Considerations for Science Inquiry

Inquiry Resource: http://www.exploratorium.edu/educate/index.html

While most teachers agree with and support the pedagogical principles and philosophy of inquiry-based laboratory activities, they still do not implement them in their classroom. Others have mistaken ideas about what inquiry-based laboratory activities are, what they entail, and what students can achieve with them.

What Are Your Challenges to Implementing Inquiry-Based Laboratory Activities?

Below is a list of common challenges and misconceptions about inquiry-based lab activities. Examine them closely. Check any that apply to you and your classroom/school situation.

____ 1. I have to teach content information to prepare students for the next grade (or the state exam) and they cannot learn it with inquiry.

____ 2. I do not have time to write all new labs to fit with an inquiry approach.

____ 3. I have to stick to the textbook. It already has plenty of labs.

____ 4. There is not enough time to cover the curriculum and fit in inquiry as well.

____ 5. Classroom management would fall apart; the kids become very chaotic if they do not have tight structure and directions for everything we do.

____ 6. I don't need to use inquiry because I use kits.

____ 7. Parents (and supervisors too) will complain if I do not give students step-by-step directions for the labs I want them to do.

____ 8. You really cannot assess inquiry-based labs very well.

____ 9. I am not really sure I can change to this all at once.

____ 10. I have heterogeneously grouped students (or low ability students) and inquiry only works with higher ability or gifted students.

____ 11. My students could never come up with their own questions to investigate.

____ 12. I don't have time to teach everything like this.

Others: Add your own.

Some Information, Tips and Strategies for Overcoming Challenges to Implementing Inquiry-Based Science Laboratory Activities.

1. **I have to teach content information to prepare students for the next grade (or the state exam) and they cannot learn it with inquiry.**

- *On page 36 of Inquiry and the National Science Education Standards, the concern of content and inquiry is addressed in this way: "…student understanding of inquiry does not, and cannot develop in isolation from science subject matter. Rather students start from what they know and inquire into things they do not know."*

- In *Inquiry Primer*, Alan Colburn says this about learning content through inquiry: "*Most studies state that inquiry-based instruction is equal or superior to other instructional modes and results in higher scores on content achievement tests. However some of these studies focused on students who were studying concrete content, which is the strength of inquiry-based instruction*."

- Many state tests, Connecticut, Michigan and New York for example, include questions that assume students have experience with inquiry-based science. Students who have not experienced inquiry-based laboratory activities will have difficulty answering inquiry related questions.

- In "Inquiry-Based Instruction", Eugene Chiapetta and April Adams offer this advice about content being taught through inquiry: "Most science educators would agree that at least five reasons exist for utilizing inquiry-based science instruction in the classroom. Inquiry-based science instruction should promote:
    i. Understanding of fundamental facts, concepts, principles, laws and theories;
    ii. Development of skills that enhance the acquisition of knowledge and understanding of natural phenomena;
    iii. Cultivation of the disposition to find answers to questions and to question the truthfulness of statements about the natural world;
    iv. Formation of positive attitudes toward science; and
    v. Acquisition of understanding about the nature of science."

2. I do not have time to write all new labs to fit with an inquiry approach.

- You do not have to write new lab- use the ones that fit with your curriculum or are in your textbook. Use the techniques you have learned in this workshop to modify them. Write new labs in the summer when you have more time or request professional development time or department meeting time to do this, perhaps collaboratively with your team or colleagues.

- In "Modifying Cookbook Labs," Clark, Clough, and Berg make this statement about needing all new lab activities:
  "..teachers need not create a new curriculum from scratch or change everything they do. Modifying the structure of pre-existing cookbook labs, asking effective questions such as those suggested here, incorporating appropriate wait-time,

acknowledging and playing off student ideas, and exhibiting positive, nonverbals are all key …."

- Alan Colburn writes in "How to Make Labs More Open-Ended": "You can use materials and activities you already have on hand and feel comfortable with, yet challenge your students in ways that help them think like scientists."

- Labs that are designed to teach particular process skills to students need to be done in a more traditional step-by-step method to ensure that all students learn the same techniques.

- You can find inquiry-based lab activities in some of the new middle level science textbooks or from other curriculum resources in print or online.

3. I have to stick to the textbook. It already has plenty of labs.

- Many of the labs in the textbook are confirmatory in nature and, as such, provide little student involvement except the step- by- step following of directions. Most must be modified to be considered inquiry-based.

- In "Implementing the Learning Cycle," Colburn and Clough say this about textbook laboratory activities: "….Textbooks determine most pedagogical decisions. Teachers typically begin by introducing content verbally, then use a cookbook activity to illustrate and 'verify' what they just presented, and finish with end-of-chapter problems or a highly structured activity in which students practice using the new content. In this process students are rarely mentally engaged in a meaningful manner. This traditional approach to teaching science is inconsistent with the objectives set forth in the NSES."

4. There is not enough time to cover the curriculum and fit in inquiry as well.

- Inquiry should not be considered an add-on or a separate part of the curriculum but rather a vehicle or method for teaching what you would normally teach.

5. Classroom management would fall apart; the kids become very chaotic if they do not have tight structure and directions for everything we do.

- Llewellyn answers this concern this way in Inquire Within: "Classroom management skills are essential to inquiry learning but an active, child-centered classroom should not be equated with chaos or unstructured instruction. When students do hands-on and manipulative-based science, we can expect the noise level to rise somewhat. Inquiry may appear on the surface to be open-ended and unstructured. However as student involvement increases, so does the need for the teacher to manage classroom movement and communication. When teachers use inquiry-based strategies, they may find that teaching requires more preparation and anticipation of possible student questions than traditional approached do."

- Lynn Rankin in Exploratorium's Foundations refers to inquiry teaching in this way: "Inquiry teaching is not chaotic – it is a carefully choreographed activity." She adds this description of the teacher role during an inquiry-based lab activity: "Although inquiry teaching demands a different relationship between teacher and student than more traditional methods, it requires a high level of organization, planning, and structure, both

by the teacher and the students……During the inquiry process, the teacher walks around the room, interacting with groups of students as they experiment."

6. I don't need to use inquiry-based lab activities because I use kits.

- Inquiry and NSES p 36 has this to say about kit-based instructional materials: "These materials can increase the probability that students' thinking will be focused on the right things and learning will occur in the right sequence. However, the use of even the best materials does not guarantee that students are engaged in rich inquiry or that they are learning as intended. "

- Not all kits are inquiry-based, even if they claim to be. Many have directed activities that need to be modified in the same manner as cookbook labs.

7. Parents (and supervisors too) will complain if I do not give students step-by-step directions for the labs I want them to do.

- If you make the change from your traditional instruction to inquiry-based lab activities slowly and progressively, giving more responsibility to students after both you and they have become comfortable, there is likely to be little or no problems with complaints. As a matter of fact, you will probably find that it is just the opposite – students become much more engaged and thus enjoy and prefer the inquiry approach to the traditional confirmatory labs or textbook labs. If students are having difficulty with the new approach, ask them probing questions to move them along or suggest they consult with students in other groups. In "How to Make Lab Activities More Open-Ended", Alan Colburn addresses the concern in this way, "the lack of directions may initially confuse some students. However, students do eventually catch on if the teacher perseveres." Students may need to have several opportunities with the new approach before they become comfortable.

- When you begin to implement inquiry, explain to the students that you want them to work like scientists so they will be slowly taking on more responsibility for their lab work. If you expect parent complaints, sending home an explanatory note about inquiry with copies of key sections of the National Science Education Standards and state standards should ease parents concerns. You can also give your supervisor or administrator a copy of the letter.

8. You really cannot assess inquiry-based labs very well.

- Llewellyn answers this question in this way in Inquire Within: "Inquiry-based learning can be assessed like any other concept or topic in science. To assess student progress in inquiry-based learning, however, teachers need to use alternative methods of evaluation. "

- We will address assessment methods for inquiry-based labs in another section of this workshop**.**

9. I am not really sure I can change to this all at once.

- You are not expected to make an overnight change to inquiry-based lab activities. Begin slowly by making small changes to the activities you would ordinarily do and then move on when you feel you and your students are ready.

- Alan Colburn and Michael Clough write in Implementing the Learning Cycle:

"By making a gradual transition …., teachers and students can become accustomed to the new roles in a less stressful manner."

10. I have heterogeneously grouped students (or low ability students) and inquiry only works with higher ability or gifted students.

- The National Science Education Standards clearly advocate inquiry-based teaching for ALL students and outline that position on page 221: 'All students, regardless of sex, cultural or ethnic background, physical or learning disabilities, should have the opportunity to attain high levels of scientific literacy……..The understandings and abilities described in the content standards are outcomes for all students; they do not represent different expectations for different groups of students."

- In *Inquire Within*, Llewellyn's view is equally as strong: "The ability to think creatively and critically is not solely for high-achieving student. Inquiry-based instruction can and should be done equitably at all levels."

- In "Inquiry Primer," Colburn also asserts how students of all abilities can be successful with inquiry-based science instruction: "Perhaps this is one source of confusion about inquiry-based instruction being for 'advanced' students. This, of course, is a misconception. After all, elementary students learn quite effectively using hands-on inquiry based materials in the hands of a skillful teacher. Still research seems to support the idea that students can discover concrete concepts that lend themselves to direct observation through inquiry-based instruction."

- Introducing inquiry gradually allows all students to be successful with it. The hands-on nature of inquiry-based lab activities also allows students to learn from direct concrete experiences before reading the textbook information. Use of modifications strategies in the classroom can ensure success for all students. Modification suggestions from NSTA Pathways to the Science Standards, Second High School Edition include:
    - 1. Guide students as they begin to engage in the inquiry process.
    - 2. Make information resources available in multiple formats.
    - 3. Give students opportunities to express their ideas in multiple formats.
    - 4. Make the process of investigation fully accessible.
    - 5. Use technology that is accessible to all.
    - 6. Make assistive technology available when necessary.
    - 7. Emphasize cooperation and collaboration.

11. My students could never come up with their own questions to investigate.

- There are numerous levels of inquiry and only the top, most advanced level calls for students to generate their own questions. Many excellent inquiry-based laboratory activities can be done by teacher or class-generated questions. The key to inquiry is for the teacher to turn over as much of the investigative process as possible to the students until they can advance to the level of asking their own investigative questions.

- This concern is addressed this way on page 36 of Inquiry and the National Science Education Standards: "For students to develop the ability to ask questions, they must 'practice asking questions. But if the desired outcome is learning science subject matter, the source of the question is less important than the nature of the question itself. It is

important to note, however, that in today's science classrooms students rarely have opportunities to ask and pursue their own questions. Students will need some of these opportunities to develop advanced inquiry abilities and to understand how scientific knowledge is pursued."

12. I don't have time to teach everything like this.

- Not all science is intended to be taught this way. On page 144-145 the National Science Education Standards (NRC, 1996) says this: "This standard (Science as Inquiry) should not be interpreted as advocating a 'scientific method.' These conceptual and procedural abilities suggest a logical progression, but they do not imply a rigid approach to scientific inquiry. On the contrary, they imply co-development of the skills of students in acquiring science knowledge, in using high level reasoning, in applying their existing understanding of scientific ideas and in communicating scientific information."

- Lynn Rankin in chapter 5 of the Exploratorium's *Foundations* writes: "While an inquiry approach implies active learning and the development of higher-order thinking skills, hands-on methods are not the only ways to achieve these goals. Other resources are important for stimulating questions, and providing information. Books, articles, information on the Internet, and personal conferences or interviews can all be used to provoke initial interest in a topic from which research or investigations can emerge. On the other hand, these same resources might become secondary materials, providing additional support once investigations have begun. "

- *Inquiry and NSES* gives this answer: "Teaching science effectively requires a variety of approaches and strategies. It is not possible to teach all science subject matter through inquiry, nor is it desirable to do so. Teaching all science using only one method would be ineffective, and it would probably become boring to the students."

CHANGE Those "Cookbook" Labs

To become an inquiry teacher you do not need to toss out all those much loved, tried and true labs. No do not need to abandon your textbooks or kits – just CHANGE them. Many traditional "cookbook" labs can be modified and changed into inquiry labs.

Modification Advice from Douglas Llewellyn

On pages 76-78 in *Inquire Within,* Douglas Llewellyn has specific advice for teachers about how to modify a prescribed activity into an inquiry-base laboratory activity. Below is a summary of his suggestions. The entire text of the section from his book can be read in the appendix.

1. ***Add an Inquiry Investigation (or Question) at the End of the Activity.*** When you add extension and inquiry investigations after the activity, you use the activity as a springboard to inquiry. Encourage the students to raise "What if" and "I wonder" questions to take the activity further, or prepare questions as prompts to start students thinking about ways to apply the activity in other investigations.

2. ***Look at the Results Section.*** If the textbook activity provides a predetermined data table or graph, remove it. Let the students determine how they will collect and organize the data. Students will have to construct meaning for the data to organize and record them into a table.

3. ***Look at the Procedure Section.*** If the textbook or activity provides a step-by-step list of procedures, remove it. Let the students brainstorm about designing an experiment or investigation to answer the original question, prediction, or hypothesis.

4. ***Look at the Question Section.*** If the textbook or activity provides a starter question to answer, as they usually do, remove it. Start by demonstrating a discrepant event to observe. Encourage students to think of questions to investigate. Provide prompts and explorations to engage students in the original question of the activity. By encouraging students to come up with the question or problem, the investigation becomes more personal and meaningful to them. This makes the activity more like a student-initiated inquiry.

Modification Suggestions from Alan Colburn

Alan Colburn writes in "How to Make Lab Activities More Open Ended" in the *CSTA Journal*, Fall 1997, pp. 4-6 :

> Gradually modify the activities you are already doing.
> To begin with, analyze activities by deciding who is making the decisions—the teacher/text or the student. Choose a couple of "cookbook" activities. They should be activities designed for goals **other** than teaching students particular skills—you may better teach skills with a more step-by-step approach.
> Ask these questions:
> - Who decides the question the students are to investigate- teacher or student?
> - Who decides the procedures to follow answering the questions- teacher or student?
> - Who decides what to observe and data to collect – teacher or student?
> - Who decides the response to the question(s) investigated – teacher or student?
> - Who decides how to communicate this information, including data – teacher or student?
>
> Analyzing most activities, the response to each question will be "teacher". On the other hand, the ideal inquiry-based instruction is something close to that of teachers supervising student investigations. Teachers in these situations would respond "student" to most questions.
>
> Finally, after students are used to the independent thinking that comes from activities without data tables and total step-by-step directions, they (and you) may be ready for occasional activities demanding more thought on their part. You can often distil commercial activities to a single question that students answer when doing the

activity. So, rather than being given complete directions, students can simply be given the question they are to investigate. As "hints" you can give students limited materials to work with or even show a sample experimental setup. You are ultimately still in control of the environment in which students work.

They must still decide the order to follow when doing their work, quantities of supplies to use, what to record, and how to interpret their data. You may want to try this sort of activity after students understand relevant background information. You may also want to try this first with an easier activity.

More modification tips from Alan Colburn

Alan Colburn further elaborated on his suggestions for modification in "An Inquiry Primer", *Science Scope,* March, 2000 (page 42-44)

The more familiar the activity, materials, and context of the investigation, the easier it is for students to learn through inquiry. To help all middle level students benefit from inquiry-based instruction, the science education research community recommends:

- Orienting activities toward concrete, observable concepts;
- Centering activities around questions that students can answer directly via investigation (which goes a long way toward insuring the activities are oriented toward concrete concepts);
- Emphasizing activities using materials and situations familiar to students; and
- Choosing activities suited to students' skills and knowledge to ensure success.

There is, however, a caveat to these recommendations. If the activities are too challenging, students will not learn content effectively. On the other hand, if the activities are too easy, students will not develop higher-level thinking skills. Maximum learning probably occurs when the activities are "just right" – cognitively challenging, but still doable. This implies, at least in theory, a classroom where students may not all be doing the same version of an activity at the same time.

A good place to start is by tossing out any pre-constructed data tables that accompany lab activities. Have students figure out for themselves what data to record and how to record it. Initial confusion will eventually give way to success.

Once students are accustomed to recording their own data, you can make other modifications. For example, provide them with only some of the procedure. Or have students attempt the activity before you lecture on the subject matter involved. These simple changes eventually lead to true inquiry.

Resources:

Full text of both of Alan Colburn's articles can be read online.
"How to Make Lab Activities More Open Ended" can be found at:
http://www.exploratorium.edu/IFI/resources/workshop/lab_activities.html

"An Inquiry Primer" can be accessed from the National Science Teachers Association website at www.nsta.org. by visiting the archives of the middle level journal, *Science Scope*.

Strategies for Modifications to Labs from Clark, Clough and Berg

In *Modifying Cookbook Labs* (The Science Teacher, October 2000, page 40-43) Robert L. Clark, Michael P. Clough and Craig A. Berg provide the following list of suggestions for modifying labs.

> When modifying cookbook labs to mentally engage students, teachers should:
>
> - Consider including students in determining the lab question to be investigated
> - Encourage students to invent laboratory procedures (consider safety, equipment and cognitive issues)
> - Structure the experience so students are mentally engaged in the lab, even if they cannot invent laboratory procedures.
> - Encourage students to consider and defend what data is relevant and irrelevant.
> - Have students decide what their data means.
> - Require students to apply mathematical reasoning to problems.
> - Make students responsible for clearly communicating their lab work.
> - Have students set goals, make decisions, and assess their own progress.
> - Ask questions that spark ideas and reduce student frustration.
> - Refrain from summative evaluation of students' ideas and interpretations.

The full text of "Modifying Cookbook Labs" can be found in the archives of the high school journal, *The Science Teacher* at the National Science Teachers Association website at www.nsta.org.