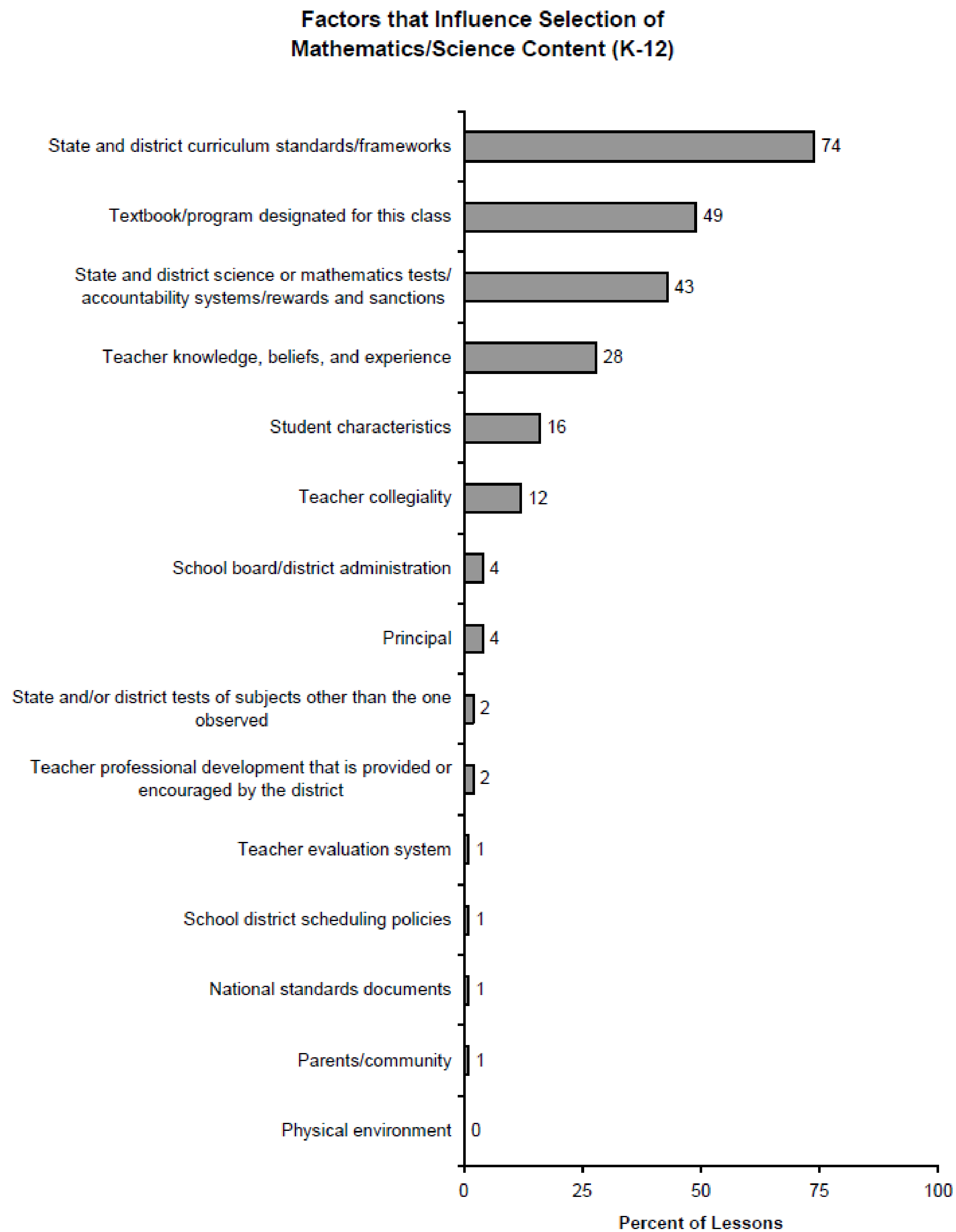
Changing the Textbook Landscape: The Impact of Inquiry-Based Science Education on Science Textbook Design, Development and Use

David Marsland

National Science Resources Center



Horizon Research, May 2003

How often are they used?

"Science teachers [in 2000] indicated that in 95% of their most recent science classes they had used a commercially published text."

Smith, PS, Banilower, E.R., McMahon, K.C. and Weiss, I.R. (2002). The national survey of science and mathematics education: Trends from 1977 to 2000.

Do the textbooks we use fit our current needs?

The skills needed to be successful competitors in the modern world economy

- A high capacity for abstract, conceptual thinking.
- The ability to apply that capacity for abstract thought to complex real-world problems—including problems that involve the use of scientific and technical knowledge—that are nonstandard, full of ambiguities, and have more than one right answer.
- The capacity to function effectively in an environment in which communication skills are vital – in work groups.

» ***Ray Marshall and Marc Tucker, Thinking for a Living***

National Science Resources Center

Smithsonian Institution ***National Academies***

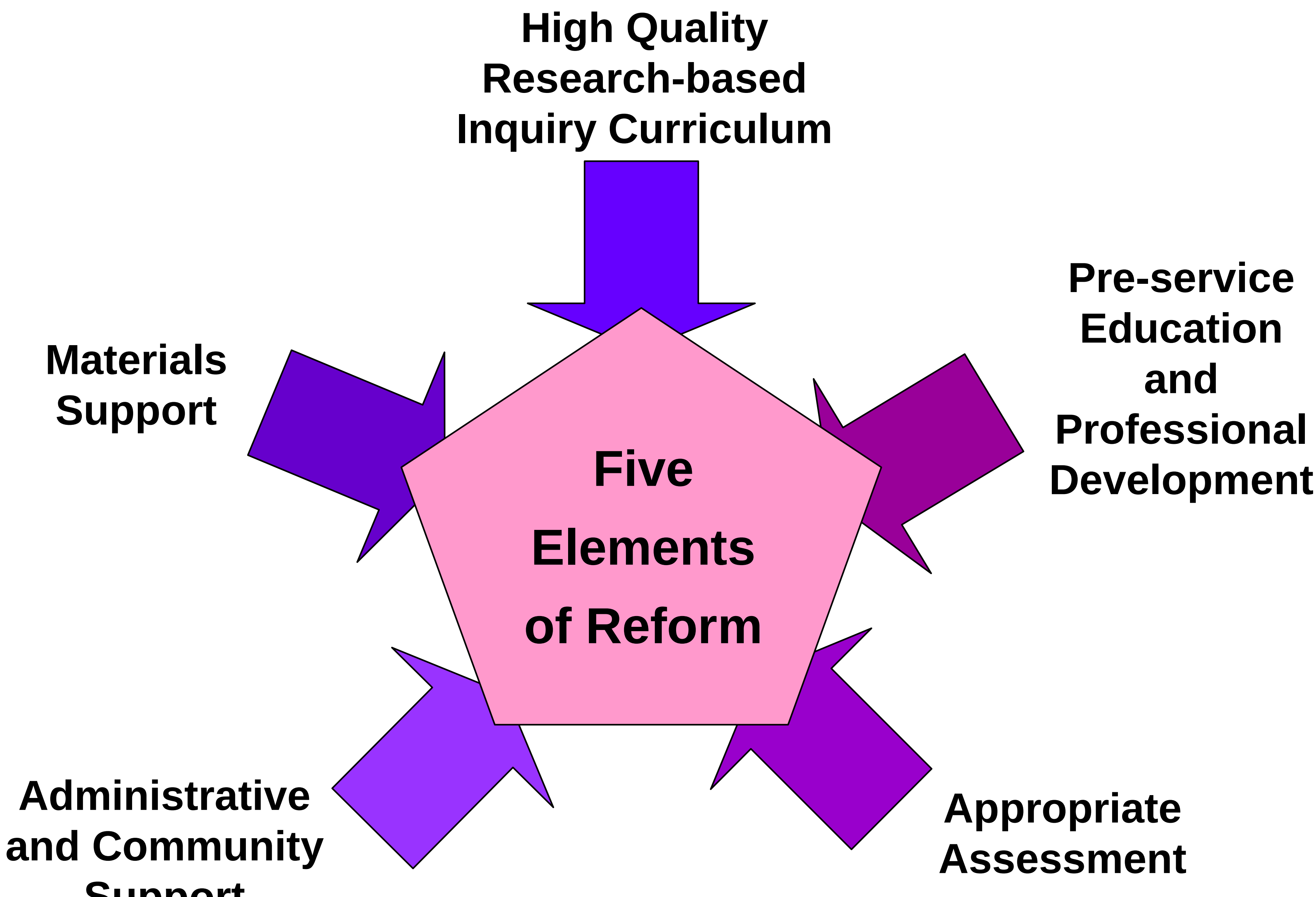
National Science Resources Center

THE NATIONAL ACADEMIES Smithsonian Institution

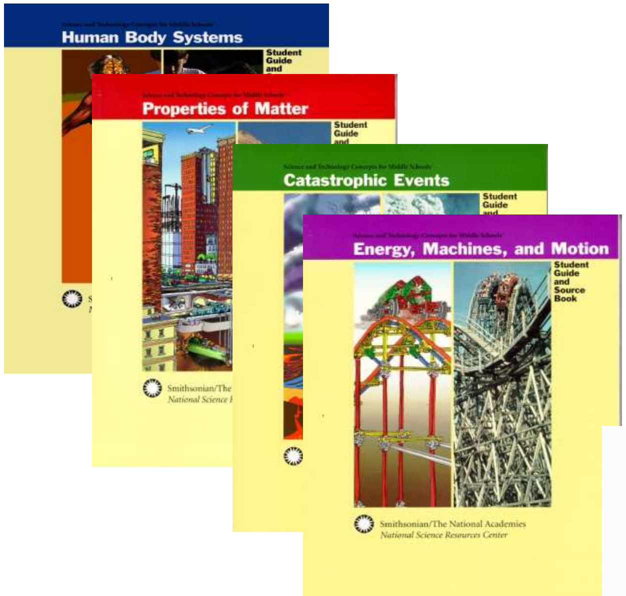
NSRC—Background

- Established in 1985 in response to concerns about the quality of U.S. science education
- Mission is to improve student performance in science in schools in the U.S. and throughout the world
- Strategy is to use the nation’s two most prestigious scientific institutions to leverage change in school districts
- Uses a reform model based on research and best practices in science education

A Strategic Approach



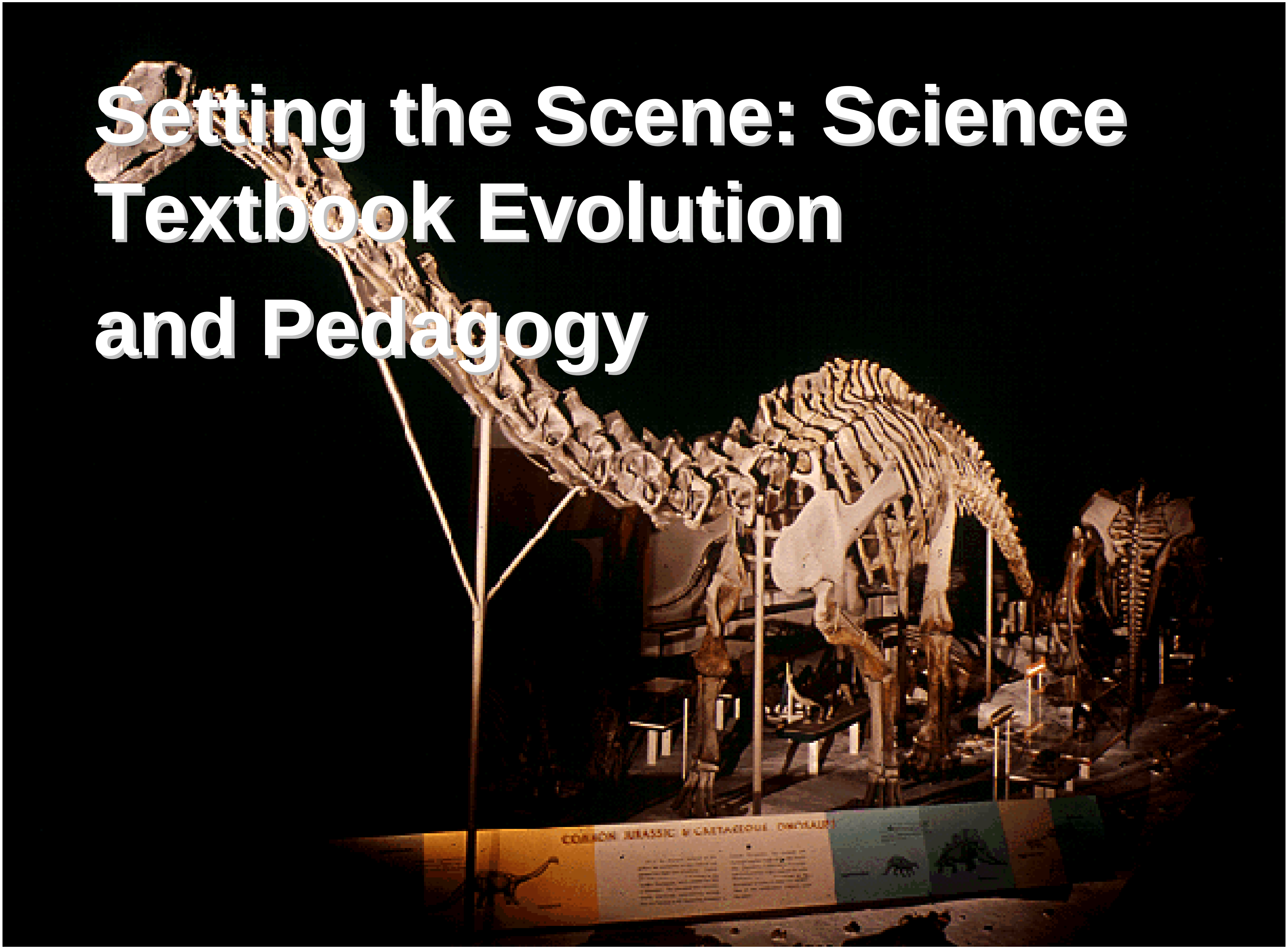
Curriculum Development



Develops and disseminates research-based science curriculum for elementary and middle schools

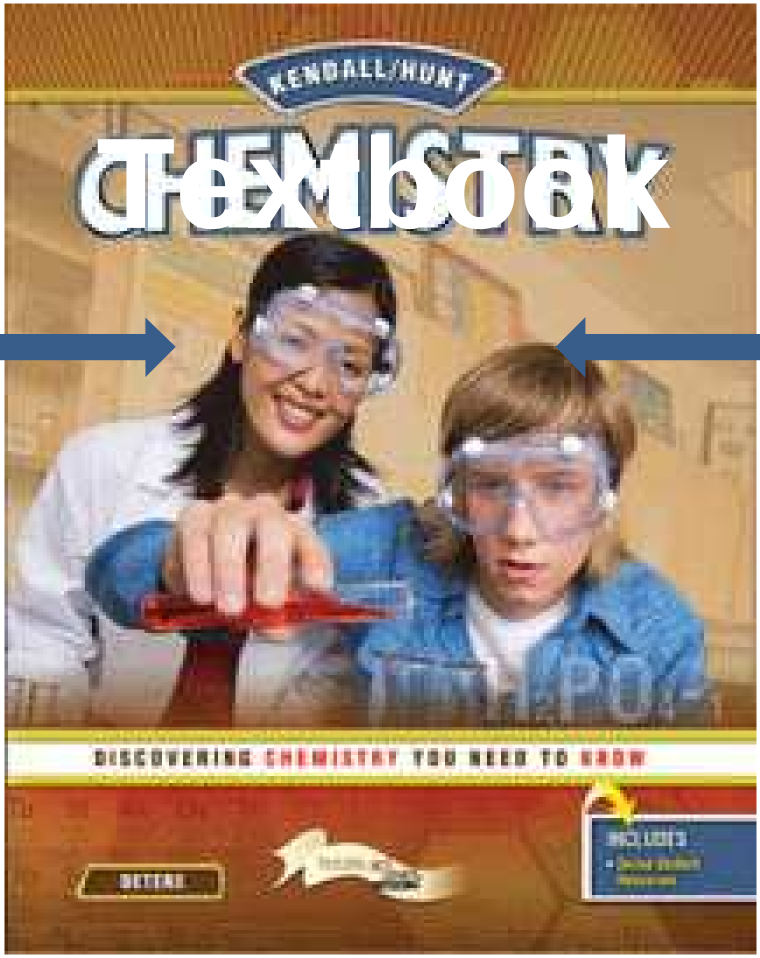

RYDER

Setting the Scene: Science Textbook Evolution and Pedagogy

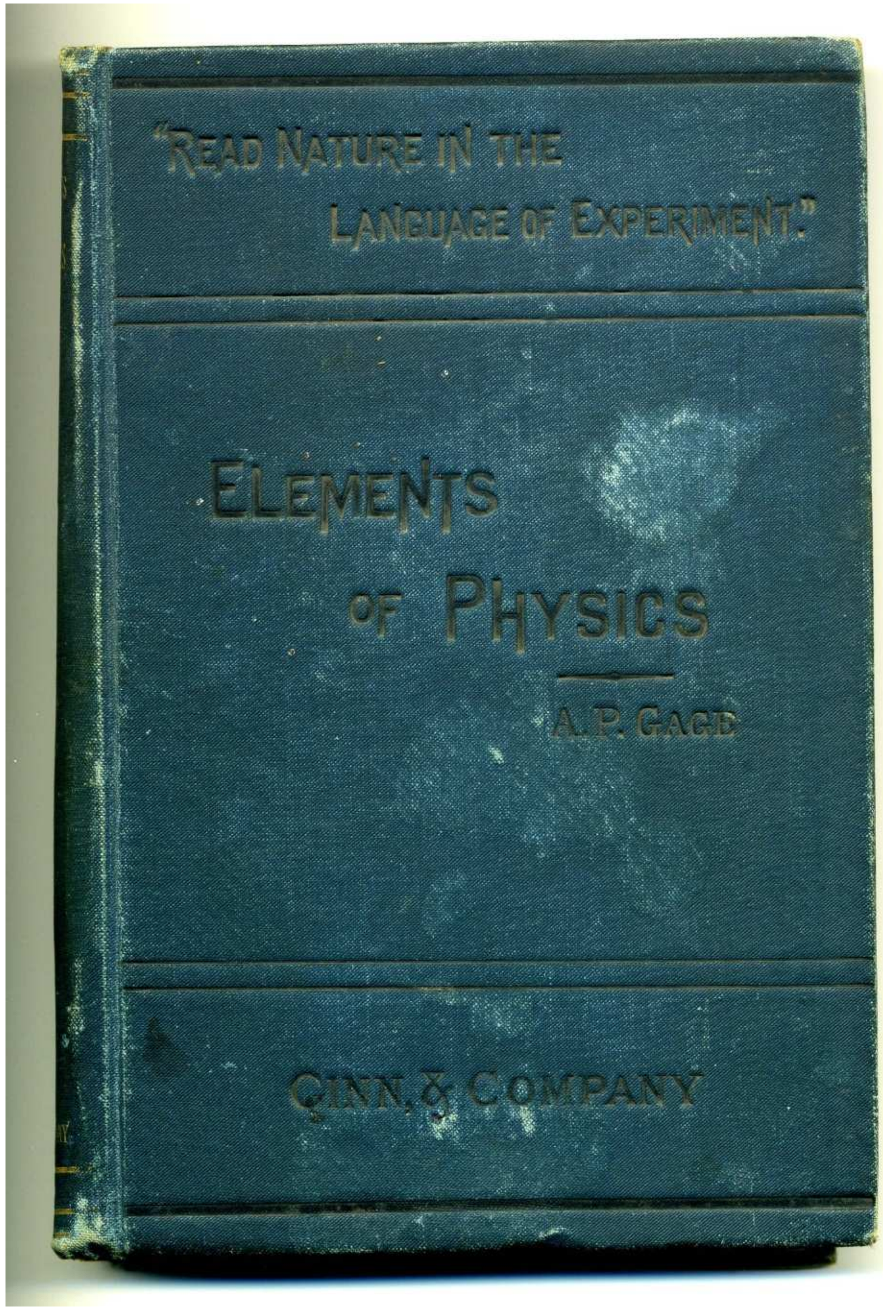


Science Content Knowledge

Textbook

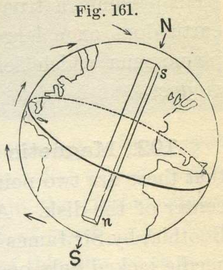


Pedagogical strategies


"READ NATURE IN THE
LANGUAGE OF EXPERIMENT."
ELEMENTS
OF PHYSICS
A. P. GAGE
GINN & COMPANY

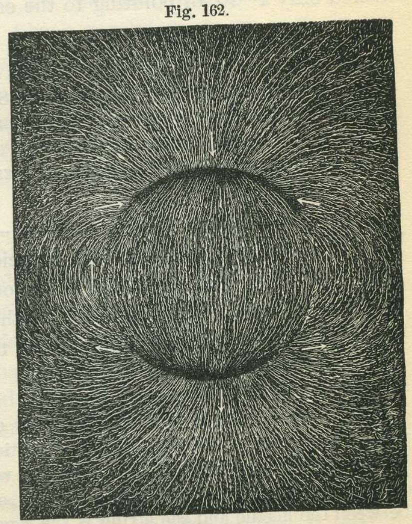
equator. A common compass needle must have the S-end loaded to keep it horizontal. Like effects are commonly attributed to like causes. These phenomena are just what we should expect if (as is very improbable) a huge magnet were thrust through the axis of rotation of the earth, as represented in Figure 161, — having its N-pole near the S geographical pole, and its S-pole near the N geographical pole; or if (as is more probable) the earth itself is a magnet.

Fig. 161.



Experiment 3. Magnetize a circular steel disk, so that its poles may be at the extremities of one of its diameters. Place it beneath a plate of glass. Sift over the glass fine iron-filings, as in Exp. 2, p. 28. Gently tap the glass a few times, so as to agitate the filings. Once in motion, they arrange themselves in lines radiating from either pole, forming graceful curves from pole to pole, as represented in Figure 162. These represent what are called *lines of magnetic force*. They represent the resultants of the combined action of the two poles. Now carry the little magnetized cambric needle around the disk. It follows the lines of magnetic force as mapped out by the filings, always assuming a position tangent to the magnetic curve, as shown in Figure 162.

Fig. 162.



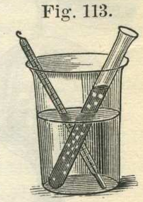
It is evident that the space around a magnet is the seat of a

XXII. EFFECTS OF HEAT CONTINUED. — LIQUEFACTION AND VAPORIZATION.

Experiment 1. Melt separately tallow, lard, and beeswax. When partially melted, stir well with a thermometer, and ascertain the melting points of each of these substances.

Experiment 2. Place a test tube (Fig. 113), half filled with ether, in a beaker containing water at a temperature of 60° C. Although the temperature of the water is 40° below its boiling point, it very quickly raises the temperature of the ether sufficiently to cause it to boil violently. Introduce a chemical thermometer[1] into the test tube, and ascertain the boiling point of ether.

Fig. 113.



Experiment 3. Half fill a glass beaker of a liter capacity with fragments of ice or snow, and set the beaker into a basin of boiling-hot water. Stir the contents of the beaker with a thermometer until the ice is all melted, observing from time to time the temperature of the contents. The temperature remains constant at 0° C. until the ice is all melted.

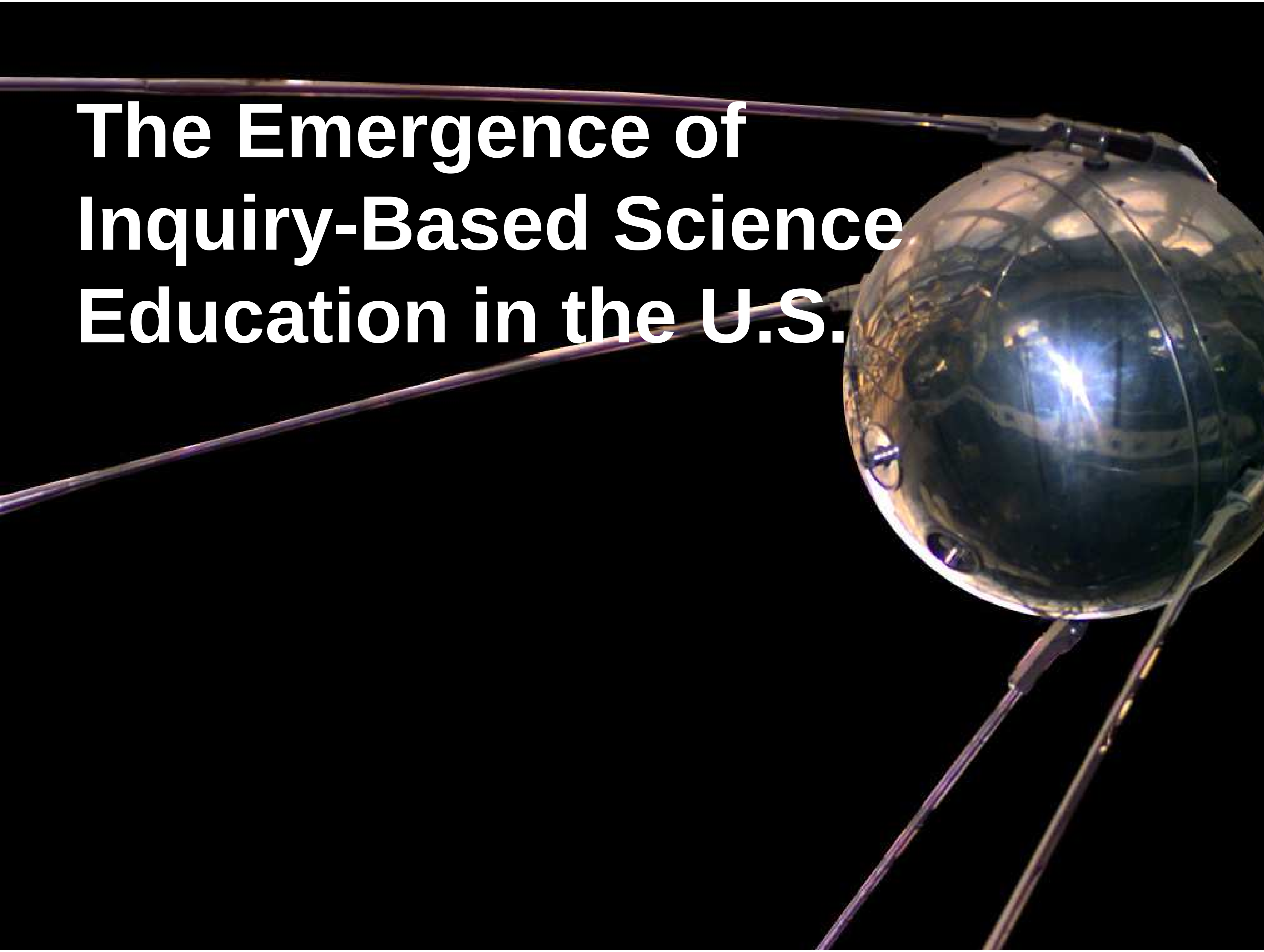
Experiment 4. As soon as the last piece of ice disappears, remove the flask from the warm water, wipe the outside, and place it over a Bunsen burner and heat. Observe that the temperature rises constantly until the water begins to boil; but after it begins to boil, the temperature remains constant as long as it boils. Place more burners under the beaker; the water boils more violently, but the temperature is not raised.

Experiment 5. Place in contact the smooth, dry surfaces of two pieces of ice; press them together for a few seconds; remove the pressure, and they will be found firmly frozen together. The ice at the surfaces of contact melts under the pressure, but when the pressure is removed the liquid instantly freezes and cements the pieces together. It is in this manner that snow-balls are formed.

NOTE. — If a thermometer is placed in a mixture of ice and water, and the mixture is subjected to great pressure, some of the ice will melt and the temperature will fall; but when the pressure is removed, a portion of the water freezes and the temperature rises. From this we learn that *the melting (or freezing) point of water is very slightly lowered by pressure.* The depression is about $\frac{1}{135}$ of 1° C for each atmosphere. On the other hand, it is found that *substances which, unlike ice, expand in melting, have their melting points raised by pressure.*

[1] A chemical thermometer has its scale on the glass stem, instead of a metal plate, and is otherwise adapted to experimental use.

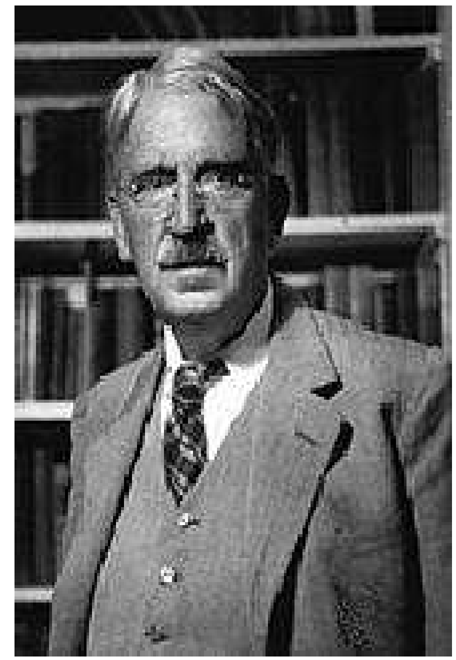
The Emergence of Inquiry-Based Science Education in the U.S.



Early Advocates of Hands-on

Huxley
1870–75 Scientific instruction and the advancement of science (Royal commission)

Charles William Eliot
President of Harvard
1869-1909



John Dewey
Philosopher
1859-1952

A Brief History of Inquiry (U.S.A)

- 1902 Dewey argues for approaches to teaching that supports teaching that has many elements of inquiry
- 1950's Sputnik creates a scare that stimulates the creations of a series of inquiry-based courses
- 1960's -70 Inquiry is adopted in some form in about 30% of high schools but then falls out of favor
- Late 1980s new and revised materials. Support for the inquiry approach for continuing research into how students learn. Revival, particularly in K-8
- Mid 1990's National and some state standards

Defining Inquiry-Based Science Education (IBSE)

Misconceptions About Inquiry

- *That inquiry is the same as hands-on.* Hands-on activities, with authentic materials are an important but not essential component of inquiry lessons. Inquiry can just as easily entail making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations and predictions and communication results (National Research Council, 1996).
- *That inquiry is unstructured and open ended.* Inquiry is sometimes unstructured with students given complete freedom to pose and research a research question, but rarely. Most practitioners of inquiry use a structured approach—Guided Inquiry—that guides the student to where the teacher needs them to be to acquire understanding, but retains some authenticity to the inquiry approach.

The Essential Features of Classroom Inquiry

- Learners are engaged in scientifically orientated questions
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically orientated questions
- Learners formulate explanations from evidence to address scientifically oriented questions
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanations

Skills Central to Inquiry Learning

- Questioning—critical thinking
- Observing
- Problem solving
- Analytical
- Application of existing knowledge
- Manipulative
- Communication and literacy
- Cooperative
- Math

The Core Implications of Cognitive Research on Curriculum Design and Teaching

- *Prior Knowledge* That students' pre-conceptions that they bring to the classroom must be engaged for them to fully grasp new concepts and new ideas otherwise they will revert to their preconceptions
- *Deep factual knowledge* To develop competence in an area of inquiry students must have a deep foundation of factual knowledge, be able to place this within the context of a conceptual framework and be able to organize knowledge for retrieval and application.
- *Taking control of their learning process* By adopting a metacognitive approach to learning students can take control of their learning process, setting goals and monitoring progress.

Adapted from How Students learn Science in the Classroom

Does inquiry fit our current needs?

The skills needed to be successful competitors in the modern world economy

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- The capacity to function effectively in an environment in which communication skills are vital – in work groups.

» ***Ray Marshall and Marc Tucker, Thinking for a Living***

Bronwyn Beven,

Asst . Director, Center for Teaching and Learning, Exploratorium, San Francisco

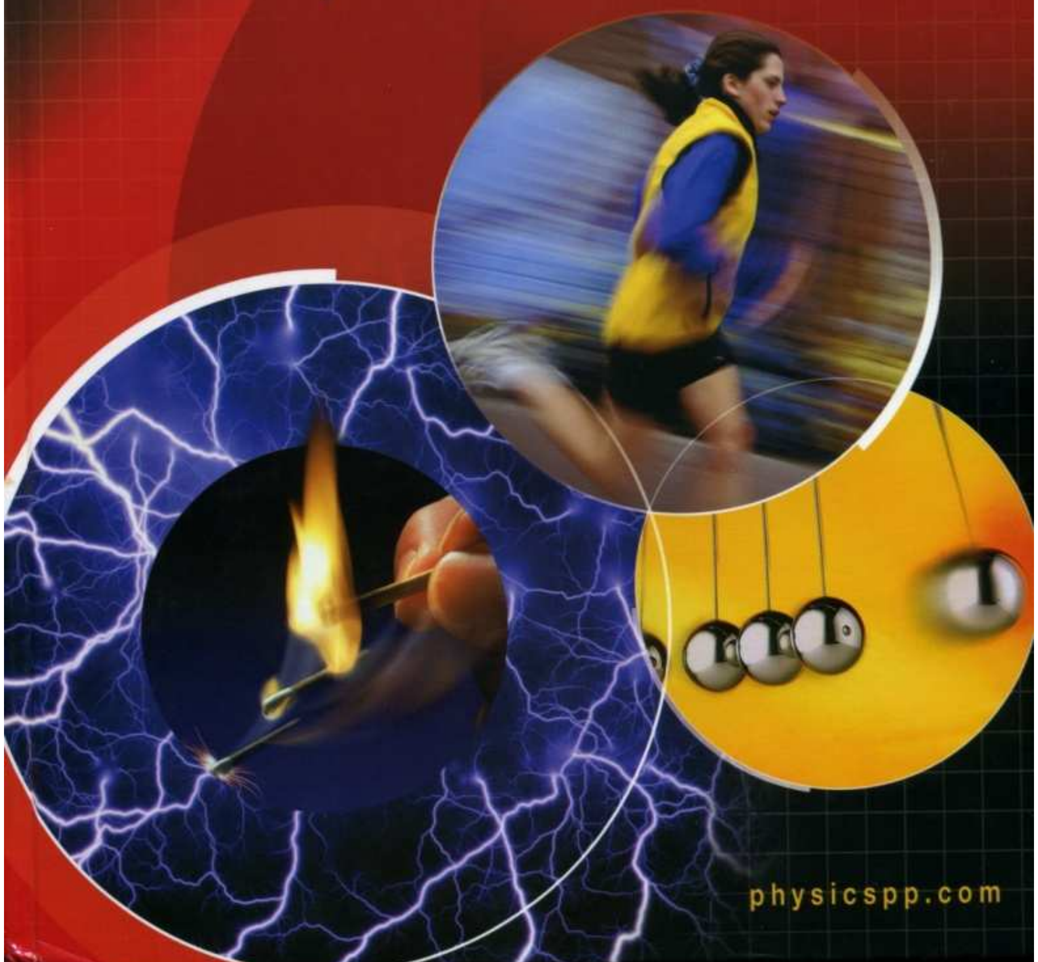
“Inquiry is a mode of teaching and learning that is about questioning, hypothesizing, and discovering. I believe it is about a shift in attitude rather than an upheaval in curriculum and classroom”

Designing to Address Prior Knowledge

Glencoe Science

PHYSICS

Principles and Problems



physicspp.com

How is a charged object affected by interaction with other charged objects at a distance?

Procedure

1 Inflate and tie off two balloons. Attach a 0.5 meter length of string to each baloon.

2 Rub one balloon back and forth on your shirt six to eight times, causing it to become charged. Hang it by the string with a piece of tape.

3 Rub the second balloon in the same way and then suspend it from its string.

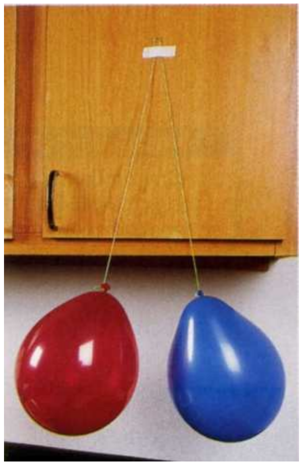
4 **Observe** Slowly bring the second balloon toward the suspended one. How do the balloons behave? Tape the second balloon so it hangs by its string next to the first balloon.

5 **Observe** Bring your hand toward the charged balloons. What happens?

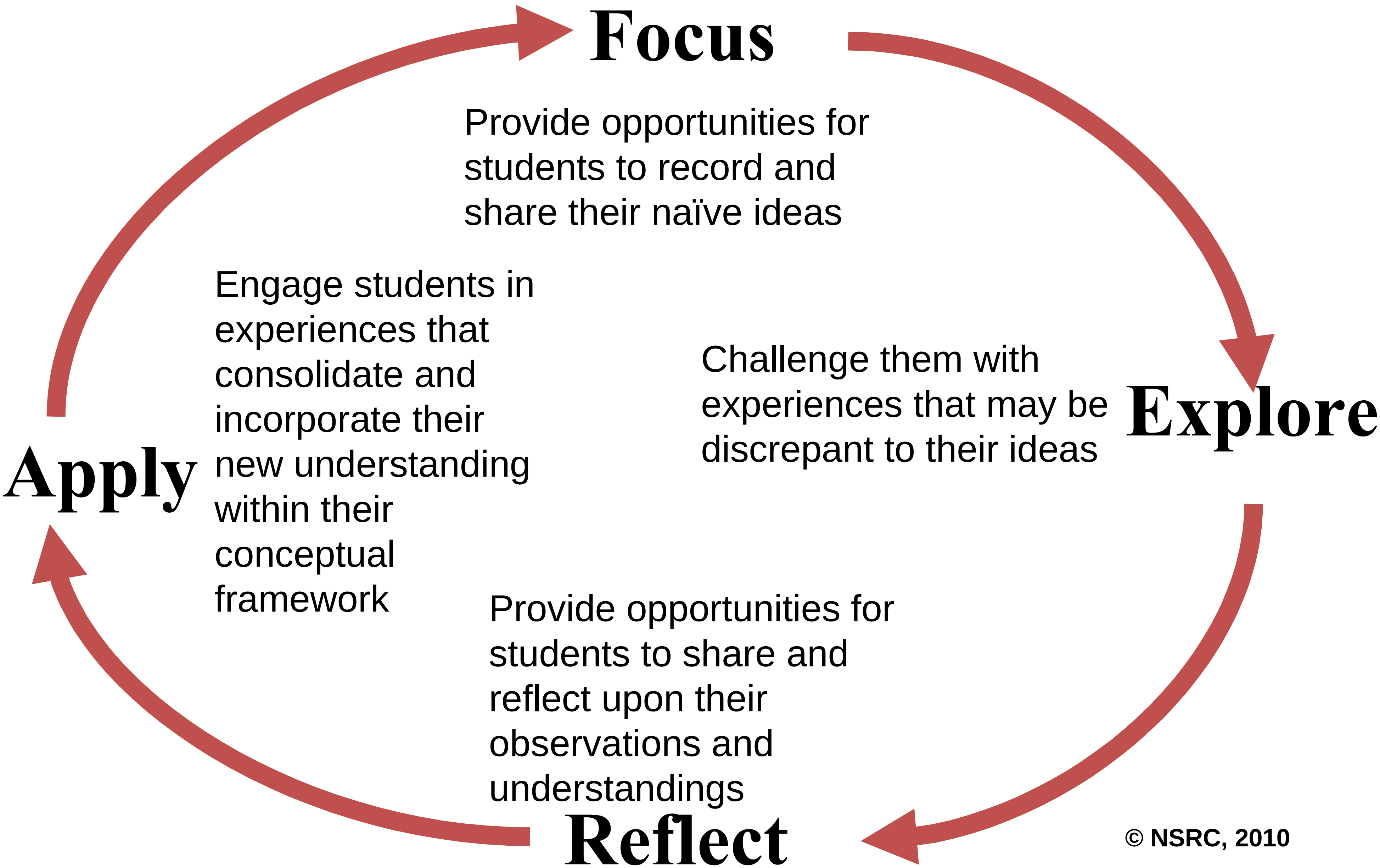
Analysis

What did you observe as you brought the two balloons near each other? What happened as your hand was brought near the balloons.

With what two objects have you previously observed similar behaviors of action at a distance?



Using a Learning Cycle to Address Misconceptions



Restructuring for Inquiry

- Providing opportunities for students to work in groups where they can record and share their existing knowledge of the phenomena to be investigated
- Providing exploratory activities to stimulate discussion
- Engage students in the formulation of questions regarding the topic
- Allowing students to take some responsibility for aspects of the activity design, including apparatus and procedure design, collection and analysis of data etc.
- Keeping materials simple but engaging. Complex materials require steeper learning curves and detract form the core purpose of the activity.
- Designing instructions and structured questions that address common misconceptions, direct students to focus on specific observations and stimulate new explanations and additional inquiry
- Encouraging sharing and reflection of the experience. Sharing and explaining each others data

Designing for hands-on is not the same as designing for inquiry

"You know from daily experience that electric irons, toasters, stoves and light bulbs all get hot when electric charge flows through them. Apparently a flow of charge can produce heat in certain parts of the circuit. Before we investigate the relation between….."

From Energy: A Sequel; to IPS (Introductory Physical Science)

Inquiry 6.2
Measuring Electrical Current in a Parallel Circuit

PROCEDURE

1. Set up the parallel circuit shown in Figure 6.5, with two lightbulbs in parallel, two batteries, a switch, and an ammeter in series with a switch.

2. Suppose you placed the ammeter at different places in this parallel circuit. What do you think you would find? Write a prediction in your science notebook about what the current is like at different locations in this circuit.

3. Design and carry out a procedure to test your prediction.

4. Discuss the following questions with your group:

   What can you conclude about electrical current in this kind of circuit?

   How can you explain your results?

5. Share your ideas with the class.

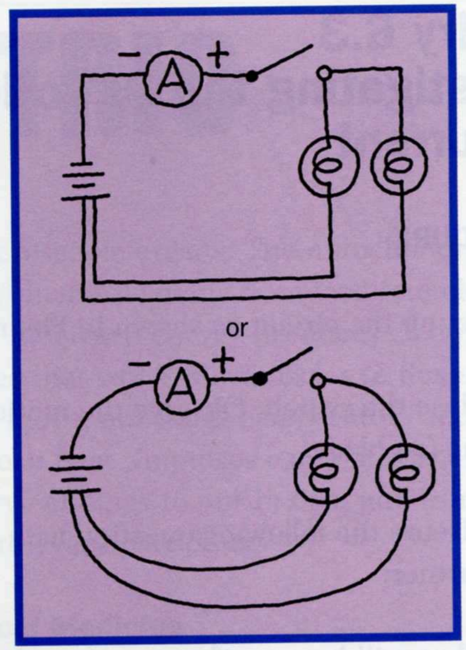
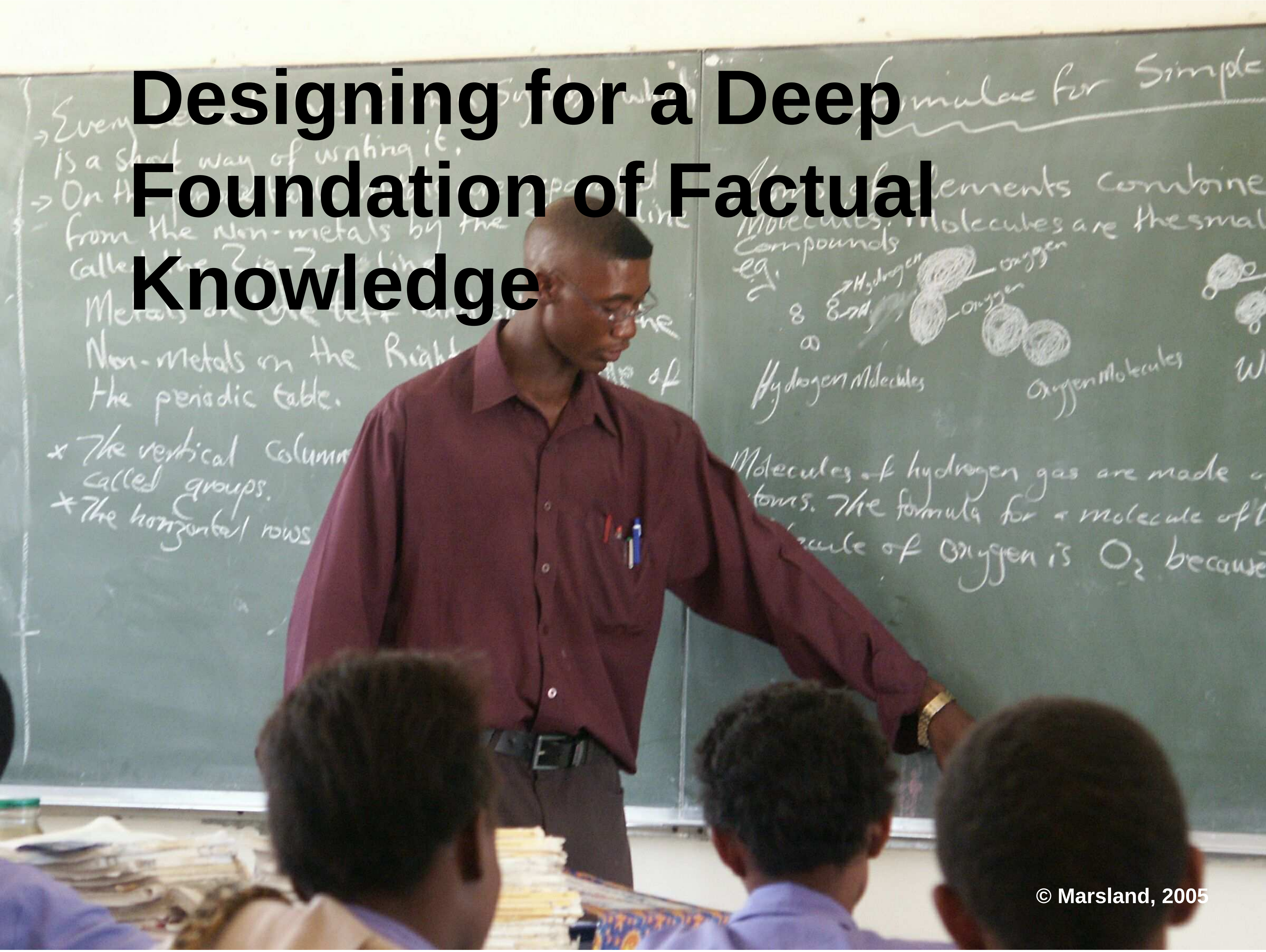


Figure 6.5 *Circuit for Inquiry 6.2*

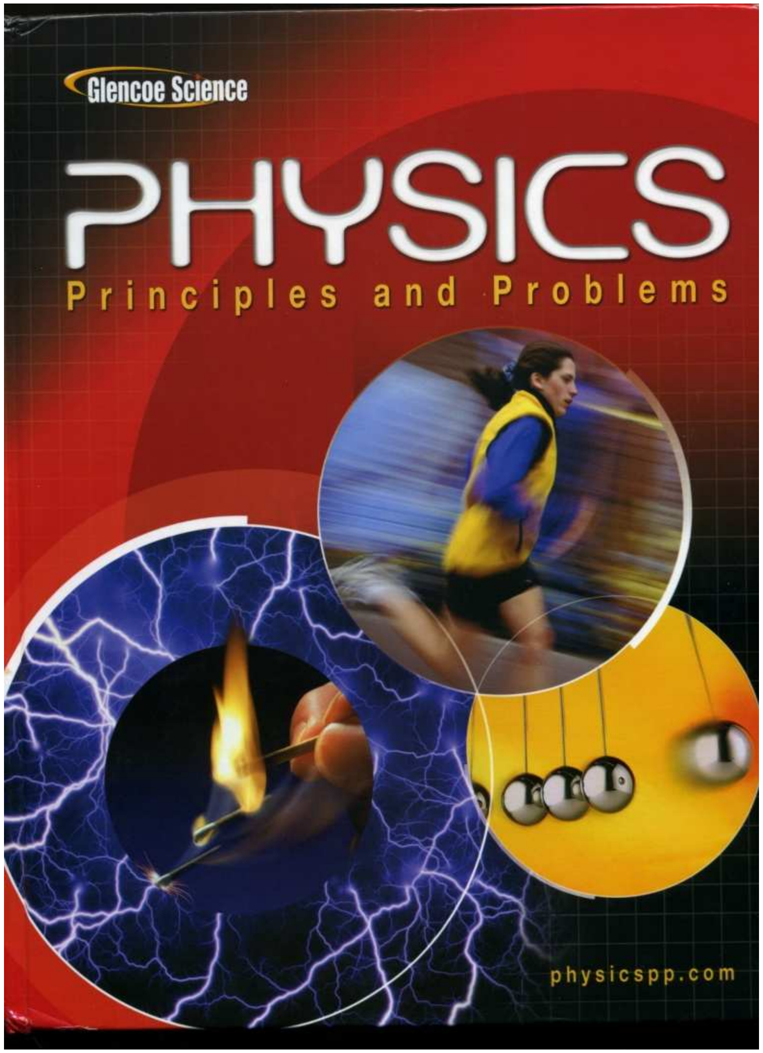
- “Since textbooks, along with the teachers’ own knowledge and beliefs , strongly influence their instruction, the way these text treat laboratory experiences appears important”
- National Research Council. (2006). America’s Lab report: Investigations in High School Science. Committee on High School Science Laboratories: role and Vision, S.R. Singer, ML Hilton, and H. A. Schweingruber, Editors. Board on Science education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington DC: The National Academies Press. P 61

Designing for a Deep Foundation of Factual Knowledge

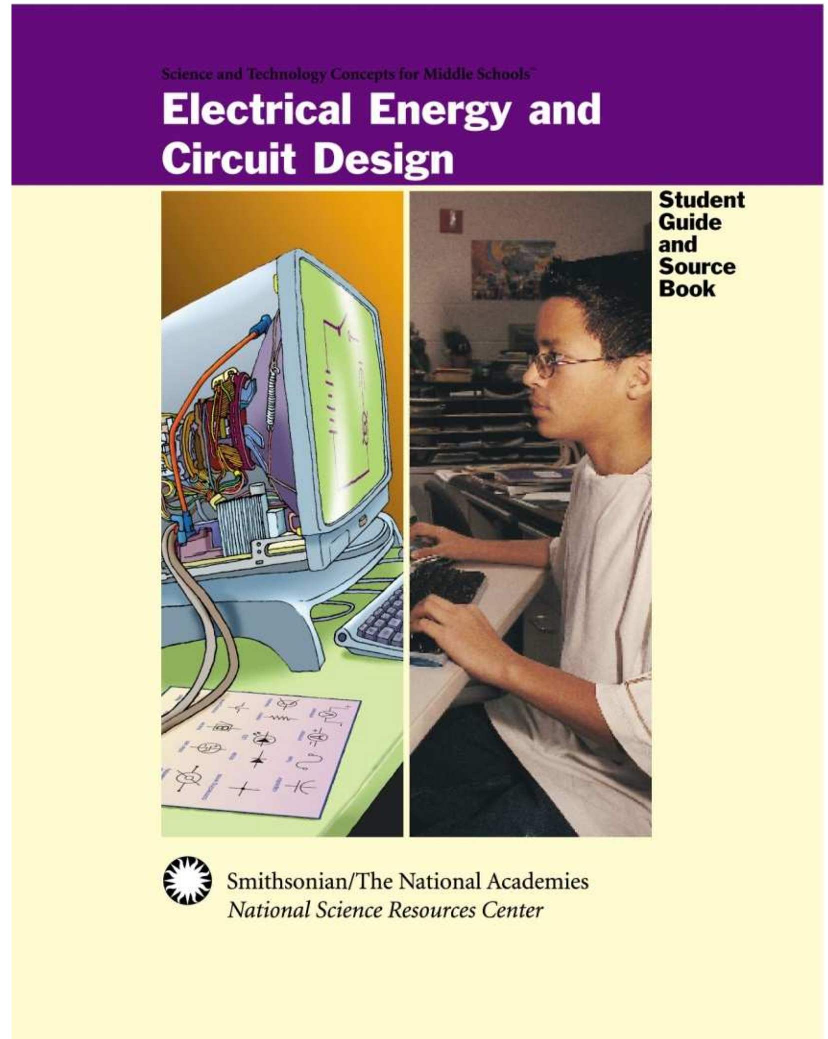


CONTENTS

Philip Zitzewitz 2001



Philip Zitzewitz 2001



Sound Concept Storyline

Unifying Concept
Sound is generated by a kinetic disturbance.

Unit Concept
Sound varies in frequency (pitch) and loudness (volume).

Grade-Level Concept
Sound is produced by vibrations that move through objects and the air. Pitch and volume are important properties of sound.

Subconcept 1
Sound is a form of kinetic energy that may be generated by a variety of means. Sound travels as kinetic waves through different media.

Lesson 1: Pre-Unit Assessment: Thinking about Sound
Students discuss sound and explore tuning forks.

Lesson 2: How Sound Travels
Students investigate how sound produced by a tuning fork travels through different media.

Subconcept 2
The pitch of sound varies with the frequency of vibration of the generating mechanism.

Lesson 3: Making Sounds with Nails
Students investigate the difference between pitch and volume.

Lesson 4: Making Sounds with Rulers
Students investigate length as a variable that affects pitch.

Lesson 5: Exploring Pitch
Students continue to explore the relation between frequency of vibrations and pitch.

Lesson 6: Vibrations We Can't See
Using a slide whistle, students investigate the sounds generated by a column of vibrating air.

Lesson 7: Designing a Reed Instrument
Students use a vibrating reed to examine the characteristics of pitch.

Lesson 9: Making Sounds with String
Students examine how a vibrating string makes sound and how the length of a vibrating string affects pitch.

Lesson 10: Changing Pitch by Changing Tension
Students study how the tightness of a vibrating string affects pitch.

Lesson 11: Tuning a Stringed Instrument
Students experiment with varying the length and tension of strings on a harp.

Lesson 12: How Do Different Strings Sound?
Students discover how the thickness of strings affects pitch.

Subconcept 3
The volume, or loudness, of sound is dependent on the amplitude of the vibration.

Lesson 13: Making Louder Sounds from Strings
Students examine how to vary the volume of the sound.

Subconcept 4
Humans can both hear and produce sound.

Lesson 8: Making a Model Eardrum
Students discuss vibrations of the human eardrum.

Lesson 14: Making Sounds with Air and Strings: The Human Vocal Cords
Students use rubber bands to model the sounds produced by humans.

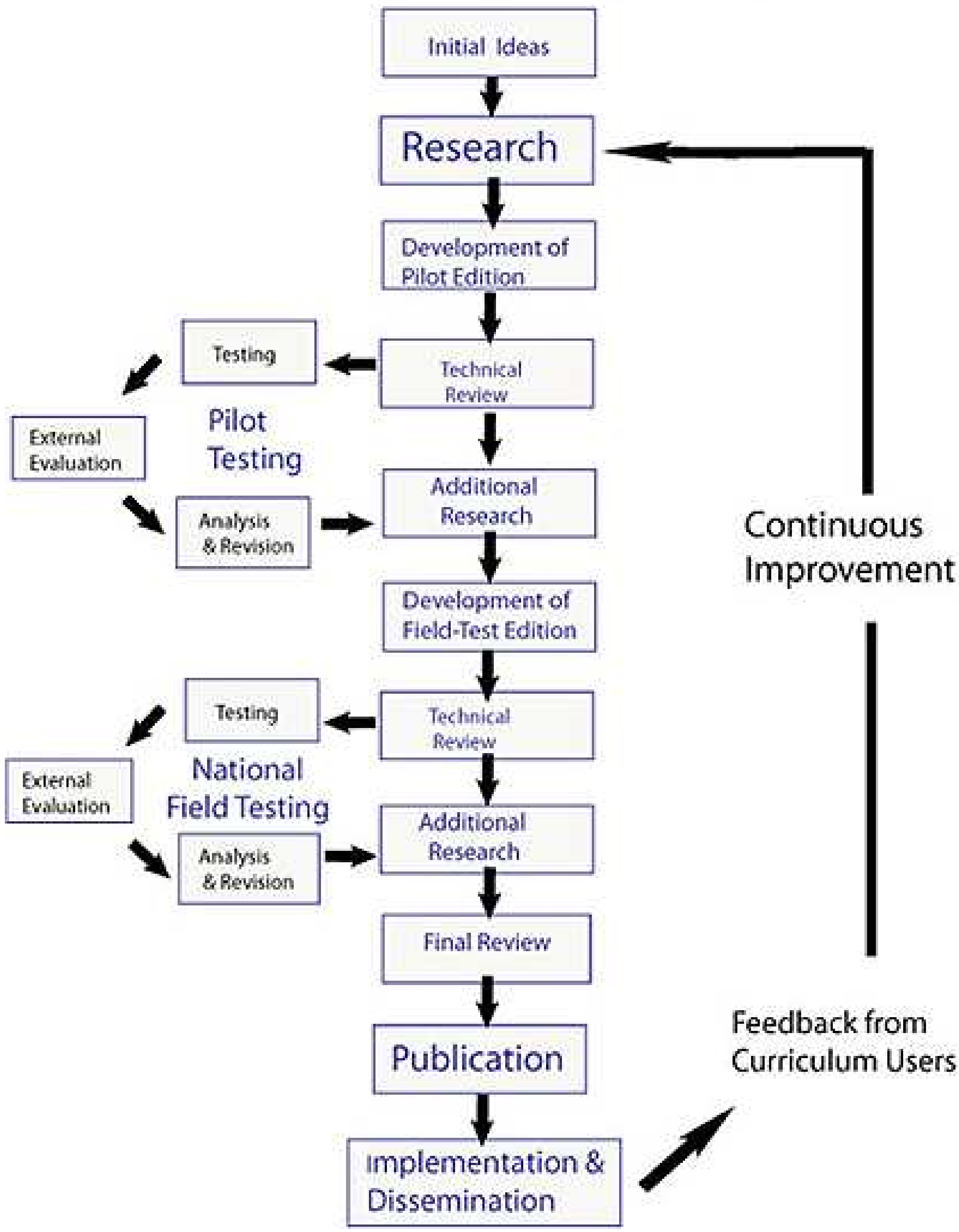
Subconcept 5
Sound may be generated by a variety of types of instruments.

Lesson 15: What Have We Learned about Sound?
Students plan how to design a musical instrument.

Lesson 16: Sharing What We Have Learned
Students complete their instrument design, test and improve it, and present their results to the class.

Lesson 17: Post-Unit Assessment: Sharing What We Have Learned about Sound
Students discuss and reflect on what they have learned.

NSRC Curriculum Development Cycle

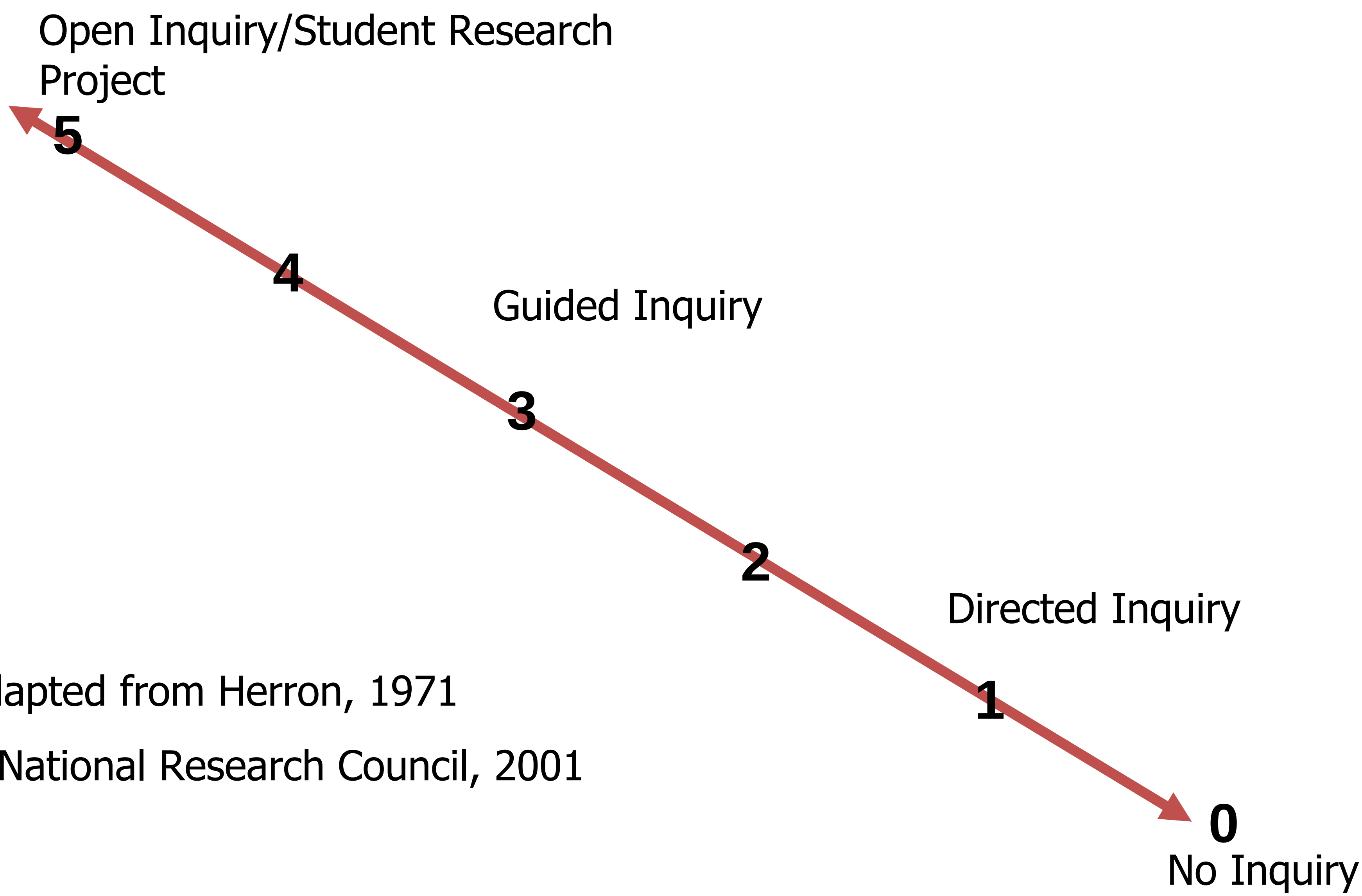


Requiring Students to take responsibility for their learning

The Inquiry Continuum: What is provided to the student?

Level of Inquiry	Question/ Problem	Hypothesis or Prediction	Procedure	Results and analysis	Evaluation/ Conclusions
0	*	*	*	*	*
1	*	*	*	*	
2	*	*	*		
3	*	*			
4	*				
5					

The Inquiry Continuum (Gradient)



Adapted from Herron, 1971

& National Research Council, 2001

Example:

An inquiry in which students investigate corrosion

Focus

- *Discuss with other members of your group what you think the word corrode means (Your teacher will ask you to share your definition)*
- *Think about the following questions and then discuss your ideas with other members of your group.*
- *Do metal objects that are placed outdoors corrode?*
- *What causes corrosion?*
- *Do all metals corrode?*

Move to explore

Explore

In this inquiry you will design an experiment to compare how typical environmental conditions—exposure to air and water cause different metals to corrode. The metals you will investigate are the same ones you used in Inquiry 23.1. Discuss with members of your group how you could set up an inquiry to determine the effects of air and water on one of these metals. Look at the apparatus [provided] in the plastic box to give you some ideas. Think about the following questions:

- *What conditions will you need to create to show that both air and water affect the corrosion of metals?*
- *How will you create these conditions?*
- *How will you ensure that all comparisons you make are fair?*

(Marsland, Properties of Matter, 2006).

Getting Started

1. Your teacher will ask for volunteers to operate the Van de Graaff generator and to perform the following steps:

A. Hold the pith ball by the thread with the Van de Graaff generator turned off. Bring the pith ball near the metal ball on top of the generator, as shown in Figure 3.1. Does anything happen?

B. Move the pith ball away from the generator, and turn the generator on for a few seconds. Then bring the pith ball back close to the generator. What happens to the pith ball?

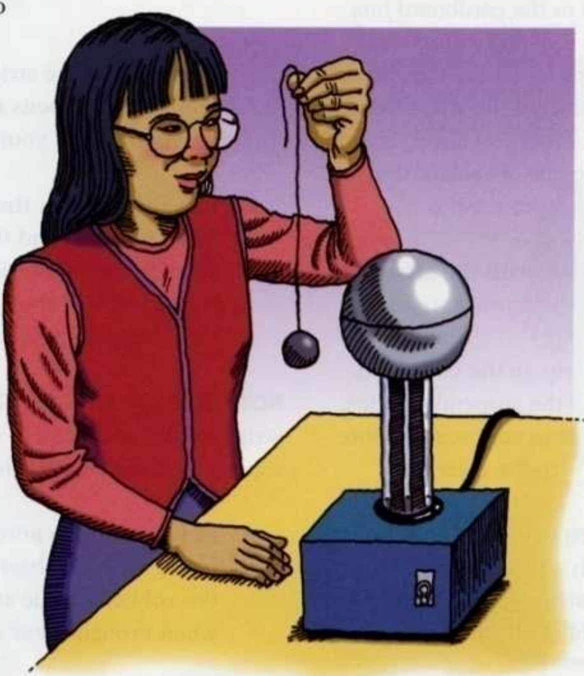


Figure 3.1 *What do you think will happen if you bring a pith ball near the Van de Graaff generator?*

MATERIALS FOR LESSON 3

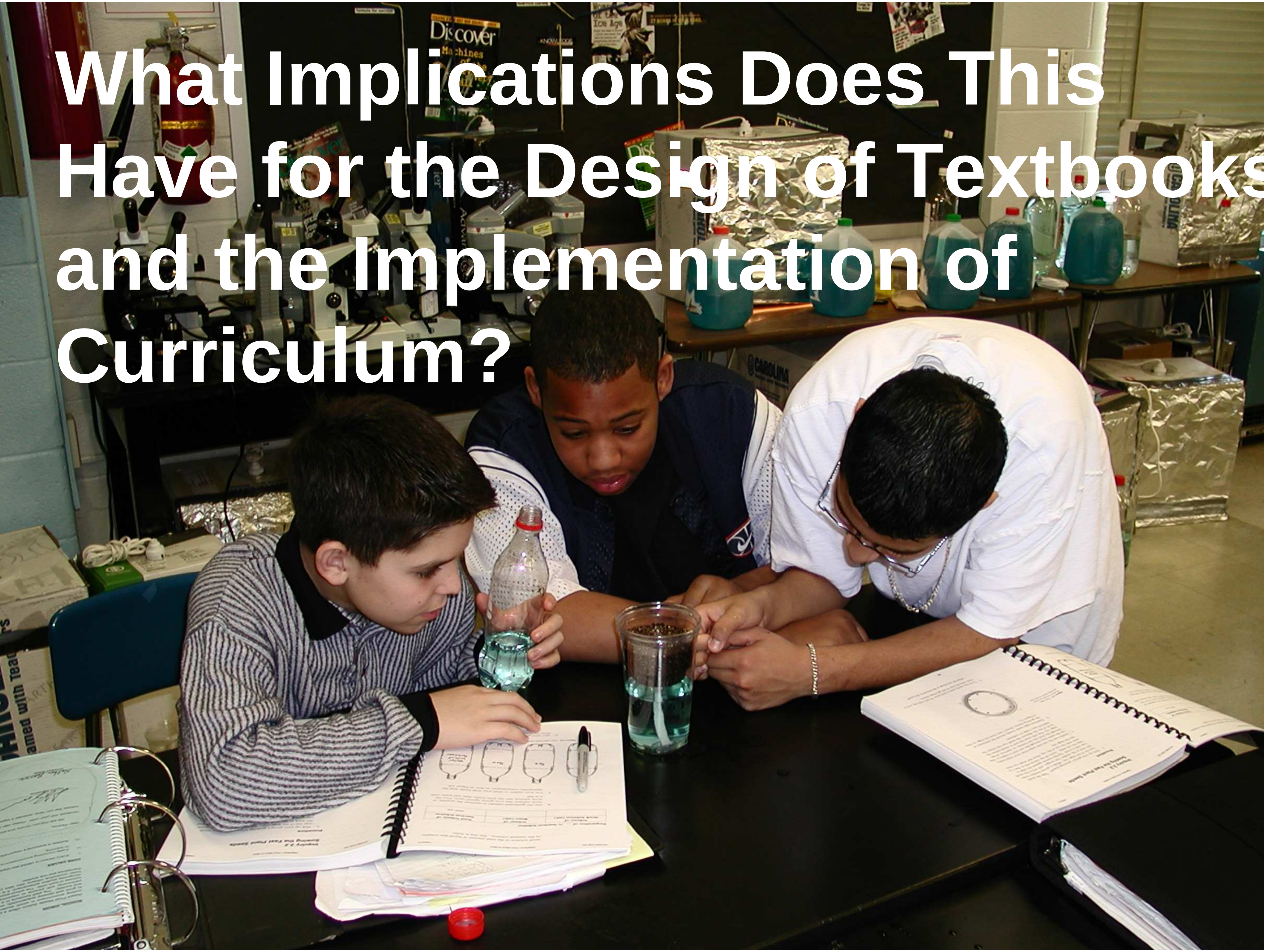
For the class

- 1 Van de Graaff generator
- 1 pith ball
- Nylon thread
- Masking tape

For your group

- 1 cardboard box
- 1 neon lightbulb
- 1 wool cloth
- 1 electric plume
- 1 Styrofoam® pad
- 1 pith ball
- 2 white plastic strips
- 2 clear plastic strips
- Nylon thread
- Masking tape or Transparent tape

What Implications Does This Have for the Design of Textbooks and the Implementation of Curriculum?



Steps I

- Content standards need to be reduced to focus on fewer themes to allow their investigation in detail.
- Courses need to be based around these few core major concepts.
- Existing single textbooks should be phased out of their central role in instruction. Textbooks should play the role of additional reading and review and should be transformed to reflect that role

Steps II

- Existing single textbooks should be phased out of their central role in instruction. Textbooks should play the role of additional reading and review and should be transformed to reflect that role
- Materials need to be selected (or developed) that are driven by student investigation. These materials should consist of student books, comprehensive teacher guides, and the laboratory materials need to support IBSE. They should be based on research into how people learn and produced through an extensive R & D process.

Steps III

- Teachers will require professional development to implement these materials and to help enact a change in the role of the teacher in the classroom. Pre-service training for science teachers should be based in the principles of IBSE.
- Assessment needs to reflect the inquiry nature of science. Assessment should have both a performance and written component. Emphasis should be placed on opportunities for assessment that inform the teaching process.

Shifting to IBSE Classrooms

(The traditional textbook verses inquiry)

Traditional text-book

- Teacher centered
- Experiences mainly from listening and reading
- Hands-on component teacher or book directed
- Note-taking, book, or lecture based
- Assessment: mainly selected response

Inquiry (research-based)

- Student centered
- Learning cycle-based
- Experiences from direct experiences with authentic materials
- Major hands-on component
- Inquiry-based. Students take increasing responsibility for their investigations
- Science notebooks and reading research
- Wide variety of assessment