High School Labs –
It’s as Easy as ABC
(Activity Before Concept)

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High School Labs

• Why labs?

• Why ABC (Activity Before Concept)?

• How do we do ABC?

• ABC in a larger instructional model
Labs = Science

• Aristotle and Galileo
  – Which falls first: heavy objects or light objects
  – Aristotle’s argument
  – Galileo’s thought experiment
Galileo’s Thought Experiment
Galileo’s Thought Experiment
Let’s ask nature

• Experimental approach to find out
  – Paper and pen falling
  – Pen and weight falling
  – Paper and paper falling

• Experimental observations bring closure
• Experimental observations raise questions
AMERICA'S LAB REPORT
Investigations in High School Science

www.nap.edu
Framework

Definition of Laboratory

- Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science.
Framework

Goals of Laboratory Experiences

• Please discuss
Framework
Goals of Laboratory Experiences

• Mastery of subject matter.
• Developing scientific reasoning.
• Understanding the complexity and ambiguity of empirical work.
• Developing practical skills.
• Understanding of the nature of science.
• Interest in science and science learning.
• Developing teamwork abilities.
Outline

• Context for the study
• NRC study process (committee & charge)
• Definition and goals of laboratory experiences
• Laboratory experiences and student learning
• Institutional and policy factors
• Next steps
Findings
History of Laboratory Research and Practice

• For over 150 years, scientists and educators have assumed labs are essential to learning science.

• Historically, laboratory experiences were isolated from the flow of science teaching.

• This approach remains typical today (we call these “typical” laboratory experiences).

• Researchers asked whether typical laboratory experiences added value.
Findings
Recent Trends

• Researchers draw on principles of learning from cognitive research.
• Studies focus on *how* to sequence science instruction.
• Researchers design and study units that integrate labs, lecture, discussion, reading.
• We call these “*integrated instructional units.*”
Findings

Integrated Instructional Units > Typical Labs

• Mastery of subject matter
• Scientific reasoning
• Understanding the nature of science
• Interest in science

Other goals – inadequate evidence

• Understanding the complexity and ambiguity of empirical work.
• Developing practical skills.
• Developing teamwork abilities.
Conclusion 2
Design Principles can Help Labs Achieve Goals

1) Clear learning outcomes in mind.
2) Thoughtfully sequenced into the flow of classroom science instruction.
3) Integrate learning of science content with learning about the processes of science.
4) Incorporate ongoing student reflection and discussion.
Findings

Current Lab Experiences

• Focused on procedures, not on clear learning outcomes.
• Isolated from the flow of science instruction.
• Do not integrate learning of science content with processes of science.
• Few opportunities for reflection and discussion.
• Do not reflect instructional design based on cognitive research.
• Students in lower-level science classes and in schools with high concentrations of minorities spend less time in lab.
Conclusion 3
Quality of Lab Experiences

• The quality of laboratory experiences is poor for most students
High School Labs

- Why labs?

- Why ABC (Activity Before Concept)?

- How do we do ABC?

- ABC in a larger instructional model
Why ABC (Activity Before Concept) 

**Experience**

- Experience is required – science is experiments
  - Learn baseball without ever seeing the game
  - Learn baseball without ever having equipment
  - Knitting without instruction

- Why do we think students can learn science by watching?
Why ABC (Activity Before Concept)

*Common Experience*

- Television viewing habits of African Americans and Anglo Americans
  - 10 top programs
  - Only 2 programs in common
- What are the common programs?
- What is the lesson?
  - Every time I made a reference to television, I was disenfranchising some group of students.
Black/White TV

Cedric the Entertainer
One on One
Girlfriends
Half & Half
The Parkers
My Wife and Kids
The Bernie Mac Show
**Monday Night Football**
Fastlane

**CSI**
Friends
ER
Everybody Loves Raymond
Survivor: Thailand
Law & Order
Will & Grace
CSI: Miami
Scrubs

**Monday Night Football**
Why ABC (Activity Before Concept) 

Common Experience

• There is no common experience
  – TV, music, food, vacation, movies, travel, home
  – Can someone imagine what a mango tastes like?
  – TRADITIONAL BOOKS ARE FILLED WITH “You know; Imagine”
    • … like waves at the ocean
    • …like a recipe for making brownie
  – Examples from your teaching
  – Examples from literature or movies
Why ABC (Activity Before Concept)

**Misconceptions**

- Misconceptions Research
  - You’re asking people to change the way they look at the world.
  - They must have some evidence and some experience.
  - They must have a reason to change.

- Phase of the moon
- Colder in the winter
- Acorn → mighty oak
High School Labs

• Why labs?

• Why ABC (Activity Before Concept)?

• How do we do ABC?

• ABC in a larger instructional model
How do we implement ABC

- With Inquiry
- By engaging students intellectually
Explore

• Sample laboratory activity
Question: How does carbonless duplicate paper work?

1. What observations did you make; what data did you collect?

2. How do you interpret your results?
   – What is your model for how the paper works?
Explain

• Tweaking a lab toward inquiry
Density study in most textbooks

Density as an inquiry activity in Active Chemistry
2. Measure the mass of an empty, dry, graduated cylinder.
   a) Record the mass of the cylinder in your Active Chemistry log.
3. Add 10 mL of water to the graduated cylinder. Remember when reading the volume, take the reading at the lowest part of the meniscus, as shown in the diagram.
4. Measure the mass of the graduated cylinder and 10 mL of water.
   a) Record the measurement in your log.
   b) Calculate the mass of the water and record this in your table.
5. Add another 10 mL to the graduated cylinder and measure the mass. Calculate the mass of 20 mL of water.
   Repeat this step for 30 mL, 40 mL, 50 mL, and so on up to 100 mL.
   a) Record all your measurements and calculations in the table in your log.
6. Use the data you obtained.
   a) Plot a graph of the mass versus the volume of water. Plot volume on the x-axis (horizontal axis) and mass on the y-axis (vertical axis).
   b) As the volume of the water increases, what happens to the mass?
   Since the graph you created is a straight line (or close to a straight line), you should draw the best fit line through the data points. Do not connect the points with small segments but draw one line that comes closest to all of the individual points.
   c) From your graph predict the mass of 55 mL of water. What would be the volume of 75 g of water? Predicting data from within a graph is called interpolation.
   d) An important attribute of a straight line graph is its slope. How steep is the graph? Calculate the slope of the graph you plotted. Remember to calculate slope you divide the “rise” by the “run.” What does the “rise” of the graph represent? What does the “run” represent?
   e) Divide the mass of each sample of water by the volume. What do you notice about the relationship between the mass and the volume? How does the slope of the graph compare to the values you calculated in this step?

7. Your teacher will provide you with a sample of a liquid.

8. Dispose of your liquid sample as directed by your teacher. Clean up your work station.

Part B: Mass and Volume of Solids

1. Your teacher will provide you with three samples of two different solid materials.

2. As a group, decide on a procedure to calculate the mass/volume ratio and slopes of the graph of each material.
You can consider using either method shown in the diagrams on the preceding page and at right for measuring the volume of each solid. Volume of solids is usually expressed in cubic centimeters. One milliliter is equivalent to one cubic centimeter (1 mL = 1 cm³).

a) Record your procedure in your Active Chemistry log. Be sure to include what measurements you need to make, what equipment you will need, what safety precautions you must use, and what calculations you have to do.

When your teacher has approved your procedure, carry out your activity.

a) Carefully record all your data.

Use the data you collected.

a) Plot a mass versus volume graph for each solid. Plot both solids on the same graph.

b) How do the slopes for the two solids compare? Which solid is more dense?

c) Use the table in the Chem Talk reading section to identify the two samples of materials.

The mass of a unit volume of a material is called its density. You found the density of water by calculating the slope of the mass versus volume graph. You can also calculate density by dividing the mass of a sample of a material by the volume.

\[
\text{Density } (D) = \frac{\text{Mass } (M)}{\text{Volume } (V)}
\]

a) Find the densities of water, the other liquid, and the two solid materials.

b) Compare your answers with another lab group.

**Part C: Density and Special Effects**

1. Your teacher will display a set of four colored liquids that float on one another. The densities of each of the liquids were measured. The top layer has a density of 0.8 g/mL. The next layer has a density of 0.9 g/mL. The following layer has a density of 1.1 g/mL. The bottom layer has a density of 1.3 g/mL.

a) What do you notice about the densities of the liquids and their position in the display?
2. Your teacher will drop a pen barrel of a density of about 1.2 g/cm³ into the liquids.
   a) What would you predict will happen to the pen cap? Write your prediction in your Active Chemistry log.
   b) Observe the movement of the pen cap as your teacher places it in the liquid. Record your observation in your log.

3. You will now make a pen cap float in liquid.

Place the pen barrel in a beaker of ethanol.
Next place the pen barrel in a beaker of distilled water.
Return the pen cap to the beaker of ethanol. Slowly add distilled water to the ethanol until the pen barrel floats.

a) Before you begin, predict what you think will happen in each part of this step. Give a reason for your prediction.

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**ChemTalk**

**DENSITY**

**Density as a Property of Matter**

If you were to compare a 1 cm³ cube of iron to a 1 cm³ cube of wood, you would probably say that the iron is “heavier.” However, if you compared a tree trunk to iron shavings, the tree trunk is obviously heavier. As you discovered in this activity, a “fair” comparison of the “heaviness” of two materials is a comparison of their densities. **Density** is the mass per unit volume of a material. In this activity you measured the density of water and other liquids. You found that each sample of the same liquid had the same density and each different liquid had its own characteristic density. You also found that each solid material you investigated had its own characteristic density. Density can be expressed in grams per milliliter (g/mL) or grams per cubic centimeter (g/cm³). The table on the next page shows the densities of some common liquids and solids.

You used the slope of the mass versus volume graph of a material to calculate density. You also calculated density using the equation:

\[
\text{Density (D)} = \frac{\text{Mass (M)}}{\text{Volume (V)}}
\]
Density and Flotation

In this activity you further observed that materials with a greater density than a given liquid will sink, and materials with less density than a given liquid will float. In the column of colored liquids, the liquid with the highest density was on the bottom, and the liquid with the lowest density was on the top. The pen barrel sank in ethanol and floated in water. When you added ethanol to the water you created just the right density to have the pen barrel float within the liquid. This position of floating is where the density of the pen barrel is equal to the density of the ethanol/water. The pen barrel “found” the place where the density of the liquid was identical to the density of the pen barrel.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>wood (balsa)</td>
<td>0.12</td>
</tr>
<tr>
<td>wood (birch)</td>
<td>0.66</td>
</tr>
<tr>
<td>gasoline</td>
<td>0.69</td>
</tr>
<tr>
<td>isopropanol</td>
<td>0.79</td>
</tr>
<tr>
<td>vegetable oil</td>
<td>0.92</td>
</tr>
<tr>
<td>distilled water</td>
<td>1.00</td>
</tr>
<tr>
<td>glycerol</td>
<td>1.26</td>
</tr>
<tr>
<td>magnesium</td>
<td>1.70</td>
</tr>
<tr>
<td>aluminum</td>
<td>2.70</td>
</tr>
<tr>
<td>iron</td>
<td>7.90</td>
</tr>
<tr>
<td>copper</td>
<td>8.90</td>
</tr>
<tr>
<td>nickel</td>
<td>8.90</td>
</tr>
<tr>
<td>silver</td>
<td>10.50</td>
</tr>
<tr>
<td>mercury</td>
<td>13.50</td>
</tr>
<tr>
<td>gold</td>
<td>19.30</td>
</tr>
</tbody>
</table>
1. Look at the table in the Chem Talk reading section. Use density to identify the liquid and solid samples you investigated in this activity.

2. Calculate the density of a solid from the following data:
   - Volume of water: 48.4 mL (or cm³)
   - Volume of water and solid: 62.7 mL (or cm³)
   - Mass of solid: 123.4 g

3. Determine the density of a liquid from the following data:
   - Mass of the graduated cylinder: 33.79 g
   - Mass of the cylinder and liquid: 40.14 g
   - Volume of liquid: 13.3 mL

4. Methanol has a density of 0.79 g/mL. How much would be the mass of 589 mL of methanol?

5. Copper has a density 8.90 g/cm³. What would be the volume of a 746 g sample of copper?

6. In a well-known movie, there is a famous scene in which the hero tries to outwit the designers of a trap by replacing a gold statue with a bag of sand of about the same volume.
   a) Given the density of gold is 19.3 g/mL and sand is 3.1 g/mL, does this seem like a scientifically reasonable plan?
   b) In the movie, the hero grabs the gold statue with one hand and appears to handle it quite easily. Given that the volume of the statue appears to be about one liter, what would be the mass of the statue?
   c) A mass of 454 g has a gravitational weight of about 4.45 N (newtons) which is about 1 lb. How many pounds would the statue weigh?
   d) One gallon of milk has a mass of 3.7 kg and a weight equivalent of approximately 8 pounds. How many gallons of milk would be equivalent to the gold statue?

7. In each of the following pairs, which has the greater mass?
   a) 1 kg lead or 1 kg feathers?
   b) 1 L gold or 1 L water?
   c) 1 L copper or 1 L silver?
8. Which of the following has the greater volume:
   a) 1 kg lead or 1 kg feathers?
   b) 1 kg gold or 1 kg water?
   c) 1 kg copper or 1 kg silver?
9. Review the measurements you made for mass and volume. How certain were your measurements? If you were to make the measurements again, could you be more certain? Explain your answer.
10. In calculating density you divided the mass of the material by the volume. Review the calculations you made. Adjust the accuracy of your answers using the rule for division given in the Chem Talk reading section.

Preparing for the Chapter Challenge

Design a special effect in which an object is suspended in a liquid. Consider the density of the material you will suspend, and the density of the liquid you will use. Show the calculations that you used to make your choice of materials.

Inquiring Further

1. Is it real gold?
The new United States dollar coin has a golden color. Could it be made of real gold? Devise a method to determine if the new golden coin is any of the metals in the list on page 39.

2. Density of gas
Devise an investigation that you could do to determine the density of air.
High School Labs

• Why labs?

• Why ABC (Activity Before Concept)?

• How do we do ABC?

• ABC in a larger instructional model
ABC as part of the 7E instructional model

- Engage
- Elicit
- Explore
- Explain
- Elaborate
- Extend

\[ \text{Evaluate} \]

- Enhancing the 5E model: *The Science Teacher (9/03)*
  Available at www.cosmic.umb.edu
Can it be done?

- NSF curriculum
  - Active Physics
  - Active Chemistry
  - FOSS
  - Biology: A Human Approach

- NOTE: not an advertisement but rather a proof of concept
A lab with inquiry

• Modify a lab to make it more consistent with inquiry (ABC – activity before concept)
  – Describe lab as it is traditionally done.
  – Describe lab as it’s done with inquiry.
High School Labs – Summary

• Why labs?

• Why ABC (Activity Before Concept)?

• How do we do ABC?

• ABC in a larger instructional model
The ABC of Labs – an equity perspective

• Equity
  – Labs for All
  – Experiences and level playing field for All
  – Common experience for All
  – Student engagement for All
What’s next

- Implement changes in some of your instruction – think ABC (activity before concept)

- Choose texts that facilitate this change.

- Provide the environment for the next Michael Faraday
We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

– T. S. Eliot (Little Gidding V)
Nike over Macaulay

Let’s reject Lord Thomas Macaulay:

“Reform, reform, don’t speak to me of reform. We have enough problems already.”
Nike over Macaulay

Let’s reject Lord Thomas Macaulay:

“Reform, reform, don’t speak to me of reform. We have enough problems already.”

Let’s adopt Nike:

Just Do It
Labs for ALL
Center of Science and Math In Context

COSMIC

• Please check out our website: www.cosmic.umb.edu for a copy of the power point.

Or email with questions: arthur.eisenkraft@umb.edu
Findings

Mastery of subject matter

• Typical Labs
  • No better or worse than other modes of instruction.

• Integrated Instructional Units
  • Increased mastery of subject matter compared to other modes of instruction.
Findings
Scientific Reasoning

• Typical Labs

• Aids development of some aspects.

• Integrated Instructional Units

• Aids development of more sophisticated aspects.
Findings
Understanding of Nature of Science

- Typical Labs
  - Little improvement.

- Integrated Instructional Units
  - Some improvement when designed explicitly to develop understanding of NOS.
Findings
Interest in Science

• Typical Labs
  • Some evidence of increased interest.

• Integrated Instructional Units
  • Strong evidence of increased interest.
Findings

Inadequate Evidence

Typical Labs and Integrated Instructional Units

• Understanding the complexity and ambiguity of empirical work.
• Developing practical skills.
• Developing teamwork skills.
• PLACE AFTER AC SLIDES AND BEFORE ENGAGING STUDENTS
What is a student scientist?

Cognitive Processes

- Generating research questions
- **Designing studies**
- Making observations
- Explaining results
- Developing theories
- Studying research reports

Designing Studies

- Selecting variables
- Planning procedures
- Controlling variables
- Planning measures
Explaining results

– Generalizations
– Transforming observations
– Finding flaws
– Indirect reasoning
– Types of reasoning
Inquiry – open → guided

• Where did the carbonless duplicate fit on the continuum?
• How bad could this get?
• Need for skills and protocol to participate in open inquiry
What engages students intellectually?

*Please discuss*
When Are Students Most Engaged Intellectually

- Students help define content and task
- They had time to wonder - to find a particular direction that interested them.
- Subject topics had a “strange” quality - something discrepant or seen in a new way evoking a “lingering” question.
When Are Students Most Engaged Intellectually

• Teachers permitted - even encouraged - different forms of expression and respected student views.
• Teachers were passionate about their work
• Students created original and public products; they gained some form of expertness.
When Are Students Most Engaged Intellectually

• Students did something - participated in a political action, wrote a letter to the editor, worked with the homeless.

• Students sensed that the results of their work were not predetermined or fully predictable.
Elicit/Engage: Carousel

• What defines effective laboratory activity?
• What student learning goals do we have for laboratory activities?
• What evidence will you accept that students have accomplished laboratory learning goals?
• What aspects of laboratory activities promote student learning?
Framework

Goals of Laboratory Experiences

- Please discuss
- Makes the content kinesthetic
- Teach, inquire and test sci principles
- Tell me, I forget....
- Support science theory
- Differential learning
- Teaches how to use tools and follow instructions
- Fun
- Develop problem solving skills
- Leadership skills
Framework
Goals of Laboratory Experiences

• Please discuss
• Hands on examples
• Common framework
• 1st hand experience
• Motivation
• Confront misconceptions
• Clarification
• Problem solving
• Engaging - interest
Why ABC (Activity Before Concept)

Common Experience

• Movies
  – Chris Rock hosting the Academy Awards
    • The Aviator - no
    • Finding Neverland - no
    • What? - White Chicks
  – “the segment suggesting that the Oscars are out of touch with a huge swath of moviegoers…”