From Cookbook to Guidebook: Remaking Traditional Biology Labs Into Active Inquiries

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Dan has been the Core Curriculum Coordinator for biology since 1998 at Wake Forest University, where he holds the rank of teaching associate professor.

While trained as a cardiovascular cell biologist, Johnson's interests span the breadth of biology. He has spent nearly two decades designing, developing, and publishing inquiry-oriented biology laboratories and other active-learning instructional materials. In 2008, the National Science Teachers Association published his guide to inquiry instructional development for faculty, *40 Inquiry Exercises For the Biology Laboratory*. In 2010 the College Board used this book as a guide for developing the new Advanced Placement biology curriculum.

Johnson is a senior editor (and a regular contributor) for *Tested Studies for Laboratory Teaching,* an international open-access journal published by the Association for Biology Laboratory Education.

Johnson with, a group of educators, students, developers, and others who create open-access resources that help more students learn science successfully, published BioBook in 2011. Their second project, *Teaching Genetics with Dogs*, was launched in 2012, and uses our familiar pets to teach genetics principles and engage students more deeply.

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From Cookbook to Guidebook:
Turning Traditional Biology Labs into Active Inquiries

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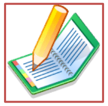
Overview

- Setting the stage
- Old vs. new “Diffusion…” lab
- General design strategy
- Q&A
- Tips & tricks, common problems
- Icons*
  -  Take-home points
  -  General strategy
  -  Tools, tricks & tips

*http://commons.wikimedia.org/wiki/Crystal_Clear

Slides, Notes, Annotations

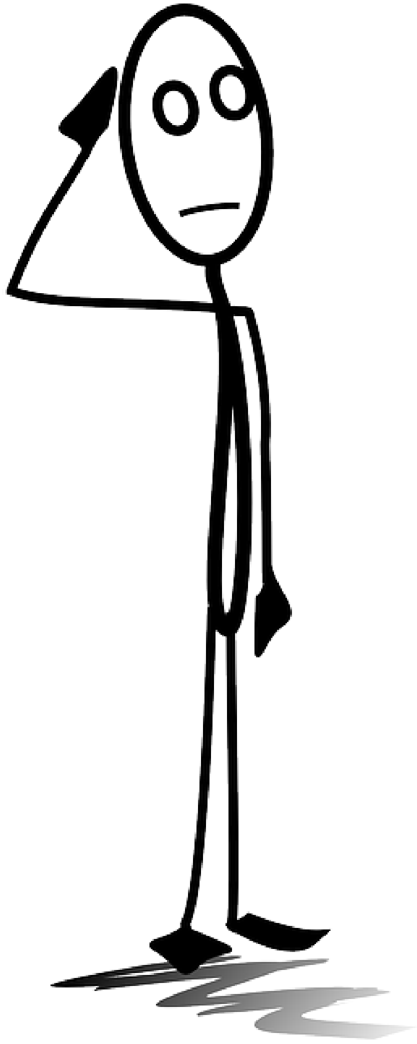
- Slides available on CHEO wiki
- Revised slides (Q&A follow-up, updated notes) to follow
- Steps to modify for online-only format marked '**N**'

Setting the Stage

- **What are main lab design barriers?**
  - Right mindset
  - Good, durable ideas
  - Hard design decisions

Setting the Stage

- How do I get into the "inquiry mindset"?



Setting the Stage: Mindset

Remember main goal of inquiry
Students should spend most of their time on:

- Autonomous exploration
- Authentic activities

Setting the Stage: Mindset

Inquiry has different-

- Outcome goals
  – Development process differs
- Assessment process
  – More frequent, open-ended
- Class structure, flow **'N'**
  – Messy, loud, less predictable
- Management strategy **'N'**
  – Instructors must adapt *in situ*

Setting the Stage: Mindset

Picture a mentored research lab experience

- What skills would you expect students to develop?
- How would students get those skills?
- How would students report their findings?

Setting the Stage: Mindset

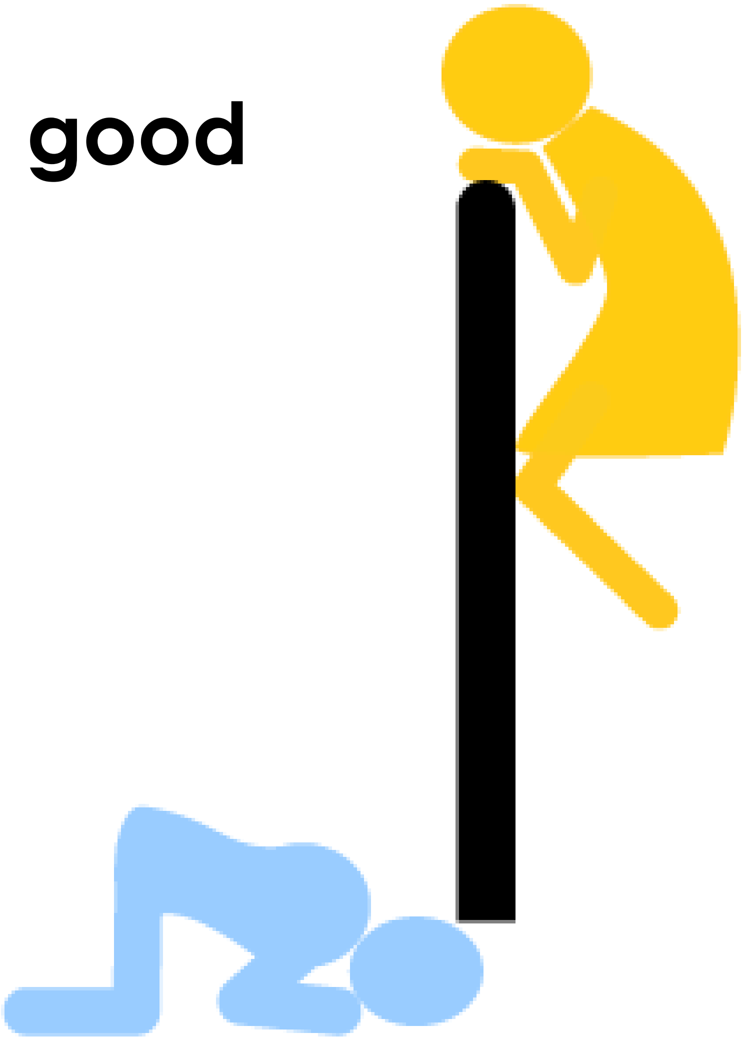
Think coaching, not content delivery

How will this lab…

- Create positive challenges?
- Identify weaknesses, & correct them?
- Provide practice opportunities?

Setting the Stage

- Where do I find good lab ideas?

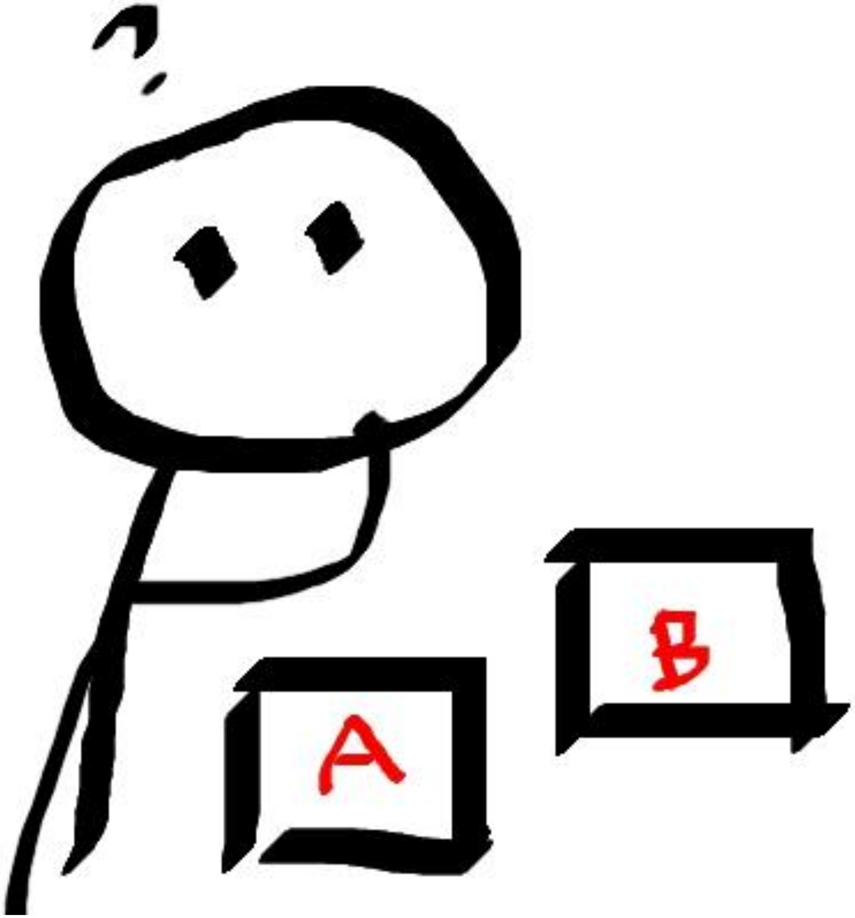


Setting the Stage: Ideas

- **Look <u>broadly</u> for inspiration**
  - Hardware, craft, pet, hobby stores
  - Science news feeds
  - Be a "catalog hoarder"
  - Maker websites, magazines
  - Citizen science programs
  - Consumer product claims
  - **Ask students** for ideas

Setting the Stage

- How do I make well-informed design decisions?



Setting the Stage: Design

- Look for **why** current lab does not work
- Think **carefully** whether to refine, renovate, or restart
- Do not be afraid to start over
  - Good ideas are not always durable

Setting the Stage: Design

- **Refine**
  - Start with existing inquiry lab (+ and –)

Setting the Stage: Design

- Refine
  - – Start with existing inquiry lab (+ and –)
- **Renovate** cookbook lab
  - – Uses existing equipment, exercises (+)
  - – Restricts design, backsliding risk (–)

Setting the Stage: Design

- Refine
  - Start with existing inquiry lab (+ and –)
- Renovate cookbook lab
  - Uses existing equipment, exercises (+)
  - Restricts design, backsliding risk (–)
- **Restart**
  - Fewer design restrictions (+)
  - Longer planning, development (–)

 "50% rule"

Diffusion Through a Membrane: Original Version

1. Fill dialysis tubing "cell" with glucose, starch, or combined sol'n
2. Float in Lugol's starch indicator

3. After 20+ minutes record:
   - Water inside "cell" is black (starch "+")
   - Water outside "cell" is "+" w/glucose indicator solution
4. Report results (worksheet, lab rept.)

Problems With Original Lab

1. Dialysis tubing
   - Unfamiliar, less engaging
   - Cannot vary properties
2. Assays show diffusion <u>indirectly</u>; do not directly observe
   (Iodine sol'n – hazardous)
3. Students report <u>known</u> outcomes

Problems With Original Lab

4. Reinforces misconception that exercise = experiment
5. Where do students:
   - Experience "positive challenge"?
   - Exercise critical thinking?
   - Make their own decisions?
   - Discover "personally novel" knowledge?

One Possible Revision Strategy

New lab has 5 stages:

- Initial assessment
- Open exploration phase
- Initial group reporting
- Guided inquiry phase
- Final group reporting

Diffusion 2.0: Initial Assessment

Instructor's Lead-In Questions 'N'

- What do you know about diffusion?
  (Assessing prior knowledge)
- How do you know it?
  (Expect evidence)
- Is ____ an example of diffusion?
  (Example vs. counter-example)

Diffusion 2.0: Open Exploration Phase

Student Directions

Your 1st challenge–

- Create a novel visual demo of diffusion
- Use any materials here in lab. **'N'**
  - Give materials list
  - Hold back the optional hints
- You have until ___ to finish, report

Optional Hints to Guide Students

- What will be diffusing substance?
- What will carry diffusing molecules?
- What will absorb color for observations?
- What can mimic membrane?
- What containers will you use?
- What will you need to quantify, and how will you do it?

Diffusion 2.0: Available Materials

- What are colored diffusible materials?
  - Offer both soluble, particulate colorants
  - **Particulate**: pigment based paint, some wood stains (see label)
  - **Soluble**: food coloring, pond dye, cherry soda, red wine, strong coffee

Diffusion 2.0: Available Materials

- What will carry, absorb color?
  - **Liquids**: water, vegetable or mineral oil
  - **Solids**: marshmallows, balsa wood, styrofoam, banana or other fruit cubes

Diffusion 2.0: Available Materials

- What can mimic cell membrane?
  - Latex vs. nitrile gloves
  - Saran wrap vs. plastic sandwich bag
  - Newspaper in 1-10 layers
  - Brown vs. white paper towels, coffee filters
  - Porous plastic membrane (for wrapping vegetables)
  - House wrap

Diffusion 2.0: Available Materials

- What containers are available?
  - Canning/jelly jars with lids, rings
  - Beakers, flasks (hard plastic is best)
  - Styrofoam or plastic cups

Diffusion 2.0: Available Materials

- How to quantify color differences?
  - Paint sample or art color charts
  - Rulers
  - Serially diluted stock sol'ns
- Miscellaneous std supplies
  - Rubber bands, parafilm
  - Strong string, dental floss
  - Duct, masking, clear tape

Diffusion 2.0: Initial Group Report

- Use a **general** question template **'N'**
  - What did you do?
  - Why did you do it?
  - What did you see?
  - What does it mean? (Ex.: "how does it show diffusion?")
- **Add** 1-2 specific qus. directed at central question
  - "Based on the demos & data, is rate of diffusion constant?"

Diffusion 2.0: Guided Inquiry Phase

- ***Options A & B***:
  - Background: rate of diffusion depends on factors like -
    - Area available
    - Concentration gradient
    - Properties of diffusing material
    - Distance
    - Temperature

Diffusion 2.0: Guided Inquiry Phase

- ***Options A & B*** (cont.):
  - Second challenge is to determine:
    - ***Option A*** *(basic):* how **one** factor affects rate of diffusion.
    - ***Option B*** *(intermediate):* which factor **most** affects diffusion.
  - You have until ____ to report to class

Diffusion 2.0: Guided Inquiry Phase

- ***Option C*** (advanced):
  - Rate of diffusion determined by several factors.
  - **Your second challenge** is to determine which factors control how fast diffusion occurs
  - Work with others in lab to solve challenge **'N'**
  - You have until ____ to report what you discovered

Diffusion 2.0: Final Group Reporting

- **Repeat** general question template:
  - What did you do?
  - Why did you do it?
  - What did you see?
  - What does it mean?
    (Ex.: "how does it show diffusion?)
- **Add** 1-2 specific qus. about:
  - Alternate explanations
  - Links to other lab units, topics

General Design Strategy Used

- Set learning goals
- Create path to central question
  - Scaffold new exercise
  - Write specific activities
  - ID resources in existing labs
  - Compile materials list
    - Select/create reporting, assessment activities

Set Learning Goals

- **General**:
  – Determine what affects rate of diffusion
- **Basic performance**:
  – Describe molecular process of diffusion
  – Name 2+ factors affecting rate
  – Explain how/why (write or draw)
  – Support explanation w/**own** demo, data
- **Advanced performance:**
  – Build gen'l Fick eqn. w/class data

Find an Engaging Central Question

- What can students explore in diffusion?
  - Know* rate of diffusion varies
  - Unlikely to know* rate depends on:
    - Area available (A)
    - Concentration gradient (ΔC)
    - Distance traveled (ΔX)
    - Temperature (T)
    - Intrinsic properties (I) of diffusing material (molecular size, polarity, charge, etc.)

* Check w/lead-in evaluation **'N'**

Create a Path to Central Question

- Use questions to guide thinking:
  - Repeating basic templates builds thinking skills
  - Mix direct, divergent, convergent qu. **'N'**
  - Avoid extraneous questions
- Mix individual & collaborative work, enforced pauses **'N'**:
  - Assemble, discuss information
  - Elicit predictions
  - Decide next steps

Scaffold the New Exercise

1. What will be lead-in evaluation?
   – Does it ID prior knowledge?
2. What will they do in open exploration phase?
   – How does it lead to central question?
3. How will interim/initial reporting occur? **'N'**
   – Is it informative, relevant, & authentic?

Scaffold the New Exercise

4. During guided inquiry:
   – What authentic question can they explore?
   – Can they explore it MULTIPLE WAYS?
5. How will they report outcomes? 'N'
   – Is it authentic?
   – Does it foster collaborative thinking?

Pull Resources From Existing Labs

- Think **components**, not exercises
  – Rarely useful "as is"
  – Most need revision, many are scrapped
- Focus on:
  – Reusable model systems, assays
  – Collaborative reporting activities
  – Reusing equipment repeatedly
  – Formative, summative assessments

Compile Materials List

- When writing a materials list:
  - List amts. req'd in **blocks** of 2-4 students **'N'**
  - Add 25% extra for mistakes, repeats
  - Include:
    - Gen'l materials available for all labs
    - Detailed preparation instructions
    - Preferred vendors (& why) with catalog numbers

Decide on Assessment, Reporting

- Activities, guide & follow-up qus. should:
  - Consolidate learning
  - Differentiate learning goals achieved
  - Match real-world uses

Decide on Assessment, Reporting

- *Examples*:
  - What factors did you discover affect diffusion rate? (Low-stakes exposition)
  - What OTHER factors might affect its rate? (Extrapolation)
  - What is the relationship between the factors? (Integration and synthesis)
  - How could we test that? (Collaborative follow-on design)
  - Anyone have evidence saying otherwise? (Inviting disagreement)

In Summary

- New lab is guided inquiry with multiple implementations
  - Adaptable design
  - Final form depends on local reqs.
  - ONE strategy of many options

Questions?

For Questions or More Information…

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Supplemental Slides

- Practical tips, tricks, tools
- Common design mistakes

Practical Tips & Tricks: Design

- **Document** rationale, goals for lab
- Make copious notes, particularly about thought process
  - Goals & strategy should be clear to those NOT using inquiry.
  - Add notes to instructor's suppl.
- **Every** element must **earn** its place
  - Time is precious - assume "no" first
  - Think, plan "ideal to real"

Practical Tips & Tricks: Design

Create reusable design templates

- Ex.: a directed question template for experimental design
  - What are you doing?
  - Why are you doing it?
  - What do you think you will see?
  - If you see that, what will it mean?
  - If you do not see what you expect, what will it mean?

Practical Tips & Tricks

Invite technology into lab

- NANSLO labs have advanced digital cameras
- Offer other options:
  - Students can use phones to document results.

Practical Tips & Tricks

Give students time to struggle, fail, recover

- Too much structure limits challenge
- Example from demo lab:
  - Do not give hints for guided phase
  - Only give selectively as students reach barriers to progress **'N'**

Common Lab Design Mistakes

Poorly placed repetition

- **Expect** students to transfer knowledge to lab **'N'**
  - Ex.: if instructor explains diffusion in lecture, **reinforce** in lecture
    - Class Q & A
    - Video or web simulation
    - Simple demo
  - Reserve lab time for **active** inquiry

Common Lab Design Mistakes

Overloading available time

- In 2-3 hrs, students can complete 2 full activity cycles **'N'**
  - Adding more work reduces learning depth, retention time
  - If additional cycles are needed, make lab into a multi-week unit
    - Bonus: multi-week units tend to reduce overall lab operating costs

Common Lab Design Mistakes

Ignoring instructor training

- Those who never experienced inquiry as learners need to see it from student perspective
  - Novice instructors should “take” lab from experienced one
- Provide contextual support materials
  - See slides on design documentation