to understand and multipurpose
  - problem solving
  - physics principles
- Practical - efficient and robust
  - extensive usage
  - lack of maintenance time

Standard Set-up



Fields

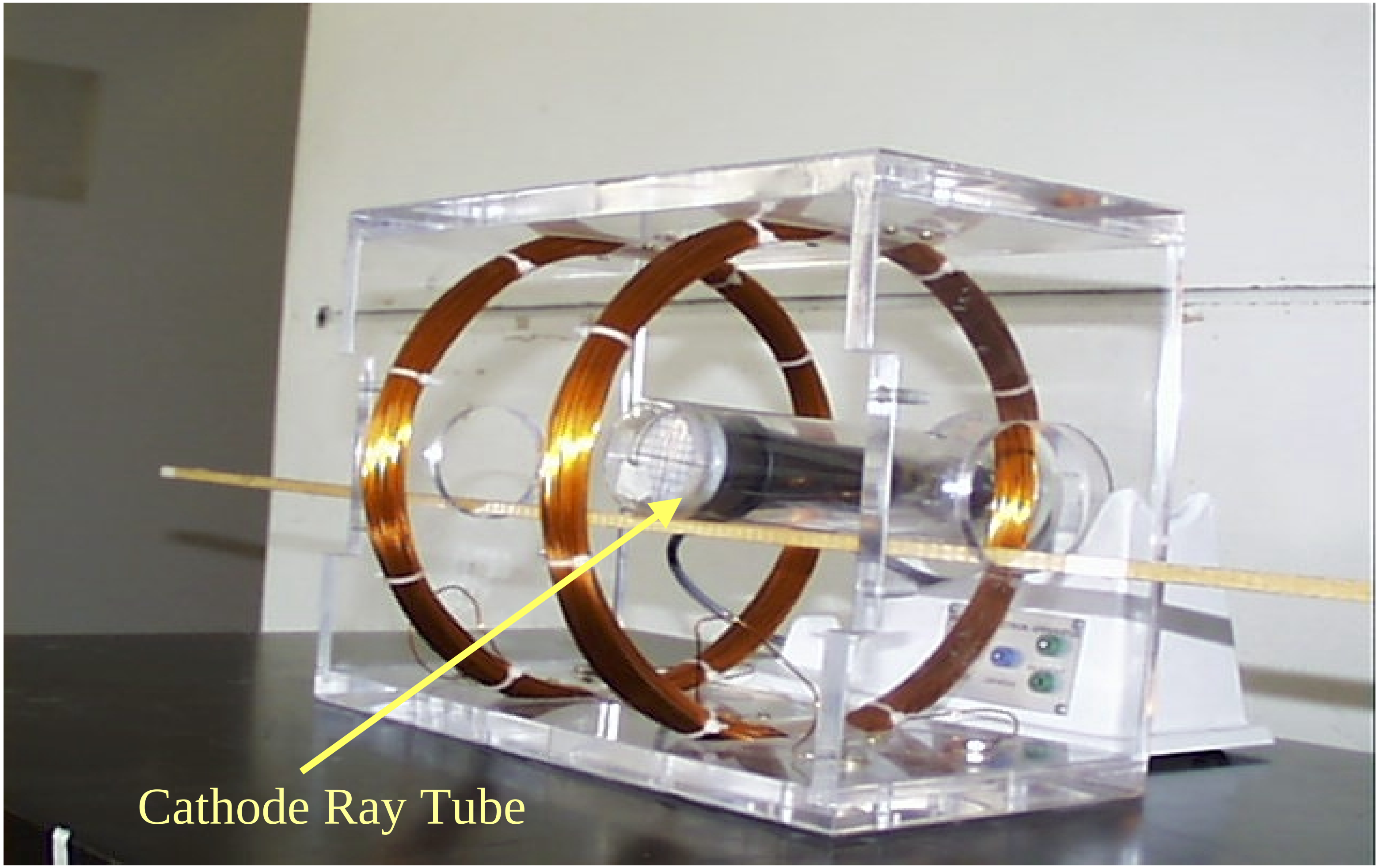
Biot-Savart



•**Measure magnetic field due to current in one or two coils**

Forces

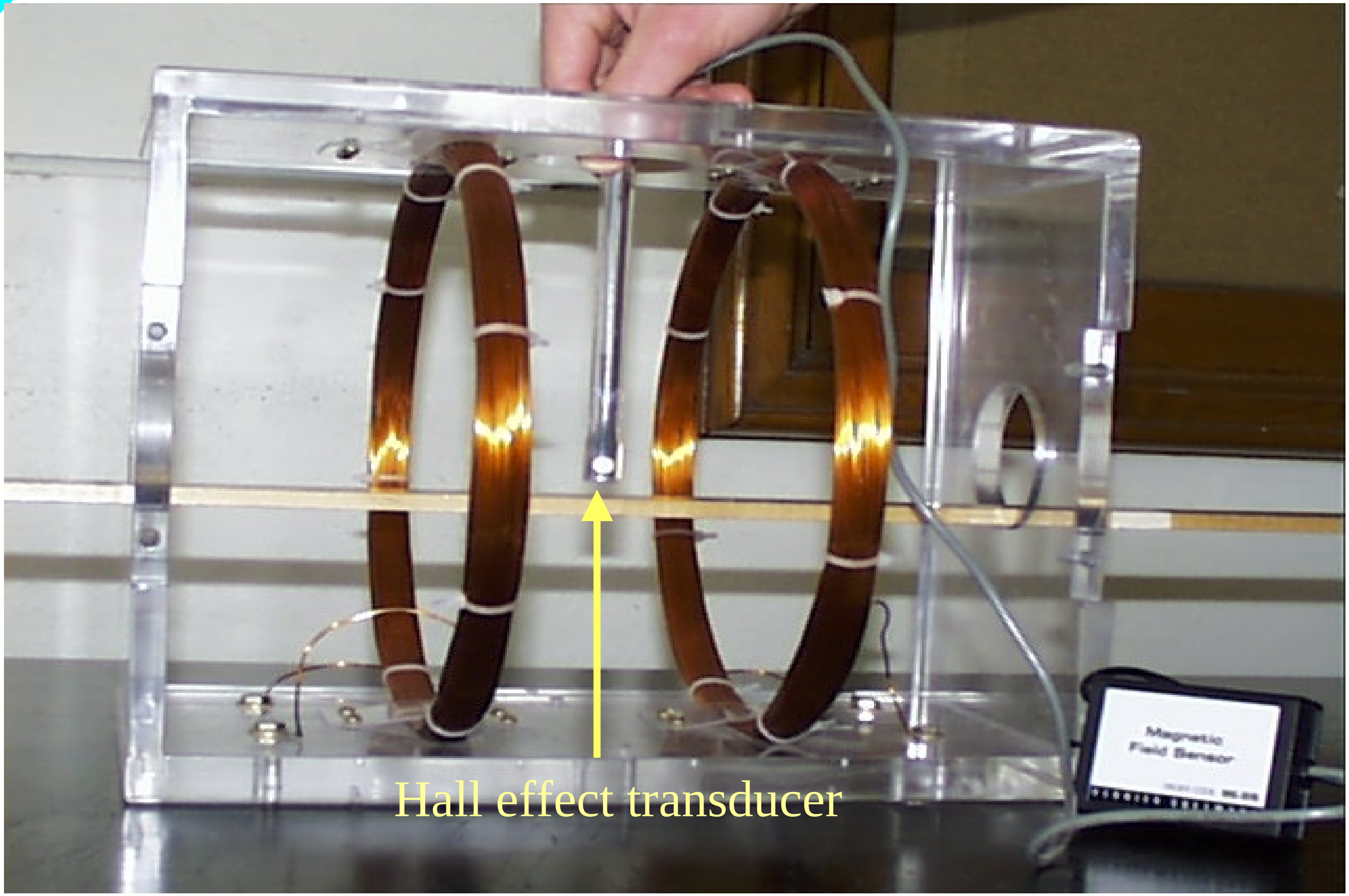
$$\mathbf{F} = q\nu \times \mathbf{B}$$



- **Measure deflection of electron beam due to magnetic field**

Flux

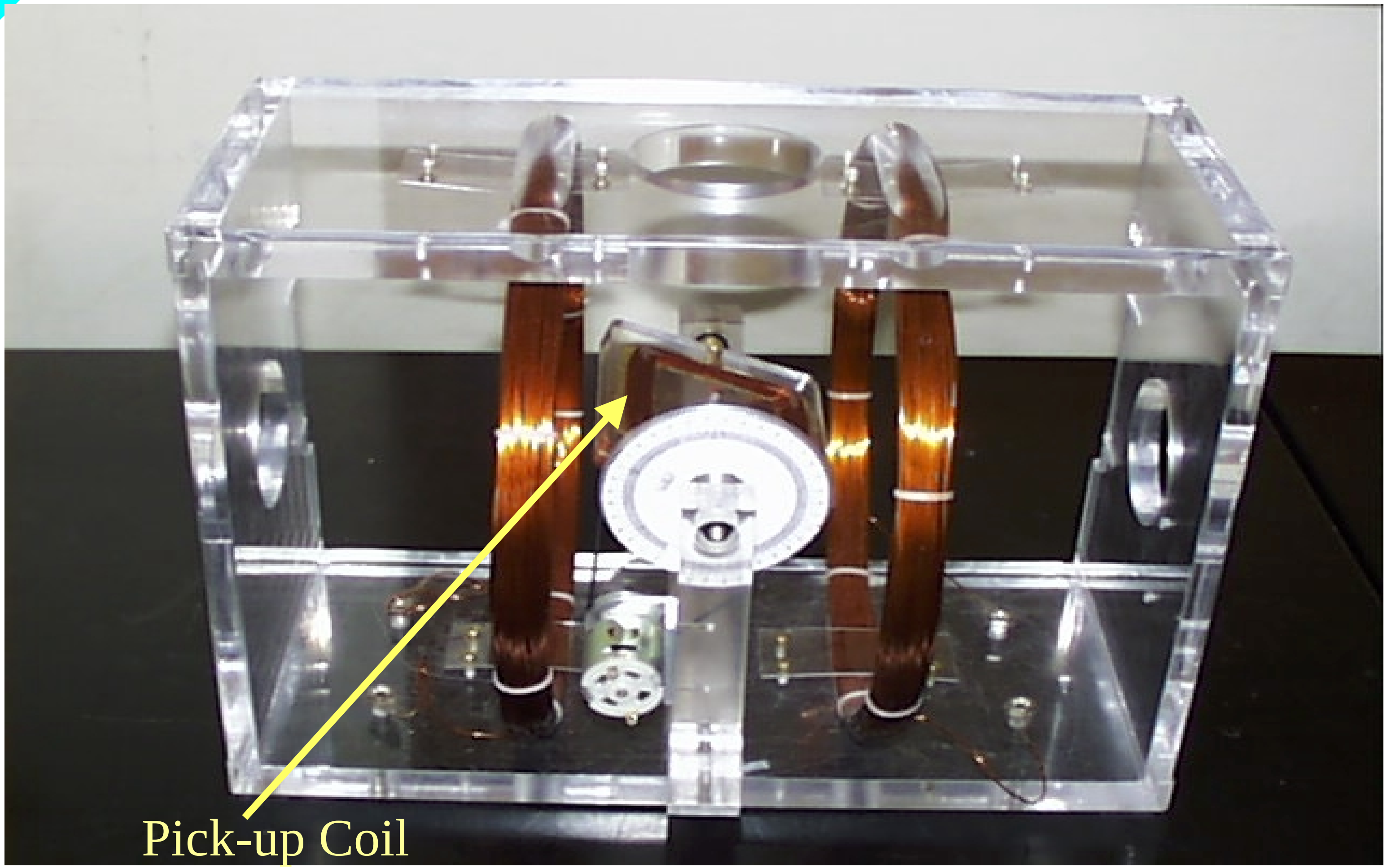
$$\Phi = \mathbf{B} \bullet d\mathbf{A}$$



•**Measure angular dependence of magnetic field measured by hall probe (or pick-up coil).**

Induction

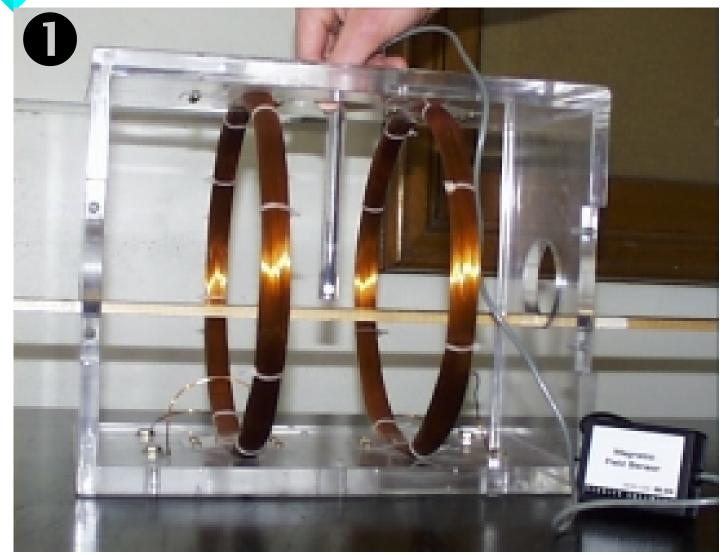
$$\varepsilon = -\frac{d\Phi}{dt}$$

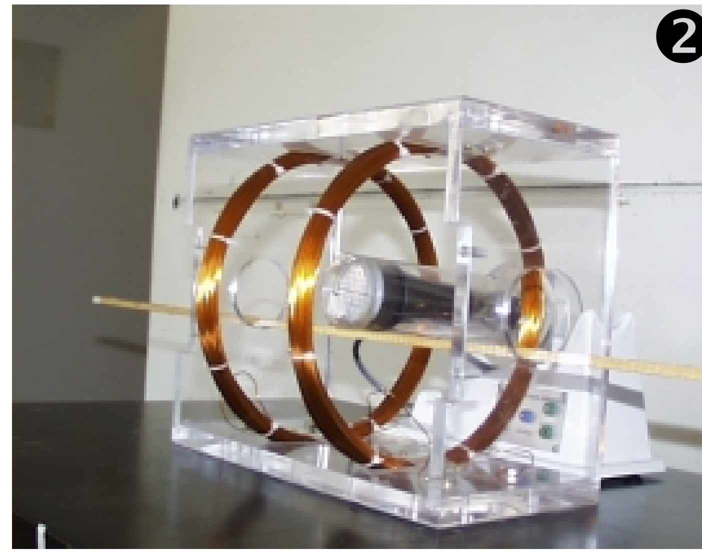


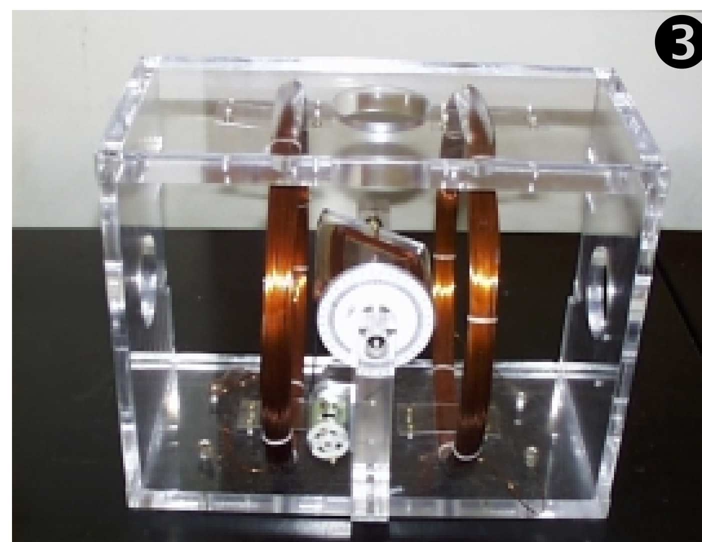
•Rotating pick-up coil with steady current in Helmholtz coils

•Stationary pick-up coil with time-varying current in Helmholtz coils.

Design Features

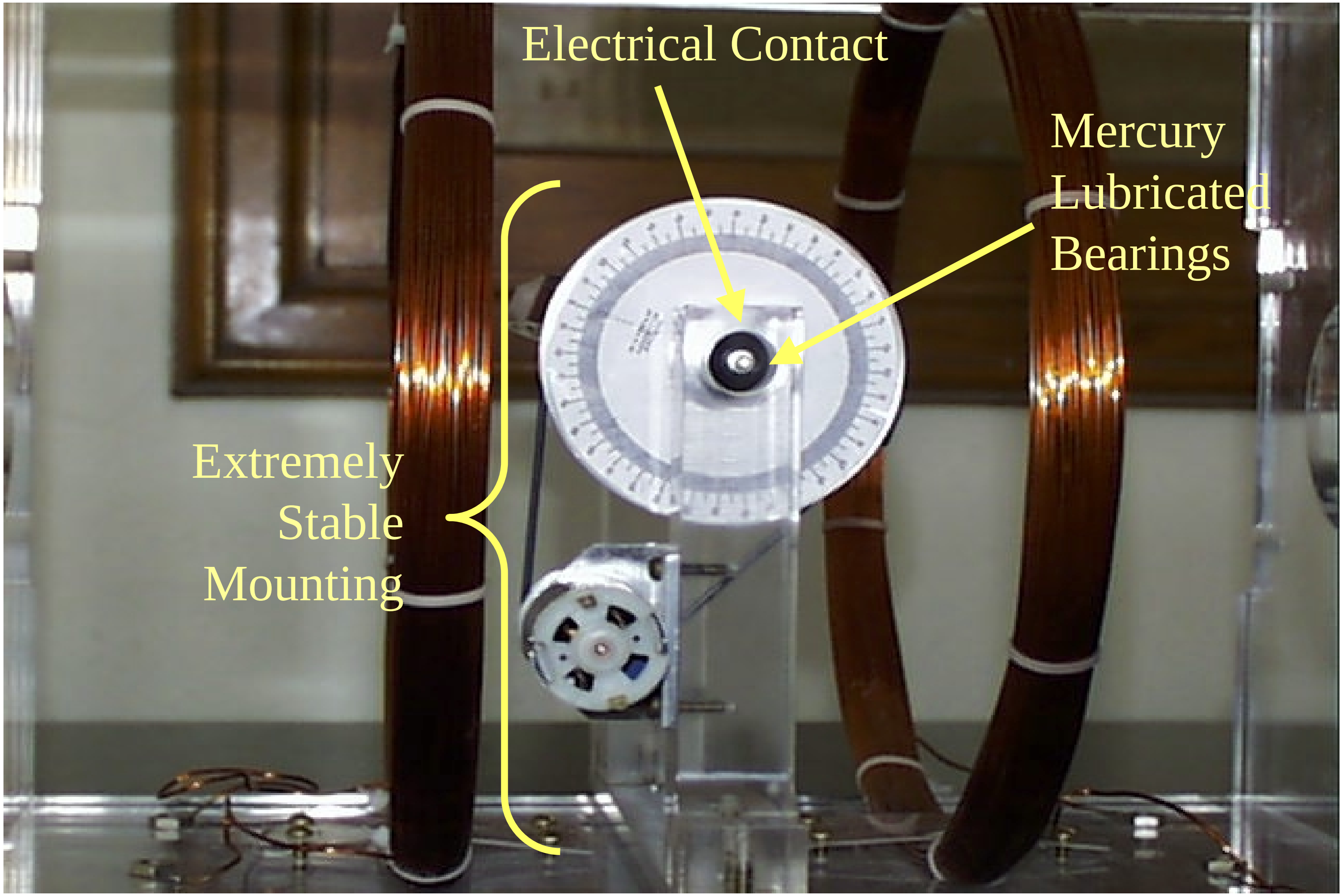






- ❶ Easy viewing and access to all parts
- ❷ Holes accommodate CRT
- ❸ Easy removal and addition of rotating pick-up coil and motor

Design Features



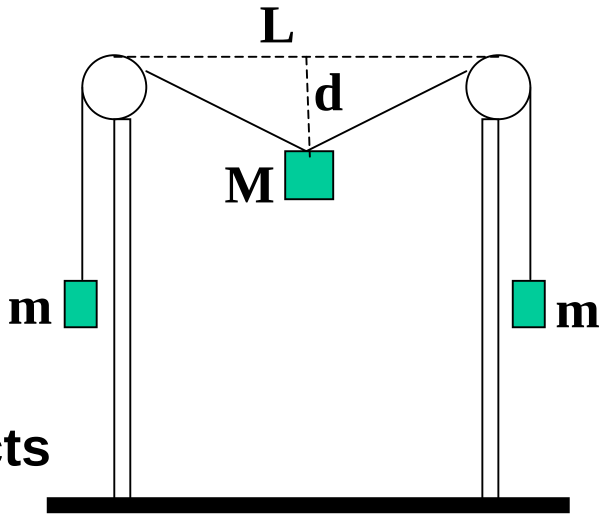
Summary

- **Uses for the apparatus**
  - **Magnetic fields of current carrying wires**
    - **single coil**
    - **two parallel coils**
  - **Magnetic forces on a moving charge**
    - **deflection of electron beam in constant field**
  - **Magnetic flux**
    - **angular dependence**
  - **Magnetic induction**
    - **rotating coil in constant field**
    - **stationary coil in time-varying field**

Optimal Apparatus - Force

One Apparatus probes many student difficulties

- **Vector Nature**
  - Independence of perpendicular components
  - Use of trigonometry necessary
- **Relationship to physical objects**
  - Forces act on objects
  - Direction of forces to connection of objects
- **Forces without motion**



Determine d as a function of m, M, L

How Do Labs Fit In?

LECTURES

Three hours each week, sometimes with informal cooperative groups. Model constructing knowledge, model problem solving strategy.

RECITATION SECTION

One hour each Thursday -- groups practice using problem-solving strategy to solve context-rich problems. Peer coaching, TA coaching.

LABORATORY

Two hours each week -- *same* groups practice using strategy to solve concrete experimental problems. *Same* TA. Peer coaching, TA coaching.

TESTS

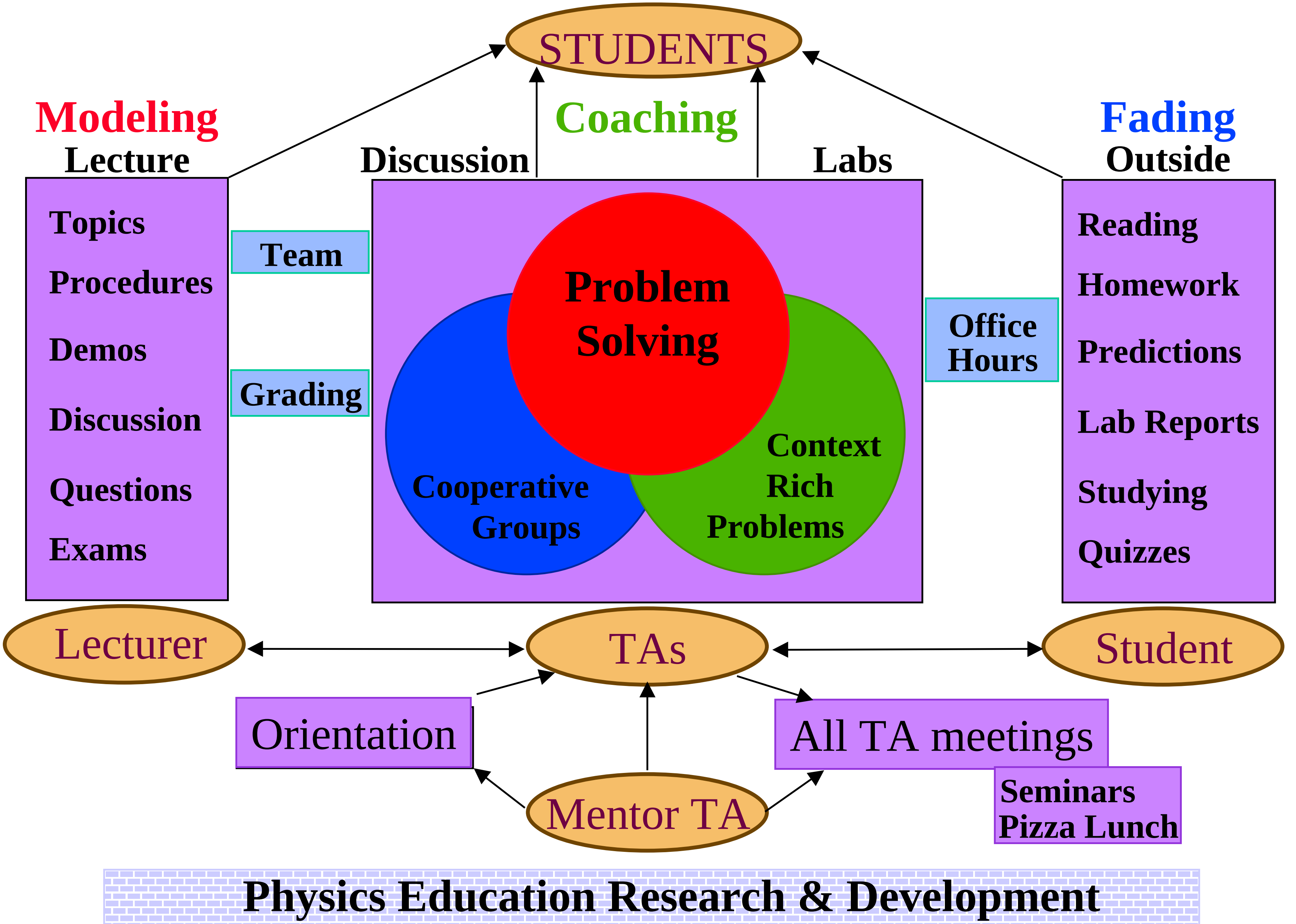
Friday -- problem-solving quiz & conceptual questions (usually multiple choice) every two weeks.

The Course as a System

Use strengths of components acting together

- **Lectures (150 - 300 students)**
  - **Model construction of knowledge**
    - **Explicit Storyline**
    - **Motivate all concepts**
  - **Model problem solving**
    - **A single explicit strategy**
    - **Always start from basic principles**
- **Recitation sections & laboratories (16 students)**
  - **Coach problem solving**
    - **Same strategy as lecture**
    - **Same concepts as lecture**

UMn MODEL FOR LARGE INTRODUCTORY COURSE



Grading

1. Instructors grade students’ journals during lab sessions.

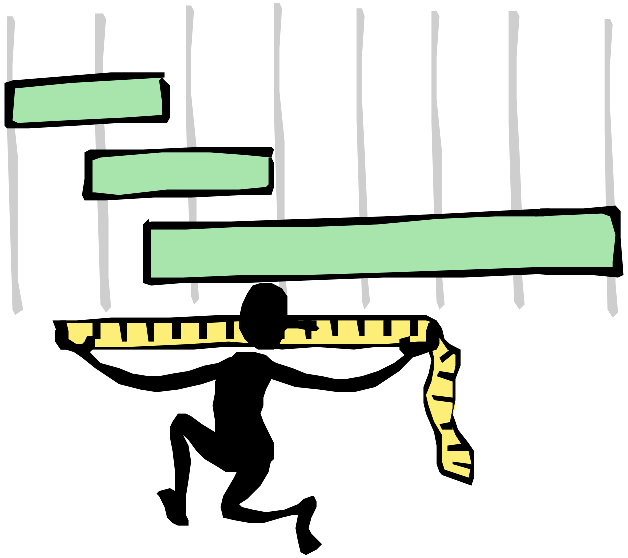
LABORATORY JOURNAL	Points
Predictions	2
Lab Procedures	2

2. At end of lab, instructors assign each student one problem to write up (due 2 - 3 days after lab)

PROBLEM REPORT	
Organization	2
Data and Data Tables	2
Results	2
Conclusions	2
Total	**12**
Bonus Points	**2**

Formative Evaluation

- Lab Reports
- Concept Tests
- Student Questionnaires
- Observations of Labs
- Interviews of TAs
- TA questionnaires



Lab Reports

Analyzed based on 5 criteria from literature on technical communication in writing

Pilot Study

One class of 15 students
- 11 of which had all 6 laboratory reports from the entire 15-week semester (n = 11)

Each student is placed into one of three groups based on the grade of the first report
- Poor

Guideline for grading laboratory reports

For Students and TAs

Problem Report:	Score
ORGANIZATION **(clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)**	
DATA AND DATA TABLES (GROUP PREDICTIONS) **(clear and readable; units and assigned uncertainties clearly stated)**	
RESULTS **(results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)**	
CONCLUSIONS **(comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)**	

Laboratory Reports as Communication

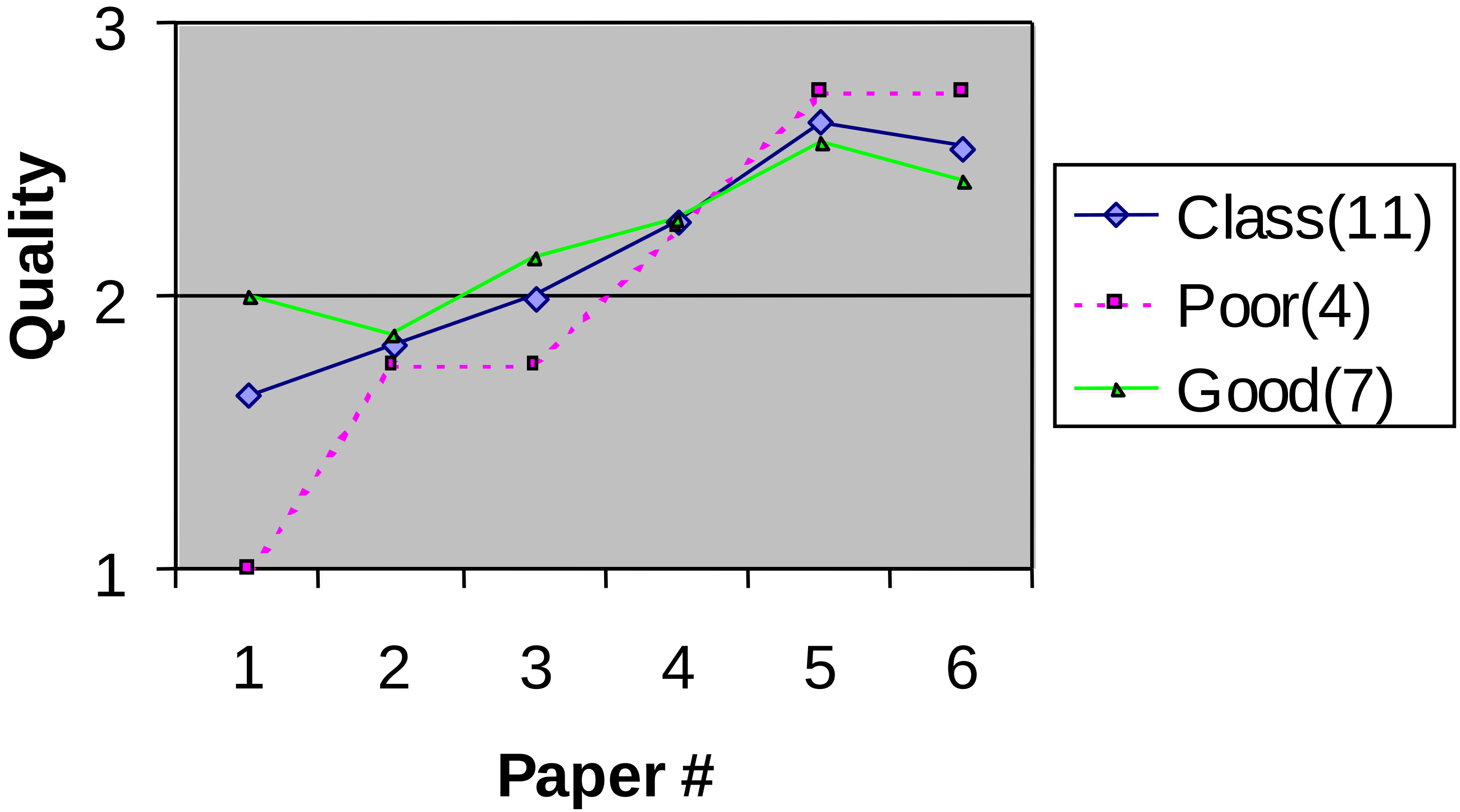
Dr. Lee-Ann Kastman Breuch Dept. Of Rhetoric, U of MN

- **Content:** **What is the subject? What information needs to be included?**
- **Context:** **What is expected in the discipline for this type of document?**
- **Audience:** **To whom is the document written? How will it be used?**
- **Organization:** **How can the information be best organized? Can the information be divided into sections?**
- **Support:** **What details, facts, and evidence can be used to illustrate main points?**

Example of quality levels - Content

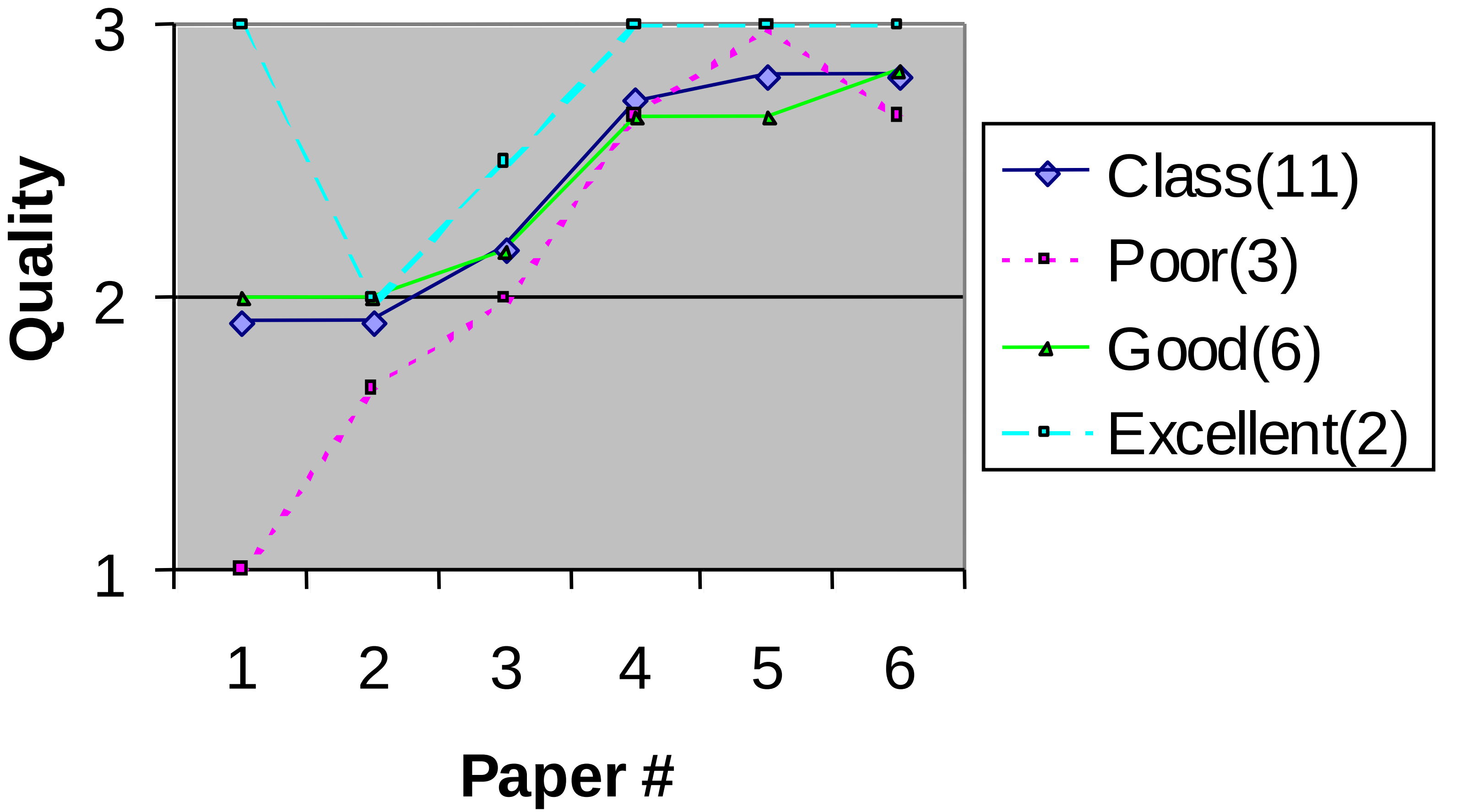
	Excellent	Good	Poor
Addresses content accurately and thoroughly	Includes accurate and complete technical information, including equations, explanations, theorems, and data.	Includes accurate technical information, but has missed some important information.	Does not include accurate or complete information.
Score	3	2	1

Content



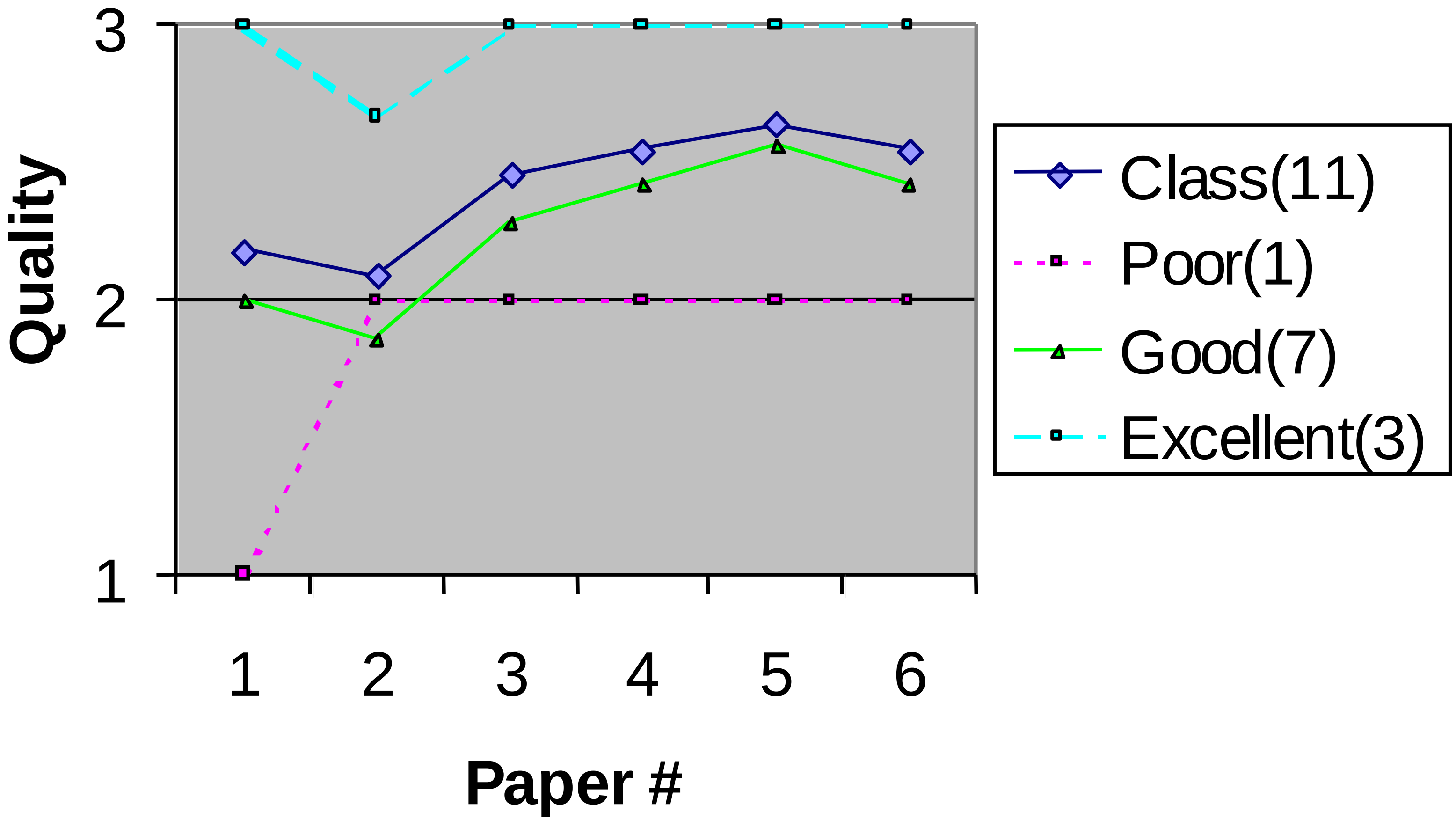
All necessary information included

Context



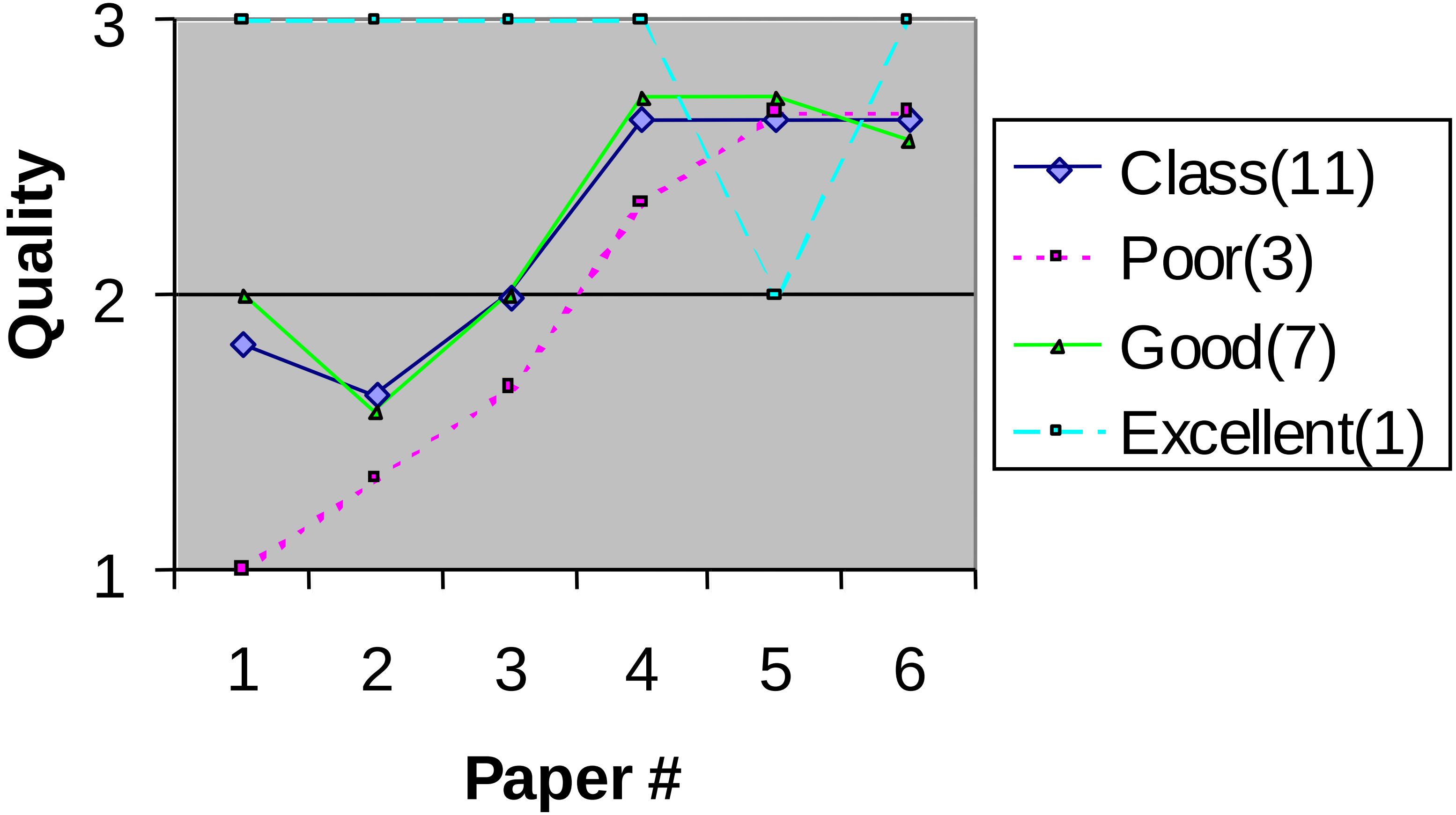
Appropriate structure for a short technical report.

Audience



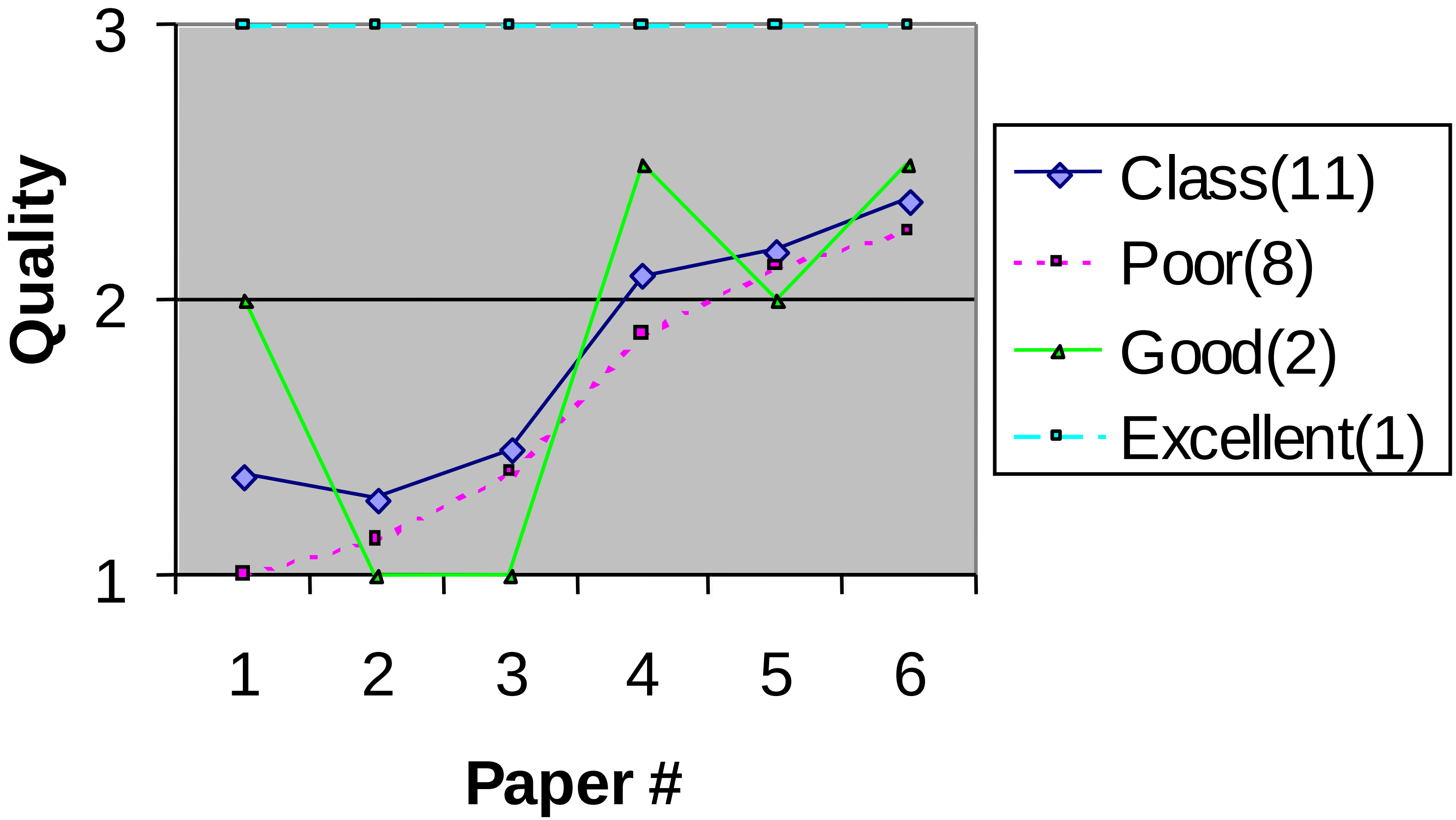
Appropriate level to communicate with introductory physics students.

Organization



Logical organization for this material.

Support



Relevant details, facts, and evidence be used to illustrate main points.

Discussion

Students of at all initial levels improved in each of the criteria

- Student groups that initially averaged poor or good reached approximately the same quality by the end of the semester
- Identifiable increases in quality apparent by 3rd or 4th report
  - content, context, audience, & organization
- Slower increases in quality of support (primarily physics)
  - majority of students only slightly higher than "good"

First-year Implementation 1997

Does Introduction of Computers Lower Student Achievement?

- For 3 of the 5 lecture sections, randomly assigned half of students to computerized labs (N ~ 200 each)
- Extensive TA training, but with minimal focus on computer use -- computer use training as needed
- Continual improvements of software
- Lab problems kept as close as possible to traditional lab problems

Force Concept Inventory (FCI) First-year Implementation (1997)

	NO COMPUTERS		COMPUTERS	
	Men (N=130)	Women (N=53)	Men (N=152)	Women (N=53)
% Pretest	47 ± 2	35 ± 2	52 ± 2	32 ± 2
% Posttest	72 ± 2	61 ± 2	74 ± 2	54 ± 2
Norm. Gain	49 ± 2	42 ± 3	50 ± 3	34 ± 3

Test of Understanding Graphs - Kinematics (TUG-K) and Problem-solving Grades (1997)

	NO COMPUTERS		COMPUTERS	
	Men (N=122)	Women (N=46)	Men (N=121)	Women (N=49)
TUG-K				
% Pretest	55 ± 2	43 ± 3	62 ± 2	45 ± 3
% Posttest	74 ± 2	65 ± 3	79 ± 2	64 ± 3
% Final Probs	53 ± 1	51 ± 2	55 ± 2	51 ± 3

Survey Results
1st-Year Implementation (1997)

Survey Statement	NO COMPUTERS (N=168) % Agree	NO COMPUTERS (N=168) Neutral	COMPUTERS (N=172) Agree	COMPUTERS (N=172) Neutral
helped me understand concepts	50	26	49	28
time well-spent learning	38	33	51	30
TA gave useful help when stuck	79	12	65	16
look forward to using . . .	16	27	47	33

	% Often/A. Always	Often/A. Always
discuss equipment difficulties	53	32
discuss physics	39	48
communicated well	64	67

Second-year Implementation

Planned Changes:

- ALL lecture sections -- 724 students, 31 TAs, 6 lecturers
- More focused TA training on computer use in labs
- Additional information in TA handbook
  - different grouping guidelines for lab, discussion section
  - different seating arrangements
  - what to watch for when monitoring groups
- Mentor TAs knowledgeable about labs

Problems:

- Large scale implementation
- Late delivery of essential equipment
- Increased sizes of lab sections (N~18 students each section)

FCI Results for Computerized labs

	1997 Men (N=152)	1997 Women (N=53)	1998 Men (N=468)	1998 Women (N=137)
% Pretest	52 ± 2	32 ± 2	50 ± 1	34 ± 1
% Posttest	74 ± 2	54 ± 2	72 ± 1	60 ± 1
Norm. Gain	50 ± 3	34 ± 3	46 ± 1	39 ± 2

TUG-K Results for Computerized Labs

	1997		1998	
	Men (N=121)	Women (N=49)	Men (N=92)	Women (N=25)
% Pretest	62 ± 2	45 ± 3	61 ± 2	50 ± 4
% Posttest	79 ± 2	64 ± 2	74 ± 2	69 ± 4

Student Opinion of Context Rich Problems in the Laboratory (N=100)

1. Do you think the lab activities were too easy, too hard, or just about the right level of difficulty?

too easy	just about right	too hard
9%	86%	5%

2. The written instructions in the lab manual were designed to guide your group in making decisions, without explaining how to conduct the lab. Do you think the written instructions provided too much guidance, too little guidance, or just about the right amount of guidance?

too little	just about right	too much
33%	60%	3%

Student Questionnaire (1992 & 1999)

	SA	A	N	D	SD
1. The laboratory activities were well coordinated with the lecture.	*23* 6	*64* 43	*17* 32	*12* 16	*3* 2
2. The laboratory problems helped me to understand the course concepts.	*10* 14	*64* 46	*7* 22	*16* 12	*3* 5
3. Working with the same group in laboratory and recitation sessions was useful.	*16* 19	*64* 59	*18* 18	*1* 2	*2* 2
4. Working with the same materials for at least two weeks helped me to understand the material.	*15* 10	*64* 54	*16* 28	*3* 6	*3* 2
5. Comparing our prediction equation to our collected data helped me understand the relationship between our graphs and the observed motion.	11	56	24	6	3

1992 one algebra-based class (n = 135)
1999 four calculus-based classes (n = 450)

Student Questionnaire 1999 (N = 400)

Rate the following components of the course using a scale from 1 to 10, with 10 being extremely useful and 1 being completely useless in helping you learn physics in this course.

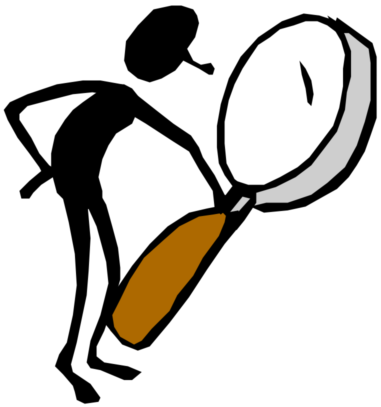
1.	Textbook	6.6 ± 0.13
2.	CGPS Discussion Sessions	6.5 ± 0.13
3.	Homework (not graded)	6.4 ± 0.14
4.	Lectures	6.1 ± 0.13
5.	Quizzes and Exams	6.1 ± 0.12
6.	Laboratory	5.5 ± 0.12
7.	Material on Class Web Pages	5.3 ± 0.14
8.	TAs in Room 140	4.6 ± 0.14
9.	Tutors in Lind Hall	4.2 ± 0.14
10.	Lecturer’s Office Hours	3.9 ± 0.12

Survey Results for Computerized labs

	1997 (N=172)		1998 (N=590)	
	% Agree	Neutral	Agree	Neutral
helped me understand concepts	49	28	55	22
time well-spent learning	51	30	47	29
TA gave useful help when stuck	65	16	73	13
look forward to using . . .	47	33	25	40

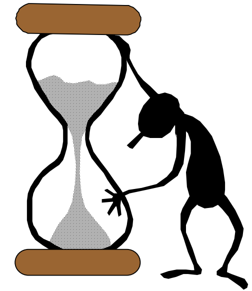
	% Often/A. Always	Often/A. Always
discuss equipment difficulties	32	33
discuss physics	48	48
communicated well	67	70

Observation data



- Several students were hired to observe the introductory calculus-based labs
- Observed 10 sections for 5 weeks
- Observers sit in lab by one group with a coding sheet
- Every minute, observe group, code interactions
- Many different codes available

Expected Lab Time



Predictions and discussion (whole-class) 15 min. (~13%)

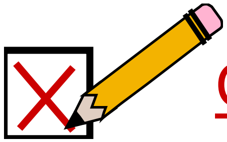
Start the lab problem:

Problem 1	Exploration & Measurement	15-20 min. (~15%)
	Analysis	10-15 min. (~10%)
	Conclusion	5-10 min. (~6%)
Problem 2	Exploration & Measurement	15-20 min. (~15%)
	Analysis	10-15 min. (~10%)
	Conclusion	5-10 min. (~6%)

Closing discussion 20 min. (~17%)

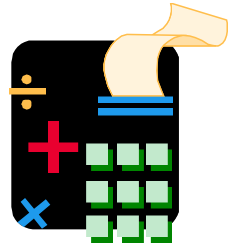
Total Time Spent: 115 min. (100%)

Observation Codes



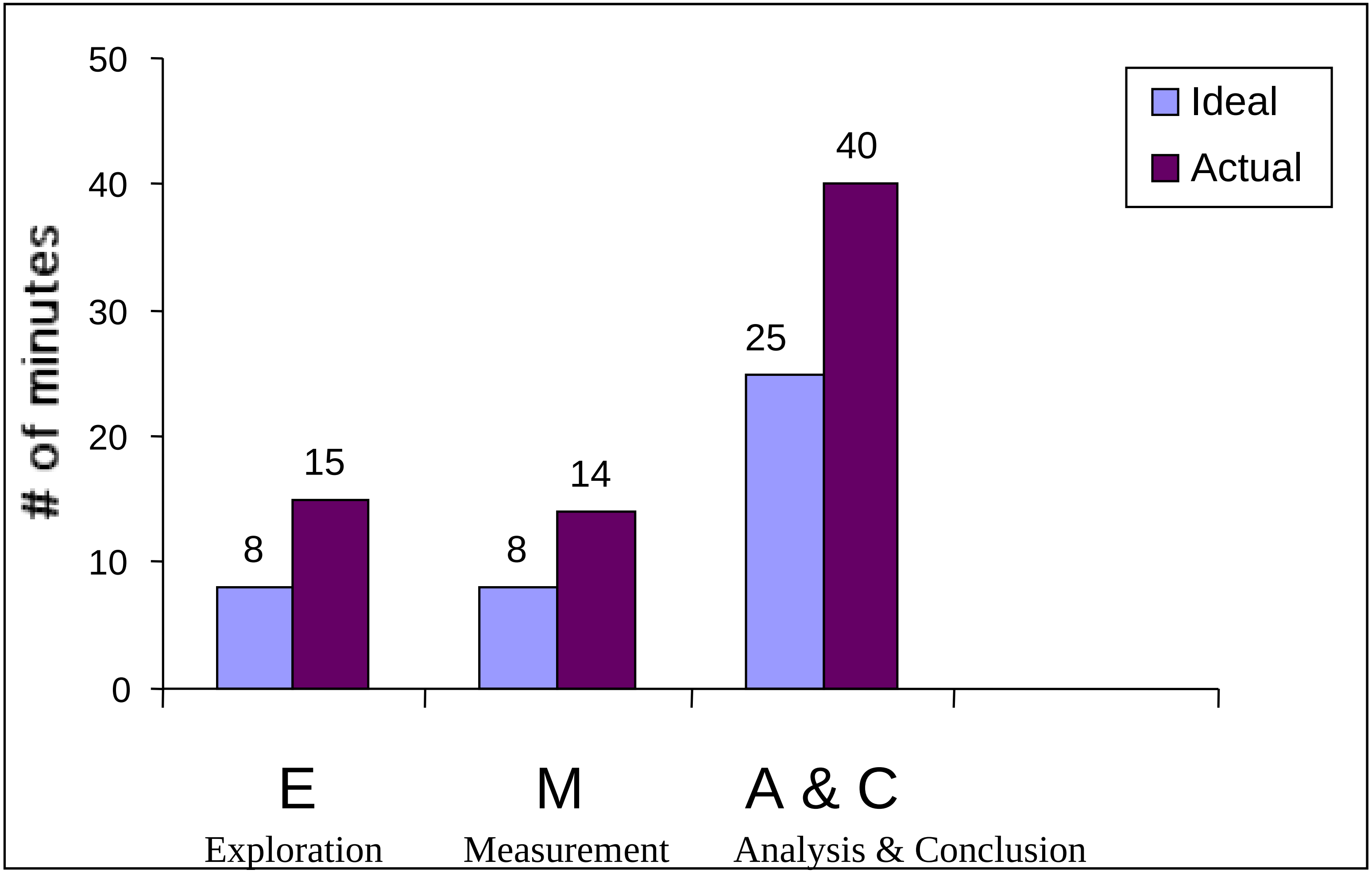
Code	What it Sounds Like
Social/off-task:	**"How did you do on the test?"**
Equipment talk:	
- **Exploring:**	**"How does this look?"**
- **Management:**	**"Move that over there." "Go get a cart."**
Taking data:	**"Take a picture now." "Let the cart go."**
Analyzing data:	**"I think this equation is the right one."**
Management talk:	
- **Group:**	**"Who's writing this down?"**
- **Task:**	**"We only have ten minutes left."**
Talking physics:	**"I think that's acceleration, not velocity."** **"What about friction in our case?"**

Some Results



	Ideal	Actual
Time spent working on problems	80 min	67 min
Number solved problems	2	1
What do groups talk about? ◆Social Talk ◆On task lab talk	 5% 95%	 9% 91%

How much time do students spend in the different parts of a single problem?



What do students talk about?

Equipment		**18%**
• Figuring it out	(11%)	
• Working with it	(7%)	
Taking data		**10%**
Analyzing data		**31%**
Management		**15%**
• Task management	(15%)	
• Group management	(0%)	
Talking to the TA		**9%**
Talking physics		**6%**

Conclusions

- Lab time is spent solving the problem—not talking about the football game
- Too much time is spent on each problem, mostly in analysis
- Little physics talk among the groups

Conclusion

Given a cooperative-group problem solving pedagogy that yields stable, high gains on standardized conceptual tests, the careful implementation of computer measurement and analysis tools in the laboratory did not change student achievement.

NEXT PHASE:

Is it possible to use the new computer tools to target explicit student difficulties, resulting in a higher level of student achievement?