Inquiry-based Laboratory: Transition Your Favorite "Cookbook" Labs

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AUHSD
1. What are inquiry-based labs?

2. Traditional vs. Inquiry Model (Density)

3. Transitioning a classic lab

4. Sample Investigative Lab Rubric

5. Ways in which students may communicate findings
What is Inquiry?

- “encourages students to **construct** and/or **discover** knowledge with an understanding of how scientists study the natural world” (AP Central)

- “the creation of a classroom where students are engaged in essentially **open-ended, student-centered, hands-on** activities” (Colburn, 2000)

- “the **activities** of students in which they **develop** knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (National Research Council, 1996)
explanations

Teacher

Student

opportunity

lab

students

National

skills

证据

知识

解释

学生

教师
Inquiry Continuum

- **Confirmation** - students confirm a scientific principle via prescribed procedural activity
- **Structured-inquiry** - teacher presents question and procedure
- **Guided-inquiry** - teacher presents question and students design their protocols
- **Open-inquiry** - students generate their research questions and protocols
TRADITIONAL Lab

“Density of a Liquid/Solid” CONFIRMATION ACTIVITY

What we used to do:

- Background/Introduction
- Recipe-like procedure
- Pre-constructed data table
- Directed on what to graph
- Analysis questions (to see if they “get it”)

vs. INQUIRY Investigation!

What we do now!
INQUIRY Model: Density PRE-LAB Investigation

- Present students with question a “What is the density of an unknown liquid?”
- Students design the experimental protocol (prior knowledge and/or Online research)
- Students construct their data tables
- Students graph mass vs. volume (part of Research Proposal)
INQUIRY Model: Approval of RESEARCH PROPOSALS

- Students must demonstrate a novice conception of the **content** (e.g. density) and **skills** (e.g. measurement, calculations, graphs, etc) embedded in the pre-lab activity.

- Students must provide testable **research questions** and hypotheses (provide sentence frames/starters if needed).

- Students must provide a sound **methodology** (an experimental protocol that tests their hypotheses).
INQUIRY Model

And then they are free to investigate!
Inquiry Model: Overview of STUDENT-DIRECTED Investigation

Students DO the following:

1. Generate their own questions (open-inquiry)
2. Experimental protocols
3. Data collection and organization
4. Data analysis (summary/descriptive statistics; e.g. mean, standard deviation, percent error)
5. Graphical representation of trends in data
6. Evidence-based conclusions/discussions
7. Communication of findings
Transitioning Traditional Labs: Things to Consider while planning

- What’s the **objective**? (What do you want the students to learn?)

- What **content** and **skills** are requisite for the students to generate meaningful/relevant questions, hypotheses, and experimental protocols? (no need to front load--on a “need to know” basis)

- What structured-inquiry **pre-lab** activity would be useful to scaffold higher-level inquiry investigations, such as guided- and open-inquiry?
Transitioning Traditional Labs: Suggested “How to’s”

1. RESEARCH PROPOSAL (must demonstrate proficiency)
2. Get rid of the background/introduction/purpose
3. Pose meaningful questions, and allow opportunities for students to ask their own questions to investigate
4. Don’t give students the recipe; students should develop their own methodologies (e.g. protocols, materials, data tables, graphs, etc)
5. Expect students to write evidence-based conclusions
6. Provide students the opportunity to communicate their findings to an audience
Question: How many drops of water can a penny hold?

Introduction: Surface tension, cohesion, polarity, etc.

Procedure: Place as many drops of water on a penny as you can.

Data Table: Fill in the chart.

Analysis Questions: e.g. Why did the water form a dome?
Question: How many drops of water can a penny hold?

Purpose: Explore the surface tension of water

Materials: Penny, water, dropper

Methods: Place a penny on top of a paper towel. Carefully add as many drops of water as you can using the provided dropper.

Data:

<table>
<thead>
<tr>
<th>Trial #</th>
<th># of drops of water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis Questions:

1. Why does water form a dome on top of the penny?

2. Explain how the polarity of water contributes to surface tension.
Let's transition the Old Penny Lab!

1. What **PRE-LAB** activity would you have the students do to scaffold a Surface Tension Investigation?

2. What *pre-lab component* would you require students to include in their **RESEARCH PROPOSALS** to demonstrate they are ready to extend their understanding of surface tension?
The Inquiry-based Surface Tension Investigation

1. List some research questions that you think your students may ask. (What variables do you think they will choose to test the surface tension of water?)

2. What type of data analysis do you think is possible in this Guided-Inquiry Investigation.
1. What variables do you think they will choose to test the surface tension of water? (e.g. temperature, solute concentration, penny characteristics, other substances/solutions, etc)

2. What type of data analysis do you think is possible in this Guided-Inquiry Investigation? (e.g. mean, graph, standard deviation, t-test)
Sample Investigative Lab Rubric
Communicating Evidence-based Findings

- DataBlitz
- Mini-Posters
- Research Poster
Sample DataBlitzes
Hypothesis: If water attraction pulls itself together into a tight arrangement, then the penny will contain more drops of water than alcohol.

Independent Variable: Water and Alcohol

Dependent Variable: Drops

Control Group: Penny (Tails) 2005

Conclusion: According to the data the penny holds more drops of water than the alcohol because water molecules are tightly bonded. The alcohol molecules are a bit less interlocked and it spreads more on to the penny.

<table>
<thead>
<tr>
<th>Penny (Tails, Same penny)</th>
<th>Trail</th>
<th>Alcohol (97%) 23°C</th>
<th>Water 22°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>29</td>
<td>35</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td>2005</td>
<td>4</td>
<td>29</td>
<td>36</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>29</strong></td>
<td><strong>33.75</strong></td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis: If water is dropped on a paper towel, it will take less drops to leak through than alcohol because it has less chemicals.

Conclusion: It takes less drops of alcohol to leak through a paper towel than water.

Possible explanation: Alcohol has hydrogen that can form bonds with more alcohol, AND other products. Another reason why alcohol might have taken less drops to get through the paper is because it has acidic properties while the water does not.

Independent Variable: water & alcohol
Dependent Variable: number of drops
Control Group: 1 sheet of paper towel
The results of room temperature water/ regular milk drops on a penny

Hypothesis: If you apply droplets of regular milk and room temperature water on a penny then the room temperature water on the penny will consist longer.

Research question: What liquid can last the longest on the penny?

Conclusion: From the data, the results showed that room temperature water can contain more drops on the penny than regular milk. This means that water’s surface tension lasted longer than the regular milk.

Explanation: The milk’s cohesive forces broke faster than the water. The water molecules stuck together longer.

<table>
<thead>
<tr>
<th></th>
<th>White milk</th>
<th>Temp. water</th>
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<tbody>
<tr>
<td>Mean</td>
<td>28.75</td>
<td>40.5</td>
</tr>
<tr>
<td>Variance</td>
<td>3.6875</td>
<td>110.25</td>
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<tr>
<td>Observations</td>
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<td>5</td>
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<tr>
<td>Pearson Correlation</td>
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<td></td>
</tr>
<tr>
<td>Hypothesis</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>-2.24319</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.044155</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>2.131847</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.088309</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.776445</td>
<td></td>
</tr>
</tbody>
</table>
Comparing Water with Different Quantities of Salt

RESEARCH QUESTION: Does different quantities of salt affect the number of drops possible on a penny?

HYPOTHESIS: If we add different quantities salt to water and place drops on a penny, the different quantities will have different amounts of drops that actually fit on the penny.

INDEPENDENT VARIABLE: Salt

DEPENDENT VARIABLE: Number of drops

CONCLUSION: Our hypothesis needs to be rejected because we cannot prove it. There was too much variability in our trials to prove that there was a clear result in the addition of more salt.

PLAUSIBLE EXPLANATION: A plausible explanation of why the results were all over the place was either because we dropped the drops from different heights, we let the drops fall too fast, or both.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23(2mL)-22 (6mL)</td>
<td>29(2mL)-48 (6mL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.39(2mL)-6.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6mL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2(2mL)-2.81 (6mL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.28</td>
<td></td>
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<tr>
<td></td>
<td>2.57</td>
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</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.78</td>
<td></td>
</tr>
</tbody>
</table>

How Many Drops of Salt Water Fit On Top the Head Side of a Penny
What about your “cookbook” labs?

Feel free to peruse the mini- and full-research posters

Contact: Ron Michelotti

michelotti_r@auhsd.us


<table>
<thead>
<tr>
<th>Lab Part</th>
<th>Score (100)</th>
<th>Advanced (100%)</th>
<th>Proficient (80%)</th>
<th>Needs Improvement (50%)</th>
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</thead>
<tbody>
<tr>
<td>Research Proposal</td>
<td>10</td>
<td>Complete and on time (in Science Notebook)</td>
<td>NA</td>
<td>Completed after deadline. (in Science Notebook)</td>
</tr>
<tr>
<td>Title</td>
<td>5</td>
<td>Title indicates the nature of the investigation.</td>
<td>Title is somewhat indicative of the nature of the investigation.</td>
<td>Title is vague.</td>
</tr>
<tr>
<td>Background (Literature Review)</td>
<td>10</td>
<td>The background clearly provides the context, or what is known, for the research question(s).</td>
<td>The background is provided, but there is little “tie in” to the nature of the investigation.</td>
<td>The background is poorly stated and provides little context for the investigation.</td>
</tr>
<tr>
<td>Research Question(s)</td>
<td>5</td>
<td>Question is narrowly focused and suggests how an answer might be investigated. It is answerable.</td>
<td>Question is answerable but not narrowly focused.</td>
<td>Question is too broad and not practically investigated.</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>5</td>
<td>Hypothesis is testable and clearly stated in “If… then…” format.</td>
<td>Hypothesis is clearly stated.</td>
<td>Hypothesis is poorly stated.</td>
</tr>
<tr>
<td>Identification of Variables</td>
<td></td>
<td>Specifically predicts relationship between independent and dependent variables. Correctly identifies specific, measurable independent and dependent variables.</td>
<td>It predicts the influence of one variable on another. Identifies variable being tested (IV) &amp; variable being measured (DV).</td>
<td>It doesn’t directly mention the variables. Variables and constants significantly incomplete &amp;/or inaccurate.</td>
</tr>
<tr>
<td>Methodology</td>
<td>15</td>
<td>Accurately tests the hypothesis. Conducts or analyzes at least 3 trials. (5 pts) Procedure is in past tense/passive voice, accurate, complete, easy-to-follow, and reproducible by another person. (5 pts) Complete, detailed list of Materials (size, conc., quantity) presented in vertical list format. (3 pts) An appropriate Statistical Test is selected, and described, to determine the significance of their results/data. (2 pts)</td>
<td>Attempts to test hypothesis. Multiple trials attempted or need is recognized. Procedure generally complete. Minor errors/omissions make it difficult to follow or not always repeatable. Not in past tense/passive voice. Most materials are listed and appropriate. An appropriate statistical test is selected, but not coherently described.</td>
<td>Does not address hypothesis. Single trial, poor understanding of use of multiple trials. Procedure difficult to follow. Major omissions or errors. Materials quite incomplete or inappropriate for experiment.</td>
</tr>
<tr>
<td>Statistical Tests</td>
<td>20</td>
<td>Data Table with descriptive title contains accurate, precise raw and analyzed data reported in correct SI units. (5 pts) Data summarized in well organized, easy-to-read Graph &amp;/or Figures. Descriptive title, appropriate labeling, keys, etc. (5 pts) Sample Calculations (including data analyses) are clear and devoid of error. (5 pts) Written Summary of data in a clear, concise, logical manner. Patterns identified and described, but no conclusions drawn. (5 pts)</td>
<td>Data table with accurate data, most units labeled or implied. Minor errors. Title absent or trivial. Data displayed in well organized easy to read graph &amp;/or figures. Minor errors in use of units and labeling. Sample calculations contain minor errors. Reasonable, but somewhat unclear summary of data. Patterns in data not clearly identified.</td>
<td>Data table inaccurate, confusing, and/or incomplete. Missing units. Graph/figures presented in a confusing and/or sloppy fashion. Sample calculations contain multiple errors Summary is unclear and illogical. Patterns in data not identified.</td>
</tr>
<tr>
<td>Conclusion/Discussion</td>
<td>25</td>
<td>Scientifically valid, logical CLAIM which clearly addresses the research question (problem). (5 pts) Claim is well supported by appropriate and sufficient analyzed data and/or observations (EVIDENCE). (5 pts) Justification (REASONING) clearly shows why the evidence supports the claim AND includes relevant scientific literature. (5 pts) Limitations of the study are detailed: sources of error identified (and explained) AND appropriate recommendations made to reduce error. (5 pts) Generates specific questions for future study and discusses the relevance of the research. (5 pts)</td>
<td>Scientifically valid, logical claim; though weak attempt to address the problem. Provides appropriate, but insufficient evidence to support claim. Justification links the claim and evidence, but the claim is inadequate supported by the evidence and/or relevant scientific literature. Sources of error identified but not necessarily explained and/or no recommendations to reduce error. Weak attempt to generate questions for future study.</td>
<td>Claim is incomplete or illogical. Does not address the problem and/or hypothesis. Does not provide appropriate evidence to support the claim. Missing or unreasonable justification—does not does not link evidence to claim. Weak/trivial attempt to identify sources of error and/or no recommendations to reduce error. Incomplete or inappropriate attempt to extend or apply knowledge.</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>5</td>
<td>Cited [reputable] work/literature is listed in correct bibliographic form (MLA- Modern Language Association).</td>
<td>Cited work is incomplete OR not in correct bibliographic form.</td>
<td>Cited work is incomplete AND not in correct bibliographic form.</td>
</tr>
</tbody>
</table>
Inquiry-based Laboratory:
Transition Your Favorite "Cookbook" Labs

Planning- Setting the Stage!

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How to’s:

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