Why (not) Inquiry Labs?

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My bio

- 46 year old career changer. Teaching 2016-Present
- 22 year corporate career started when I was 19.
  - 1992-94 Corning Inc. - Technician
  - 1996-2000 Imaging & Sensing Technology - Manufacturing / R&D Engineer
  - 2000-2003 CoorsTek - Sales & Marketing Manager
  - 2003-2006 Imaging & Sensing Technology & Heraeus GmbH - Director of Sales
  - 2006-2014 Kinesis Inc. - President & Equity Partner
- AAS Chemical Technology - Corning Community College 1994
- BS Chemistry Elmira College 1997
- MAT SUNY Empire State College 2017
- 3 Patents, Published, National/Regional Research and Business Strategy Presentations.
- International business experience in many different end-user industries.
Despite strong policy statements, frameworks for education and standards guidance, implementation of inquiry learning and argumentation in the science classroom is s-l-o-w.
Teaching chemistry is my “retirement job.” Therefore, if it isn’t fun, I don’t want to do it.

Fun is structured, planned, predictable and organized.

If it isn’t intellectually rewarding, it isn’t fun.

My Mindset in Chemistry
“Pass on what you have learned. Strength. Mastery. But weakness, folly, failure also. Yes, failure most of all. The greatest teacher, failure is. Luke, we are what they grow beyond. That is the true burden of all masters.”
Reluctance Prevails

- “Content is King” standards-based instruction
- Fear of student or teacher failure
- Potential for loss of control in the classroom or lab
- High stakes exams are a constant pressure.
How did I get started?

1. Identification of the thing I hated more than titrating past an endpoint
2. Decision and commitment to not do it anymore

Inspired by one honest question at a summer conference July 2017
Liquid Rainbow Density Lab

Pre-Lab Discussion

Density is defined as the ratio of mass to volume. The density of pure water is 1g/mL. Objects with a higher density will sink and objects with a lower density will float. When making a density gradient with solutions, the solution with the highest density will sink to the bottom and the lightest density will be on top.

Purpose
The purpose of this lab is to observe the properties of density by layering solutions to create a density gradient.

Equipment
balance
Water
Eye dropper
Food Color
Sugar
4- 50 ml beaker
Plastic spoon
50 ml graduated cylinder

Procedure
1. Label 4 beakers red, yellow, green, blue
2. Place the red beaker on the balance and zero. Weigh 1.5g of sugar into the red beaker. Record the Mass in the data chart.

Observations and Data

<table>
<thead>
<tr>
<th></th>
<th>Mass of Sugar</th>
<th>Volume of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions and Questions

MATH PROBLEMS - NO WORK, NO UNITS, NO CREDIT

Observation of Density Rainbow:
1. Which solution had the highest density? Was this what was expected? [1]
2. Why did the different colors stay separated in a rainbow? [1]
3. Does the density of an object remain the same regardless of the size? Why? [1]

What color is at the top of the 50 ml gr
1. [ ]

What color is at the bottom of the 50 gr
4. A piece of metal has a mass of 520.00 g and a density of 8.4 g/cm³. What is the volume of this piece of metal, given to the correct number of significant figures? [1]

Less fun than the middle seat between sick people with cranky lap children on a flight to Europe
Easy to find no-inquiry, no-fun lab resources.

Safety Precautions
Exercise caution when using the hot plate and when handling objects that have been heated. Do not touch the evaporating dish or anything that may remain hot. Wear safety goggles while...

Beginning
Teacher passionately describes the dozens of ways everyone will have fun and what they will observe, measure and learn. Safety precautions are given in vivid, graphic and painstaking detail. No one listens or is interested. No one asks any questions aloud. Mentally, each student questions whether the teacher will see them texting at the bench.

Middle
Everything the teacher has already said is repeated for each lab group at their bench when they show clear signs of not knowing the directions, not being aware of safety, standing around doing nothing, and doing a poor job of hiding their texting activity.

"I already said this in the prelab discussion."

End
Everyone gets the answers needed whether through luck, persistence, or copying off the group nearby. Yay! 40 minutes and we survived yet another lab with chemically death all around!

Pre-Lab
Due to the widespread use of sodium bicarbonate products, the thermal decomposition reaction of Baking soda is used to prepare cakes in order. As the temperature of the cake batter reaches 350° Fahrenheit, carbon dioxide is released. The use of baking soda is necessary since the high cooking temperatures of 350° Fahrenheit cause the dough to expand. This, in turn, allows the cake and tortilla to rise.

Possible Decomposition Reactions
sodium hydrogen carbonate (s) \rightarrow sodium carbonate (s) + water (l) + carbon dioxide (g)

Materials
Baking soda
Balance, 0.01 g precision
Hot Plate
Spatula
Evaporating Dish
Crucible tongs

5. Conclusions
a. Based upon individual results, how did you rule out the other two chemical reactions?
b.
Inquiry Model & Scientific Method

PROBLEM OR QUESTION
Start with an observation and problem statement or question.

BACKGROUND RESEARCH
Students spend 10 minutes doing a Know-Need to Know Analysis and brief research.

COMMUNICATE RESULTS AND CONCLUSION
Students write a complete lab report including discussion of results and a conclusion in CER format (Claim Evidence Reasoning). Identification of additional questions and future work.

EXPERIMENTAL DESIGN
Students design an experiment, write a procedure and create a data table.

FORM A HYPOTHESIS
Based on background research, students write a hypothesis that answers the question, is testable and predicts an outcome.
How do you know the outcome?

Your question starts with the end.
- Start with the students’ bank of prior knowledge.
- Choose a question or problem that is achievable.
- Start with one of your packets and form a question or problem from the purpose.

Reinforce, but don’t tell.
- Let students work the problem.
- Facilitate and reinforce, but don’t tell.
- Let them research their way out of it.
- Post readings or links to applicable information.
- It’s a game. Wait for them ask the right questions.
- Answer directly and don’t mislead. The students MUST trust you.

You might be surprised.
- What makes it the “right way”?
- If you don’t create a culture for learning and inquiry, all you will ever see is what you show them.
- It’s like watching a bad or mediocre movie 100 times.
“If you are the hardest working person in the lab, during lab, you are doing it wrong.”

Ask the teacher
- What are we supposed to do next?
- What happened? I don’t think it worked?
- Is this calculation correct?
- Can you check my work?
- How do we do this?
- Where is the sodium chloride?
- This metal solid can go down the drain, right?
- Can I have a snack now?
- Why can’t we eat in here?
- Does this look finished?
- Can you read this and see if it is OK?
- Can I copy off yours?
- Let’s all make sure we write down the same thing.

Noise > Any Signal
- OMG! I hate lab days.
- I wonder if there are tater tots at lunch today?
- What’s happening on my Snapchat?
- Was that a text? Wonder if there’s a text.
- What’s that smell?
- Why do I have to work in this group again.
- When are we gonna blow something up in chem lab?
- Are we gonna do any fun labs?

At the Lab Benches
- Where’s my packet? Anyone have a pencil? I hate lab goggles. These aprons are stupid. What are we doing today? When is this due? Is this going to count in our grade? How many lab minutes do I have? Do I have to do this lab? When can we sit down? When do you take your driver’s test? What’s due in Algebra today? Did you do the US History homework? I wonder if he’ll see me working on my English packet.
Are you a lifeguard or a swimmer?

Image: https://jellis.com/sites/all/themes/accolari_bootstrap.img/lifeguard_pool.jpg
<table>
<thead>
<tr>
<th>Procedure? They can't write a procedure!</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No one listens to the pre-lab discussion so they don't know what to do.</strong></td>
</tr>
<tr>
<td>- Why waste your time talking if no one is listening?</td>
</tr>
<tr>
<td>- If you don't like what is happening, change it or don't do it.</td>
</tr>
<tr>
<td>- Just don't do it. At least if they ask, you won't have already told them.</td>
</tr>
<tr>
<td><strong>They rush to the data table and try to figure out the fastest way to get the lab done.</strong></td>
</tr>
<tr>
<td>- No pre-formatted data table = the students must think about what they are trying to accomplish and how they will do it before they start.</td>
</tr>
<tr>
<td>- Coaching and mentoring opportunities.</td>
</tr>
<tr>
<td><strong>Someone starts working on the conclusion questions so everyone else can copy.</strong></td>
</tr>
<tr>
<td>- Banal conclusions questions and practice exam questions have no business being on a lab. Exam practice is for homework, or classwork.</td>
</tr>
<tr>
<td>- Collaboration is the goal. Copying is not.</td>
</tr>
<tr>
<td>- A conclusion should demonstrate DEEP thinking about the experiment.</td>
</tr>
<tr>
<td><strong>How long until they tell you they don't know what to do next?</strong></td>
</tr>
<tr>
<td>- Problem solved. You don't know either!</td>
</tr>
<tr>
<td>- It is their lab, their experiment and their work.</td>
</tr>
<tr>
<td>- They have to find their own way to the end.</td>
</tr>
<tr>
<td><strong>Did you even read the procedure I wrote for you?</strong></td>
</tr>
<tr>
<td>- I have not asked this question in since May/June 2017. It feels tremendously good.</td>
</tr>
</tbody>
</table>
**Typical Timeline**

**HEALTH & SAFETY**

**5 POINTS**

Revised Concept:
1. Safety hazards
   a. Personal injury
   b. Chemical exposure
2. Accidental & Injury Prevention
   a. Personal Protective Equipment (PPE)
   b. Lab Procedures (GLP)
3. Environmental & Health Impact
   a. Impact of reactants on environment
   b. Waste disposal

In this lab, we will be using many hazardous materials such as propane, fire, and a variety of different elements. We will make sure that we avoid burning or injuring ourselves by using personal protective equipment. Our PPE includes goggles and gloves. We won't leave the propane on, stand too close to the fire, and wash our hands after the procedure to ensure work is done with good lab procedure. We must not have skin contact with any of the elements because they will result in irritation. We must also be aware of the environmental impact, as the elements can sink into soil and groundwater and pollute them.

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**Lab Day 1**

**Lab Day 2**

**Lab Day 3**

**Lab Day 4**

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**Lab Day 5: Cosmic Flames**

Cosmic Flames is a commercial product used to add color to dull, boring, pathetic campfire flames. Every campfire wants to be colorful.

**Task 1:** I would like you to identify the chemical composition of cosmic fire and verify, through experimentation, what substances are present.

**Task 2:** Either make a formulation to comparison test to the packaged product or propose and test a better formulation that will become a superior product to any other commercial campfire flame colorant.

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**Communicate your Conclusion**

Our experiment supported our hypothesis; we hypothesized that we would be able to determine the composition of the Cosmic Fire by radio different elements and comparing their effects on the flame and the bright line spectrum to the effects of the Cosmic Fire. We also tested our own replication of Cosmic Fire, which is made of C2 and C2 and found that the two were nearly identical in terms of appearance of the flame and the bright line spectrum. We collected data based on how the flame's color and bright line spectrum changed—e.g., when the potential solution was sprayed into the flame, we observed through the spectrum that the orange, green, and purple lines became brighter, and we also saw the flame change to a bright orange. In class, we learned that when energy is absorbed by electrons, they move to an excited state, and once this energy has been released, the electrons return to their ground state, and the observed changes are in the bright line spectrum. Any sources of error may have been caused by reagent from previously used solutions still affecting the flame when we spread another solution, which could potentially affect the flame's color. Considering this, we could improve our experiments by spraying water into the flame apparatus, which would equalize most mistakes.
My labs typically run for 2 weeks. I am on an A/B schedule with 40 minute periods. I have two labs per week with each section.

**Lab Day 1**
Teacher presents the problem or question to the class. The students have 10 minutes to formulate questions. Answer questions and students start writing hypothesis. Any time left is use to complete background research.

**Lab Day 2**
Students complete all background research. Students ask for workshops for any equipment they don’t know how to use and complete health and safety assessment. Experiment procedures are written and data tables are created.

**Lab Day 3**
Experimentation begins. Students assemble their equipment and gather materials needed for the experiment. All data and observations are recorded and students outline results. Students clean up work areas and wash glassware.

**Lab Day 4**
Students finish any loose-ends from experiment. Writing is the major focus at this time. Students write discussion of results including what they observed and what they measured in paragraph form. Students write Claim, Evidence, Reasoning Conclusion. Students submit finished lab report.
LAB 03: RAINBOW CYLINDER

A TEST TUBE APPEARS TO HAVE STACKED COLORS OF LIQUID.

HOW WAS THIS DONE? CAN YOU DO THE SAME?

WHAT DO YOU KNOW? WHAT DO YOU NEED TO KNOW?

YOU WILL HAVE 80 MINUTES TO ANSWER THE QUESTION: HOW CAN WE DUPLICATE MR. DAVENPORT’S RAINBOW CYLINDER?
Unique solutions to labs you have always done.
Full lab reports for every lab?

Yes, you have to train them to write.

- Use a report template that clearly states the requirements.
- Grade critically, but fairly.
- Make it look nice.
- Grouping strategies need to be considered.
- Grading Policy may need support.
<table>
<thead>
<tr>
<th></th>
<th>Problem</th>
<th>Question</th>
<th>Example Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density</td>
<td>✔️ ✔️ ✔️</td>
<td>• Duplicate teacher’s density rainbow, exactly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• What is the density of popped popcorn?</td>
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<td></td>
<td></td>
<td></td>
<td>• What is the thickness of aluminum foil?</td>
</tr>
<tr>
<td>2</td>
<td>Bunsen Burner</td>
<td>✔️ ✔️ ✔️</td>
<td>• What is the hottest part of the flame?</td>
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<td></td>
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<td></td>
<td>• Duplicate the formulation for Cosmic Flames (Bright line spectrum)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Is there potassium in bananas?</td>
</tr>
<tr>
<td>3</td>
<td>Separation of matter</td>
<td>✔️ ✔️ ✔️</td>
<td>• Separate mixture of unknown components (sand, salt, iron filings).</td>
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<td></td>
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<td></td>
<td>• Given 1L of prepared gelatin, return only pure water.</td>
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<td></td>
<td></td>
<td></td>
<td>• Demonstrate conservation of mass (bag rx).</td>
</tr>
<tr>
<td>4</td>
<td>Acid / Base</td>
<td>✔️ ✔️ ✔️</td>
<td>• Quality Control Check vinegar samples.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• How much phosphoric acid / citric acid in soda?</td>
</tr>
<tr>
<td>5</td>
<td>Redox</td>
<td>✔️ ✔️ ✔️</td>
<td>• Make a battery from pennies. Mix new and old for a challenge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Grocery Store Voltage Challenge.</td>
</tr>
<tr>
<td>6</td>
<td>Chemical Reactions</td>
<td>✔️ ✔️ ✔️</td>
<td>• Hydrogen micro rockets (Flinn Lab)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reaction Toolbox (Escape Room Tasks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>○ Turn aluminum into copper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>○ Make chalk</td>
</tr>
</tbody>
</table>
My lab catalog is constantly changing

- Lab 01: Ties In Swimming - Precision & Sig Figs
- Lab 02: Density of Matter
- Lab 03: Classification of Matter
- Lab 03: Density Rainbow
- LAB 04: Bunsen Burner Flame
- LAB 05: Cosmic Flames
- LAB 05: Flame-o-matic
- Lab 06: Physical Separation of Matter
- Lab 07-09: Pop Goes The Reaction (Inquiry)
- Lab 07: Gone Bananas
- Lab 07: Nuclear Half Life
- Lab 08: GAK
- Lab 09: Pop Goes the Reaction
- LAB 10: Slime Product Development
- Lab 10: Which Product?
- Lab 11 Water Water Everywhere and Not a Drop to Drink
- Lab 11: Hydrated
- Lab 12: Get a Reaction!
- Lab 12: How Much Sugar?
- Lab 13: Intermolecular Forces
- Lab 15: Under Pressure
- LAB 16: Part of the Solution
- LAB 17: Colligative Kitchen
- Lab 20: Vinegar Quality Control Check
My Grouping Strategy for Collaboration

Top 6 students in the class based on grades, writing ability, motivation, and leadership, make up the Molecule Group. This group of self-directed students collaborates with all other groups, but complete their own group work. These are my TAs in the lab. The molecule group writes a higher-level lab report summarizing whole-class data and observations. They take an active, facilitating role in experimentation, but do not dominate the hands-on work.

- **Molecule Group**
- **Orbital Group**
- **Isotope Group**
- **Proton Group**
- **Electron Group**
- **Neutron Group**
- **Ion Group**

4-5 Groups of 3-4 students each. 2 students from second quartile and 1-2 from third quartile. These students can (be trained to) work independently and with help from one member of the Molecule Group who collaborates with them full-time during the experiment.

The bottom quartile of students, or those with social difficulty are in the final group. This group gets the teacher’s direct attention and more assistance as needed. One of the Molecule Group works with these students as well.
2017-18 Inquiry-based labs
13% Mastery - increased 2X
Survey, Certificate, and Downloads

To complete a brief survey about this webinar, and to generate your certificate of attendance, visit: 

To Download Resources:

Want to present a webinar this year? Send an email! 
AACTconnect@acs.org