Inquiry Based Science Education, manipulating equipment or manipulating ideas?

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School Science

Knowledge: Concepts, theories, models

Methodology: Creation and validation of knowledge … INQUIRY

What is Inquiry in the Classroom?

Students

- raise questions
- plan and carry out investigations
- gather and interpret data
- draw conclusions and develop models based on evidence
- try to explain what they find, arguing and reasoning
- communicate findings and methods

What is more important?

Manipulation of ideas

or

Manipulation equipment

Minds-on ? Hands-on

Typical school laboratory

(USA 1981, 1996) Seldom are students asked to:

a. formulate a question to be investigated;

b. formulate an hypothesis to be tested;

c. predict experimental results;

d. work according to their own design;

(UK 2008) The teachers' focus in these lessons was predominantly on developing students' substantive scientific knowledge, rather than on developing understanding of scientific enquiry

Traditional Pendulum Experiment (Version I)

Length	10T	T	$T = 2\pi\sqrt{l/g}$
40 cm			
60 cm			
80 cm			
100 cm			
120 cm			

Pendulum Version II

- Make a plan for an experiment to "proof" that:

$$T = 2\pi\sqrt{l/g}$$

  - What will you vary?
  - What will you measure and how?
  - Design a table to record your data.

Designing experiments to verify formulas

- Lenses: $\frac{1}{f} = \frac{1}{s_{object}} + \frac{1}{s_{image}}$
- Mechanics: $\Sigma F = m.a$
- Electric circuits: V/I = constant (Ohm's law … V/I = R)
- Etc.

Pendulum Version III

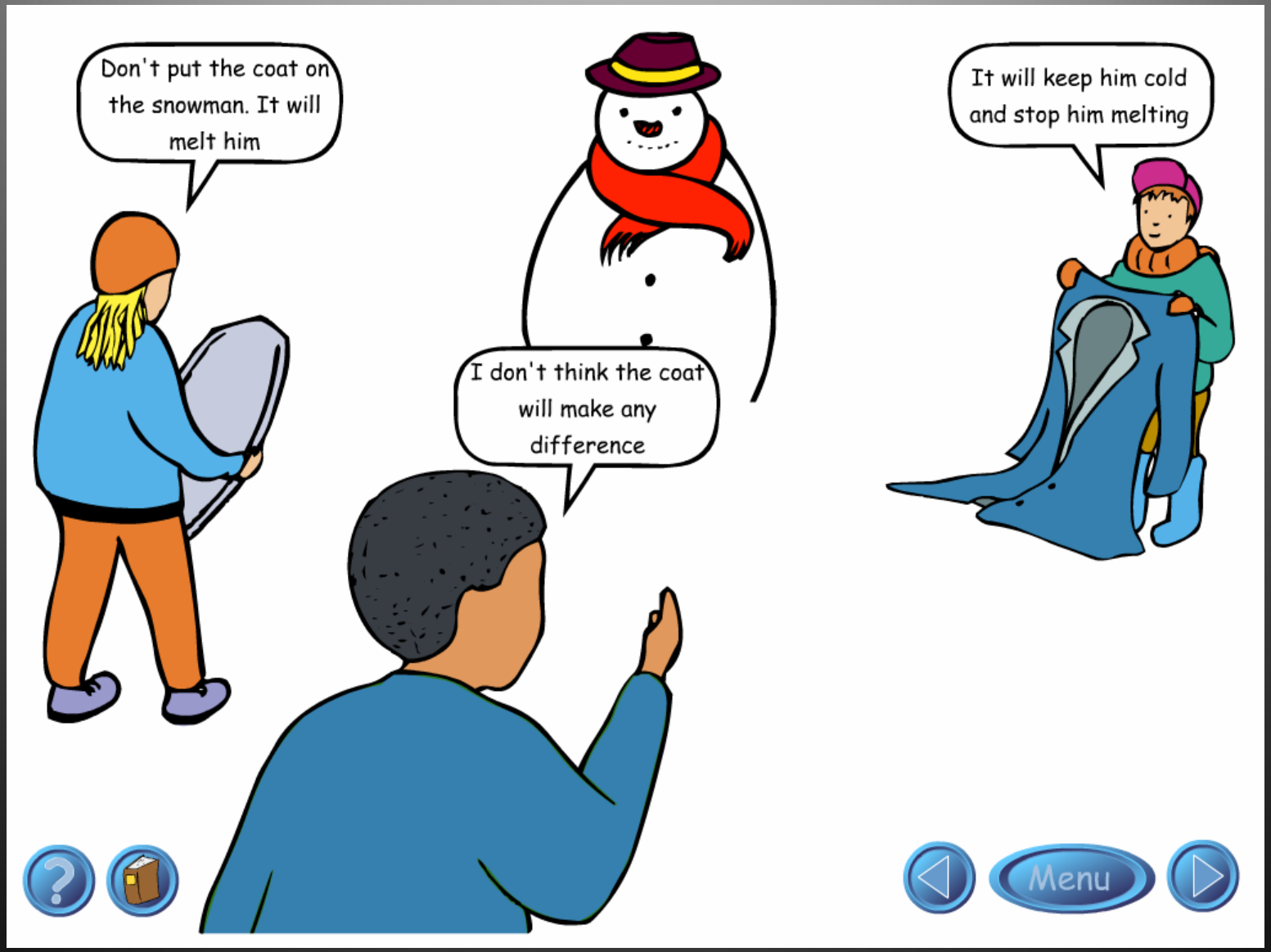
A. Make a pendulum. For your pendulum, is T constant or does it change over time?
   1. How do you find out?
   2. How can you measure *T* precisely?

B. Different pendulums, different *T*. Which factors influence *T*?
   1. Choose 1 factor, how does it influence T?
   2. Design an experiment to find out.
   3. Execute the experiment.

Phases of Inquiry

I. Asking questions, designing experiments
II. Collecting observations and measurements
III. Analyzing and interpreting data, concluding, reporting

All aspects of inquiry: Snowman



World of Ideas

World of Objects

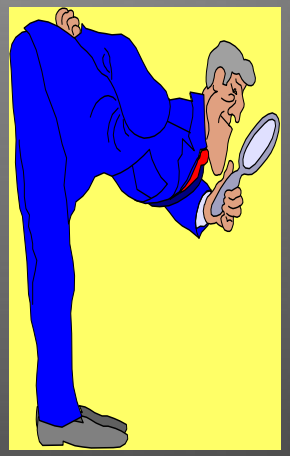
Theories

Concepts

Relationships

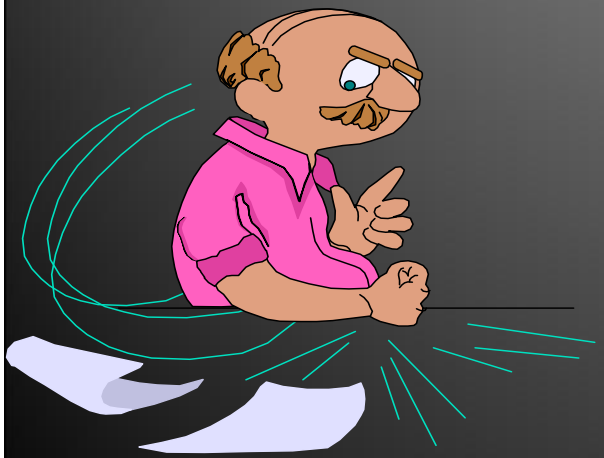
Phenomena

Observations



Experiments

Measurements



World of Scientists

Playing around theories, concepts, ideas, ……consensus?

What is more important?

Manipulation of ideas

or

Manipulation equipment

Minds-on ? Hands-on

Research

- Tamir & Lunetta (1981)
- Germann et al (1996)
- Abrahams & Millar (2008)

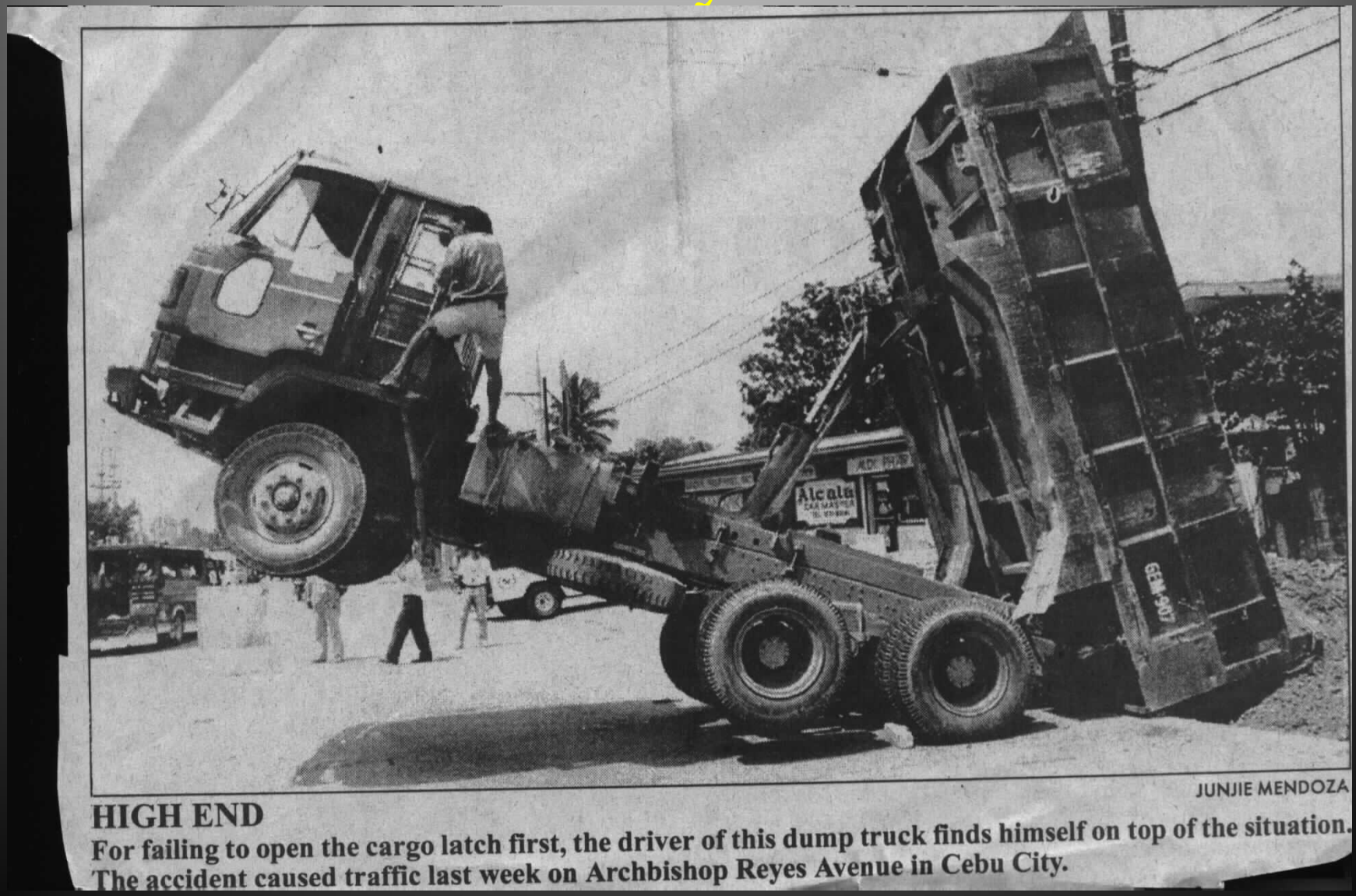
Connecting Phenomena with Concepts

Center of Mass Demonstrations

More demo’s

And more

It does not happen only with donkeys….



JUNJIE MENDOZA

HIGH END

For failing to open the cargo latch first, the driver of this dump truck finds himself on top of the situation. The accident caused traffic last week on Archbishop Reyes Avenue in Cebu City.

Sometimes it works well!

Planning and Designing Experiments

1.1 Formulating research question/problem

1.2 Formulating hypothesis

1.3 Designing experiment (independent, dependent variables, controls, values)

1.4 Designing operational definitions

1.5 Predicting results

Executing experiments

2.1 Observing, measuring

2.2 Manipulating equipment

2.3 Recording results

2.4 Calculating

2.5 Explaining or deciding experimental techniques

2.6 Working according to own design

Analysis and Interpretation

3.1 Transforming data into standard form (tables)

3.2 Determining relationships (including graphs)

3.3 Discussing precision

3.4 Discussing limitations/assumptions

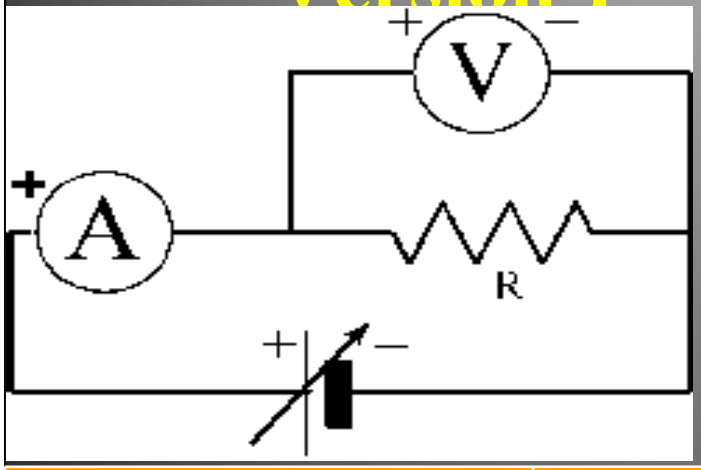
3.5 Formulating generalizations

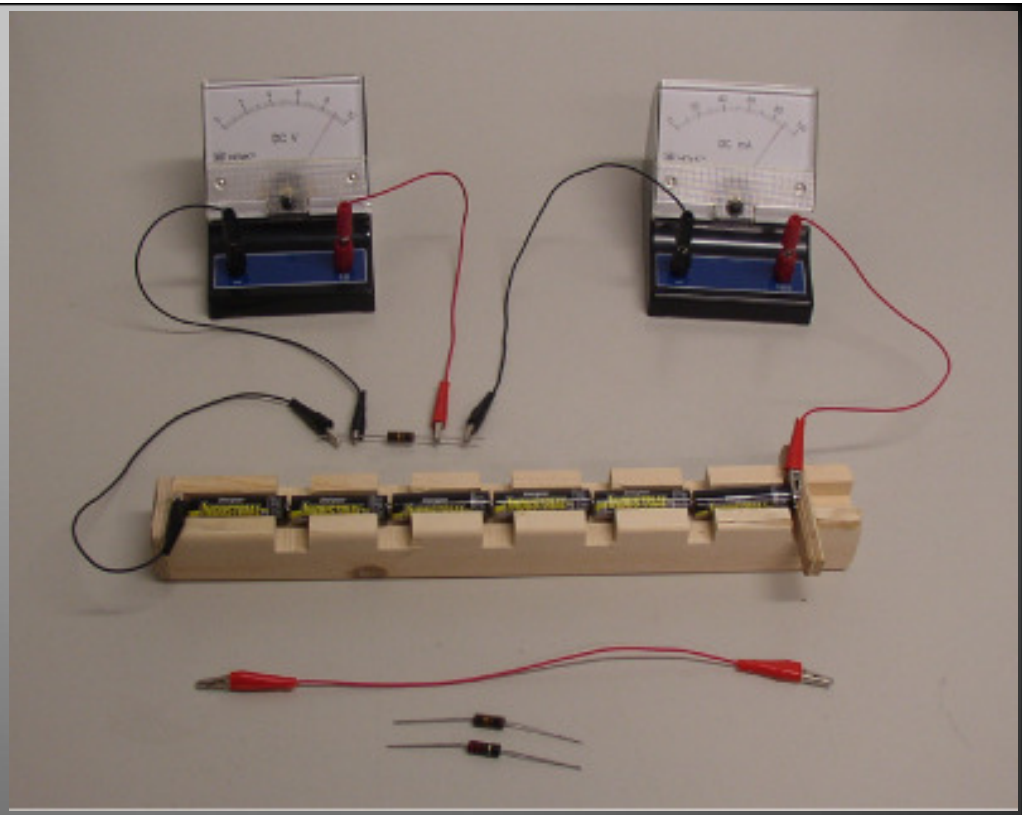
3.6 Explaining relationships

3.7 Formulating new questions/problems

Ohm's Law: V/I=constant

Version 1





Voltage (V)	Current (I)	V/I
0		
3		
4		
6		
8		
10		
12		

Ohm's Law version 2 Inquiry

- Ohm's Law: V/I = constant V: Voltage, I: Current
- Make a plan to verify this experimentally
  - What are you going to vary? What will you measure?
  - Which equipment do you need?
  - Draw the circuit you will use.
  - Design a table for your data.

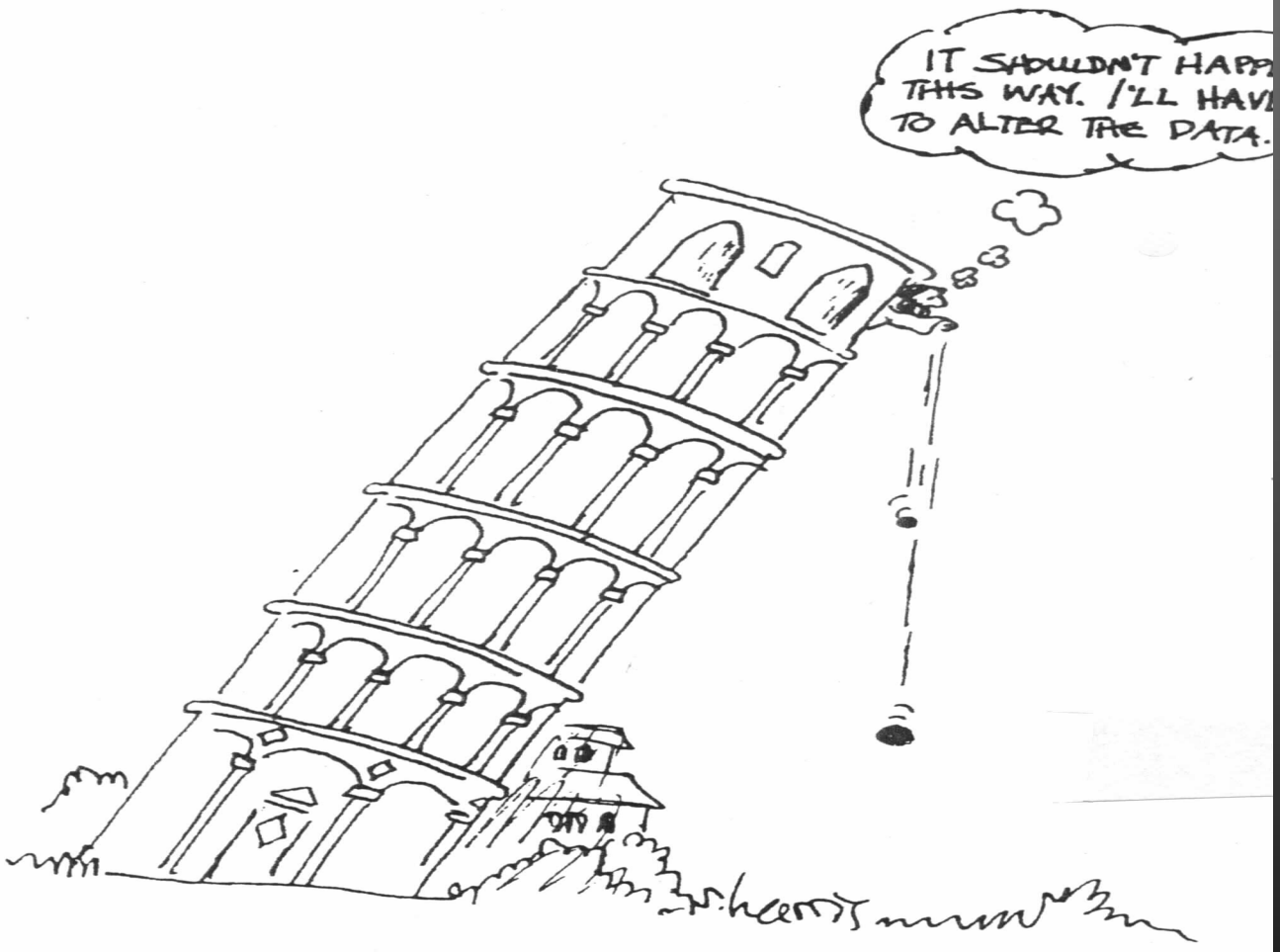
Ohm's Law version 3: Understanding

- Part 1: Guided discovery experiment such that V/I = constant becomes a discovery
- Part 2: Then follow-up with an experiment where V/I is not constant such as with a light bulb or a diode.

Example 2:

- Put part of the instructions in the wrong order. The first task of students is to put them in the proper order. That requires them to think deeply about what they are going to do…….minds on!

Galileo: It should not happen this way, I will have to alter the data.

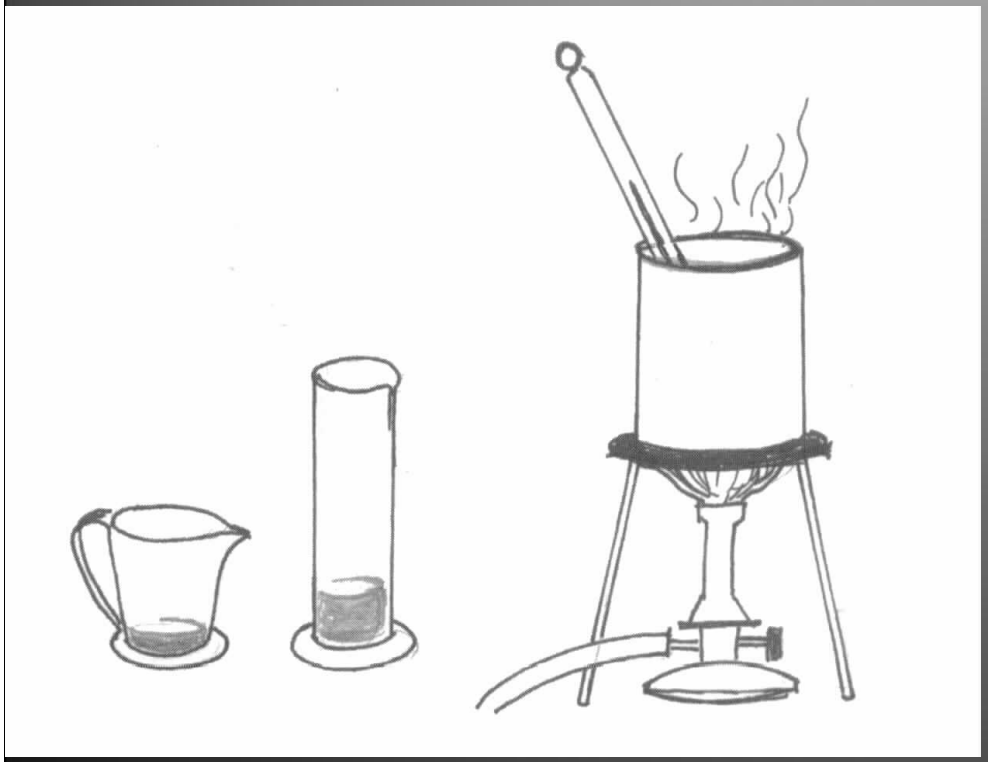


Meaning Making Tools

- P(E)OE: Predict-Explain-Observe-Explain experiments create awareness, but not yet conceptual change
- Sophisticated lesson sequences
- Models, analogies
- Metacognitive tools

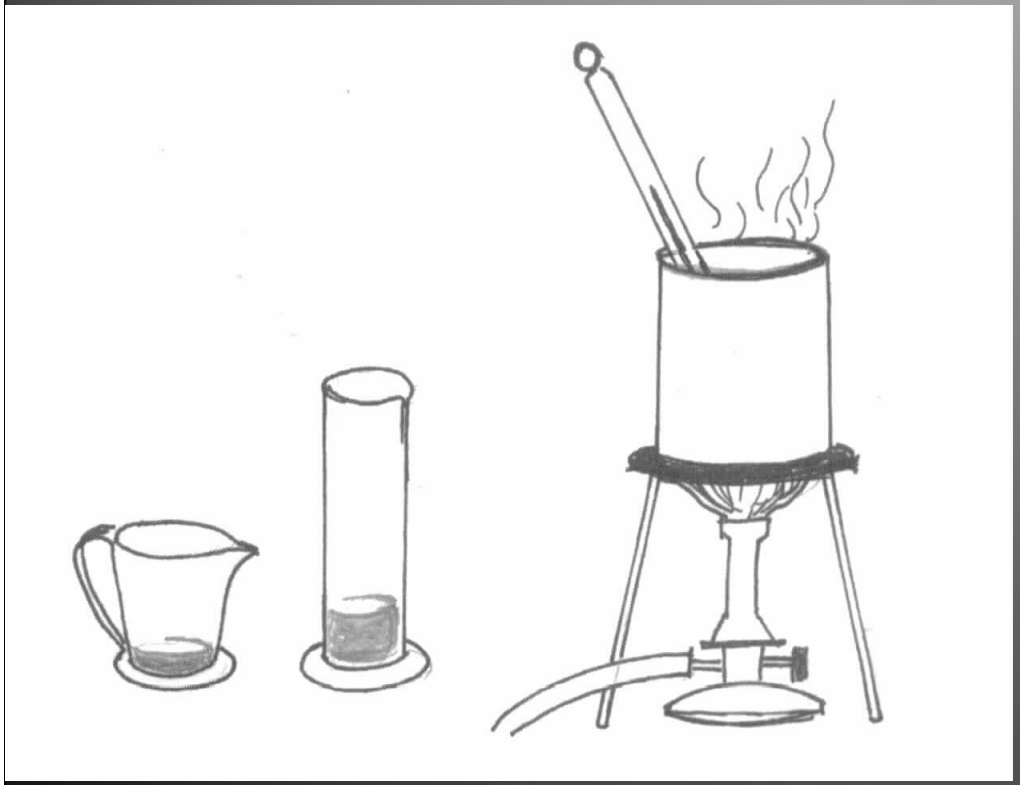
But these tools are difficult to use by teachers

Hands-on



Heat the water, measure the temperature every 30 seconds

Minds-on (!)



1. When it boils, add 200 ml cold water.
2. WATCH OUT: The temperature should NOT go above 110 ^{o}C!

Investigation/Research Skills

- Research requires:
  - Planning (research question, theory, design of experiment)
  - Execution (equipment, measurements)
  - Analysis and interpretation
- Students should get experience with all three and not only with measuring.

Research Results

Classifying of laboratory instructions of many different textbooks and lab manuals:

Most common: observation, measurement, manipulation of equipment, making of table, simple computations.

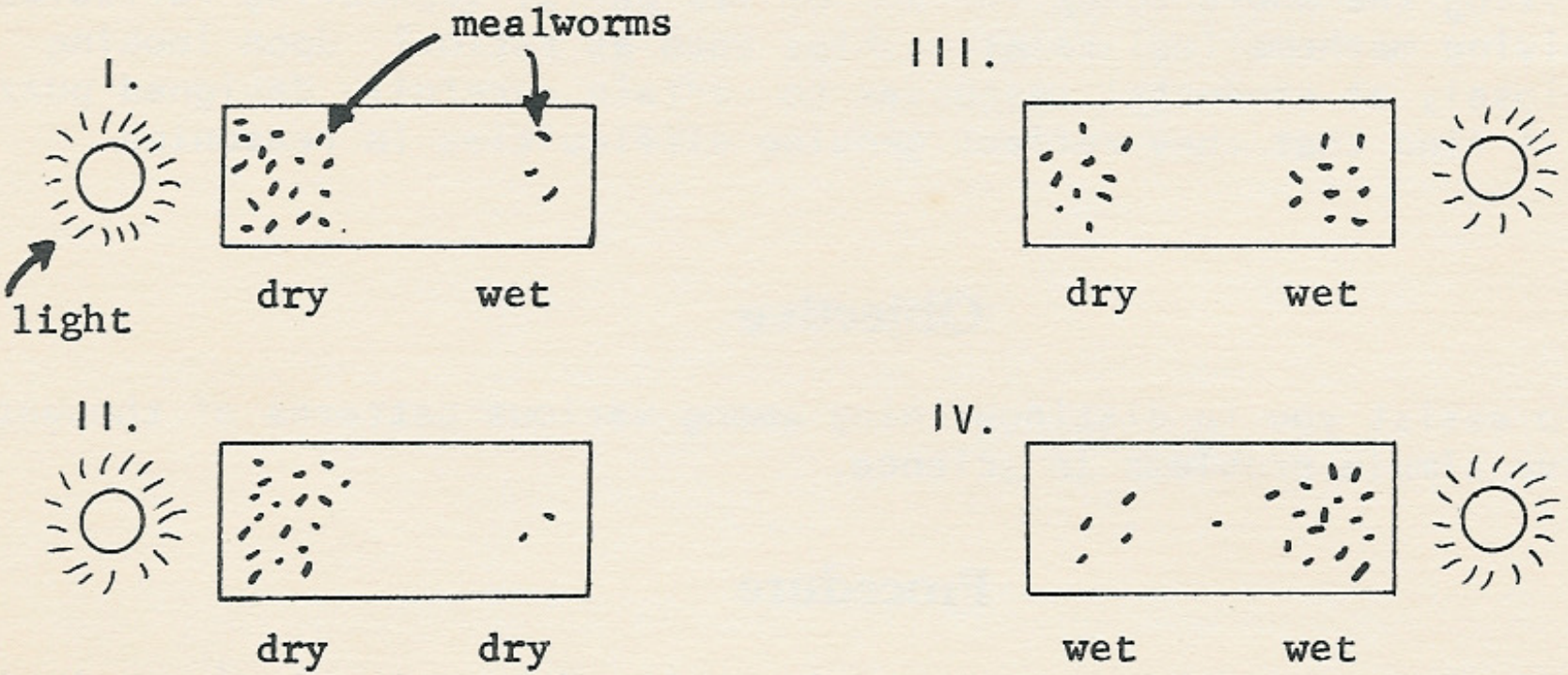
Least common: Planning & Design, Interpretation, linking the two worlds

Examples of Inquiry Activity

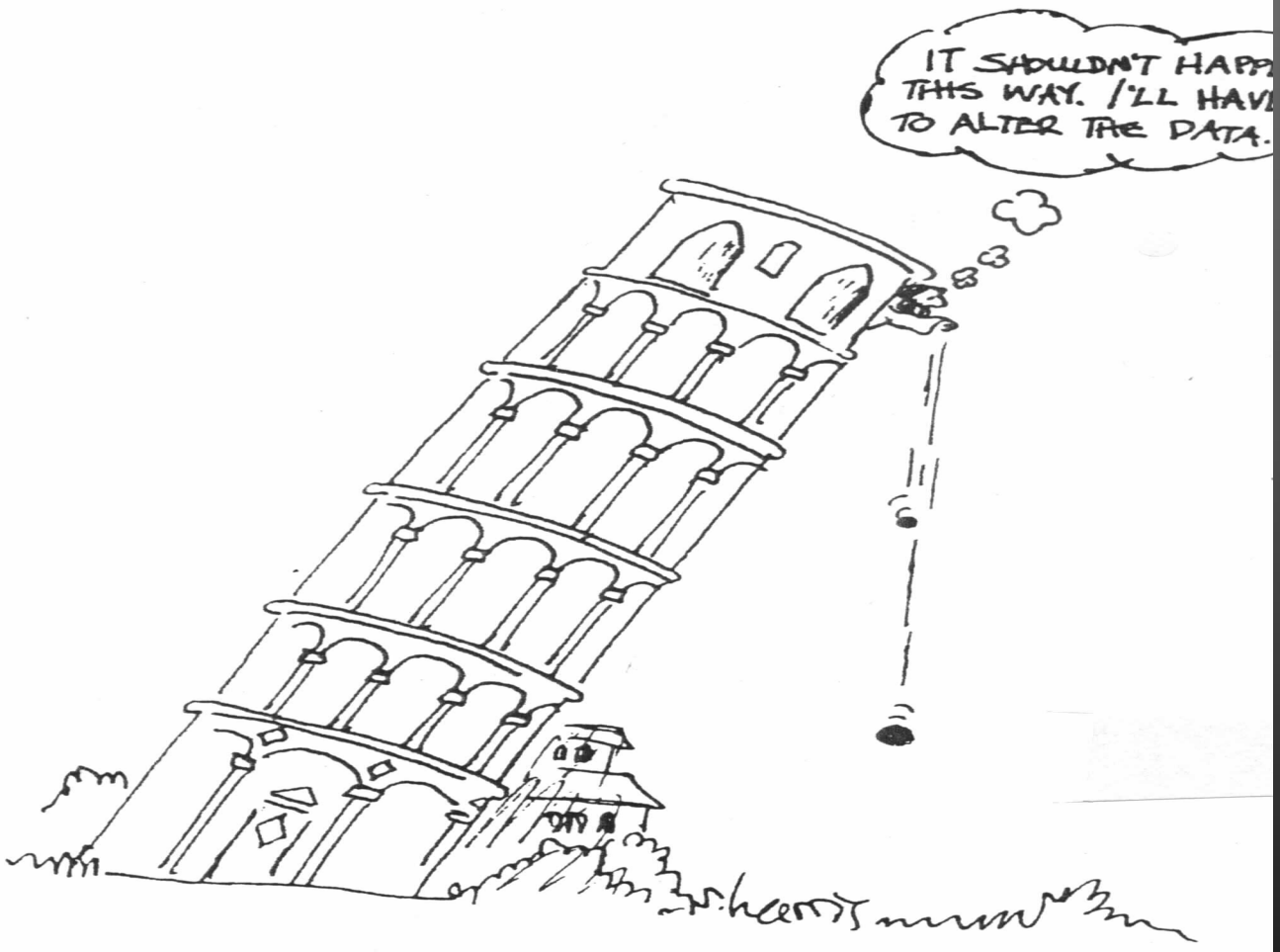
- See OHP
- See demo
- “Measure power of candle”

Suggestions Inquiry Lab

- Choose the inquiry skills to be emphasized
- Consider other options than lab
- Practice prerequisite lab skills separately
- Room for variability between students
- Check instructions versus list of skills
- Guidance, assessment


I.
mealworms
light
dry
wet
II.
dry
dry
III.
dry
wet
IV.
wet
wet

Galileo: It should not happen this way, I will have to alter the data.



Sometimes:

- Put some instructions in the wrong order and let students start with finding the proper order of instructions and why …….minds on!

Lab observed: unclear goals

Tasker and Lambert (1981) in New Zealand:

Observer joins a group of three boys: *This looks interesting*.

Student: *Yeah, we have to … fill the beaker to 150 … then um … get 5 ml of salt, then we put it in here (indicating the beaker of water) and then we put it on there (touching the gauze on the tripod) – then we have to take the heat.*

Observer*: I see and what's it all about?*

Student: *I dunno – we just have to do it and get the graph.*

Investigation Projects

- Vague question/problem
- Narrow down, make researchable
- Use literature and theory, play with equipment
- Design experiment:
  - Variables involved, design
  - operational definitions
- Pilot experiment…corrections to design/objectives
- Data collection, reporting

Task: Example of Investigation

Determine the energy output per second of a candle (power of a candle)

- What will you measure?
- Which concepts are involved?
- Sketch a set-up
- What problems do you expect?
- What assumptions are you making?

Lab course

- Decide goals, spread labs across goals
- Set clear and simple lab objectives
- Lab activity, demonstration or other?
- Check student awareness of objectives
- FORCE minds-on through written and oral questions
- Pre- and post lab discussion
- Report? May be not?

Linking Theory and Experiment

- Pre-lab discussion
- Conceptual questions in worksheet
- Conceptual questions of teacher
- Post-lab discussion before the bell rings

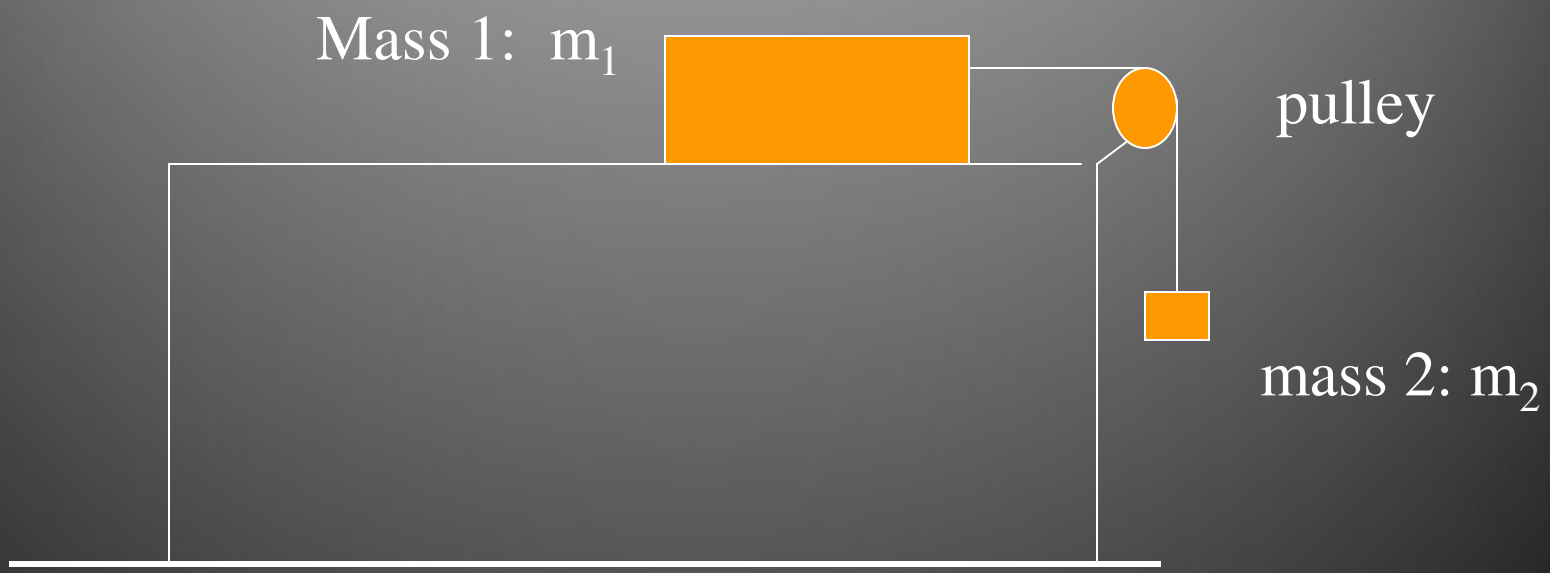
Summary

- Distinguish lab types (concept, etc.)
- Check consistency of goals versus instructions, guidance, assessment
- Use appropriate classroom management (trivial but difficult)
- Let all teaching be guided by linking the worlds of experience and ideas

THANK YOU

Choice of Experiments

- Verification of Newton's $\Sigma F = ma$



$$\Sigma \boldsymbol{F} = m_2 g - \text{friction} = (m_1 + m_2).\boldsymbol{a}$$

Conceptual Problems of Students

- Distinguish acceleration from velocity
- Distinguish force from momentum
- Friction as a force
- Difference between $\Sigma \boldsymbol{F}$ and any force
- NOT whether or not Newton's Second Law is true
- Additional problem: usually poor results with error over 20%

Please notice:

- Inquiry as educational goal (experiencing and learning how knowledge is generated and validated through research).
- Inquiry as teaching method, as a way to learn concepts, not just in science, but there are many other teaching methods.