Enhancing the Education of Scientifically Gifted Students with Inquiry Instruction

USC Summer Institute for Teachers of the Gifted

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Characteristics of Gifted Science Learners

- Strong curiosity about natural objects, the environment, and science phenomena
- Make intuitive leaps when solving problems
- High interest in investigating scientific phenomena
- Hobbies may include collecting and classifying objects
- Ability to make connections between various science concepts & phenomena
- Ability to analyze, synthesize & evaluate scientific information
- Non-school time is voluntarily spent on science related projects, reading, field activities, museum-going

High-quality educational experiences move students from knowing about to knowing how.

This is particularly true of programs for talented and gifted learners.

Inquiry instruction is one way to accomplish this.

Inquiry: A Definition

- The *National Science Education Standards* (U.S. National Research Council, 1996) defines scientific inquiry:

Scientific inquiry refers to the ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to 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 (p. 23).

What is Inquiry Instruction?

- Inquiry as part of science teaching implies two different instructional goals:
  - Students must gain understanding of *how* scientists do *their* work (a passive view of inquiry understanding), and
  - Student should gain understanding of how to conduct an investigation using inquiry (an active view of inquiry understanding)
    - Students must have an opportunity to practice these skills if they are to understand and appreciate them

What is Inquiry Instruction?

- Inquiry instruction is a teaching technique through which students investigate relevant questions that come from their own experiences
- The learner-centered nature of inquiry instruction makes it well suited as a way to differentiate teaching for learners of various levels including gifted and other high ability students

A Brief History of Inquiry Instruction

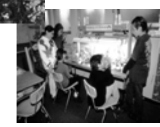
- One inquiry-like approach has been called the heuristic (step-by-step) method by English educator Herbert Armstrong (1898); no books are used and no directions from the teacher are given
- Joseph Schwab (1962) said that science instruction is just a "rhetoric (talk) of conclusions" or "final form" science so learners never get to see the processes of science, just the end products



A Brief History of Inquiry Instruction

- Herbert Spencer (1820-1903); students should directly contact nature and observe natural objects and then form their own conclusions (object-centered instruction)
- John Dewey (1909) supported project learning and said that science learning must include the *process* aspect of science, not just the information aspect
- Dewey believed that inductive thinking free from the interpretation and pressure of others was the best learning environment





A Brief History of Inquiry Instruction

- After the launch of Sputnik by the Soviet Union (late 1950s), inquiry instruction received renewed attention in curriculum design
- New curricula were developed in the U.S., many with an inquiry focus

After Sputnik: *Inquiry in the Curriculum*

- The U.S. curricula of the 1960s (many with inquiry elements) had positive effects on learners.
- Shymansky et al. (1982) found "*when the cumulative results of the research were considered, students in the new programs outperformed those in traditional, textbook-based classrooms on every criterion measured*" (p. 14).
- Unfortunately, most instruction today is didactic rather than inquiry oriented

U.S. National Science Education Standards (NSES) and Inquiry

- In the U.S. *Standards* (1996), inquiry instruction is its own standard describing how good science teaching should be accomplished.
- Students will learn science *by actively engaging in inquiries that are interesting and important to them* (*Standards*, p. 13)
- *Students at all grade levels in every domain of science should have the opportunity to use science injury and develop the ability to think and act in ways associated with inquiry* (*Standards*, p. 105)

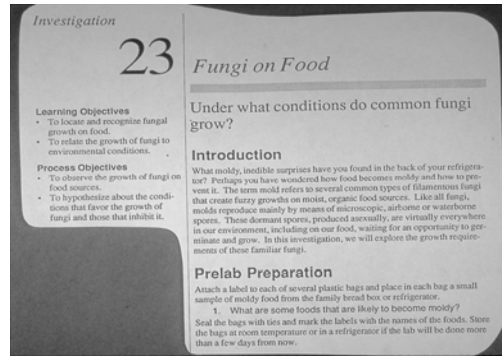
Not all laboratory instruction is inquiry-oriented but all inquiry could be seen as a form of laboratory instruction.


We must not assume that everything we do in the laboratory is inquiry. This would teach incorrect lessons about how science *really* functions.

A Taxonomy of Laboratory Types

Type	Who Decides? *Problem*	Who Decides? *Method*	Who Decides? *Conclusions*
0	T	T	T
1	T	T	S
2	T	S	S
3	S	S	S

T = Teacher   S = Student



Investigation 23

Fungi on Food

Under what conditions do common fungi grow?

Learning Objectives
- To locate and recognize fungal growth on food.
- To relate the growth of fungi to environmental conditions.

Process Objectives
- To observe the growth of fungi on food sources.
- To hypothesize about the conditions that favor the growth of fungi and those that inhibit it.

Introduction

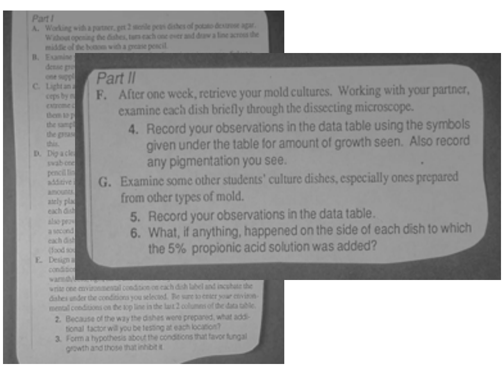
What moldy, inedible surprises have you found in the back of your refrigerator? Perhaps you have wondered how food becomes moldy and how to prevent it. The term mold refers to several common types of filamentous fungi that create fuzzy growths on moist, organic food sources. Like all fungi, molds reproduce mainly by means of microscopic, airborne or waterborne spores. These dormant spores, produced asexually, are virtually everywhere in our environment, including on our food, waiting for an opportunity to germinate and grow. In this investigation, we will explore the growth requirements of these familiar fungi.

Prelab Preparation

Attach a label to each of several plastic bags and place in each bag a small sample of moldy food from the family bread box or refrigerator.

1. What are some foods that are likely to become moldy?

Seal the bags with ties and mark the labels with the names of the foods. Store the bags at room temperature or in a refrigerator if the lab will be done more than a few days from now.



Part I

A. Working with a partner, get 2 sterile petri dishes of potato dextrose agar. Without opening the dishes, turn each one over and draw a line across the middle of the bottom with a grease pencil.

write one environmental condition on each dish label and incubate the dishes under the conditions you selected. Be sure to enter your environmental conditions on the top line in the last 2 columns of the data table.

2. Because of the way the dishes were prepared, what additional factor will you be testing at each location?
3. Form a hypothesis about the conditions that favor fungal growth and those that inhibit it.

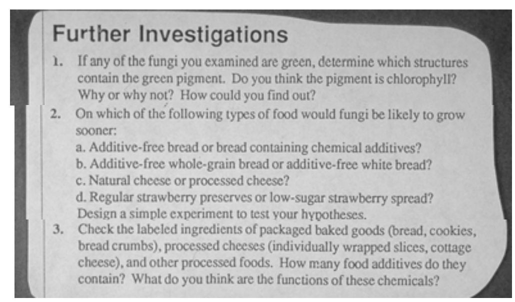
Part II

F. After one week, retrieve your mold cultures. Working with your partner, examine each dish briefly through the dissecting microscope.

4. Record your observations in the data table using the symbols given under the table for amount of growth seen. Also record any pigmentation you see.

G. Examine some other students' culture dishes, especially ones prepared from other types of mold.

5. Record your observations in the data table.
6. What, if anything, happened on the side of each dish to which the 5% propionic acid solution was added?



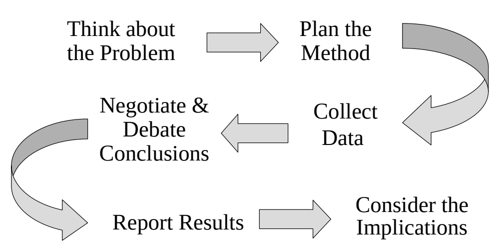
Further Investigations

1. If any of the fungi you examined are green, determine which structures contain the green pigment. Do you think the pigment is chlorophyll? Why or why not? How could you find out?
2. On which of the following types of food would fungi be likely to grow sooner:
   a. Additive-free bread or bread containing chemical additives?
   b. Additive-free whole-grain bread or additive-free white bread?
   c. Natural cheese or processed cheese?
   d. Regular strawberry preserves or low-sugar strawberry spread?
   Design a simple experiment to test your hypotheses.
3. Check the labeled ingredients of packaged baked goods (bread, cookies, bread crumbs), processed cheeses (individually wrapped slices, cottage cheese), and other processed foods. How many food additives do they contain? What do you think are the functions of these chemicals?

Scientific Investigation Model

There is no single model for conducting inquiry lessons just as there is no single way inquiry occurs in science itself.

Scientific Investigation Model



What we are doing in the laboratory is a guided discovery approach. I've tried the lecture approach and the lab format and there is no doubt that this approach works. One way is like pushing a pig up a ramp from behind and the other is like standing with an ear of corn and saying "come on!"

An Iowa Science Teacher

Inquiry Learning: Advantages

- Inquiry instruction is supported by our view of how the brain learns
  - Learning involves true *understanding*—memorization is *not* enough.
    - *Experts' knowledge is connected and organized around important concepts . . . it is "conditionalized" to specify the contexts in which it is applicable; it supports understanding and transfer (to other contexts) rather than only the ability to remember"* (*How People Learn, p.9*)

Inquiry Learning: Advantages

- Inquiry instruction is supported by our view of how the brain learns
  - Every learner has pre-existing knowledge.
    - *the contemporary view of learning is that people construct new knowledge and understanding based on what they already know and believe* (*How People Learn, p.9*)

Inquiry Learning: Advantages

- Inquiry instruction is supported by our view of how the brain learns
  - Active learning occurs when students become active participants in their learning rather than passive receivers of information.
  - Metacognition plays a role in active learning and refers *to people's abilities to predict their performances on various tasks . . . And to monitor their current levels of mastery and understanding* (*How People Learn, p.12*)

Inquiry Learning: Advantages

- Inquiry does *not* emphasize memorization; it focuses on exploring questions and trying to explain and understand phenomena.
- Inquiry involves the students in thinking about scientific concepts and how new information fits, or does not fit with what the students already know about the world.
- After students have had time to deal with the subject matter and have tried to construct new knowledge, the teacher can help students detect their incomplete knowledge or misconceptions

Inquiry Learning: Advantages

- Inquiry learning requires *active* learning. Students must think about their questions and how they might answer them. They need to evaluate their own learning in order to assess whether or not they have answered their questions
- Students have opportunities to develop and practice higher-order thinking, critical and scientific reasoning, problem-solving, communication and decision-making skills
- With inquiry, technology can now play an authentic (real) role rather than add-on role in instruction

Inquiry Learning: Advantages

- Inquiry learning occurs in contexts in which the new knowledge is useful for students (this is constructivist)
- New kinds of teaching and learning models can be developed such as task-structured rather than content-structured lesson designs
- Learning tools (math, other school disciplines, evidence, skepticism all relate)

Inquiry Learning: Advantages

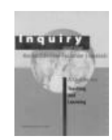
"*. . . in the investigative or inquiry lab, the learner is much more likely to be immersed in an environment rich with opportunities that evoke disequilibration (confusion & questioning) and hence give rise to the potential for cognitive restructuring (changing ones mind)*" (Saunders, 1992, p.139)

Inquiry Learning: Commonly Stated Disadvantages

- Lack of necessary equipment
- Covering content may take more time
- Teachers may lack training and examples
- Teachers may be uncomfortable with inquiry teaching (or not support such teaching)
- The role of the teacher will change
- It is harder to link to the textbook (curriculum)
- Students may lack the skills and proper attitudes

Designing Inquiry Lessons

- *Inquiry and the National Science Education Standards* (NRC, 2000) discusses the five elements associated with effective inquiry-based learning experiences



Inquiry Lesson Design: Element 1

- Effective inquiry lessons must involve students in thinking about "scientifically oriented questions," use objects and be tied to the curriculum (*NRC, p. 24*).
- Inquiry questions should ask "how" rather than "why"
- Questions should not be so complicated or difficult that the inquiry becomes overwhelming
- Questions must be age appropriate

Inquiry Lesson Design: Element 2

- Learners must gather and consider evidence (*NRC, 2000, p. 25*) and use the tools of science.
- Students must be given opportunities to practice inquiry not just learn about it

Inquiry Lesson Design: Element 3

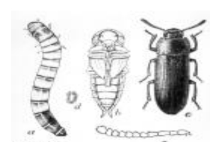
- During inquiry, students make explanations based on their prior knowledge + new knowledge acquired during the collection of evidence.

Inquiry Lesson Design: Element 4

- Students' explanations must be consistent with current scientific understanding; so students must compare their explanations with alternative explanations and ask questions about any anomalies.

Inquiry Lesson Design: Element 5

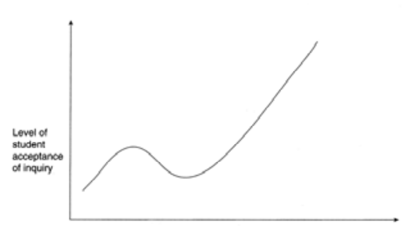
- Communication is the final component of well designed inquiry experiences
- Scientists share their work so that others may reproduce what was done and use the findings, students must communicate and negotiate their findings and explanations with others



Inquiry Instruction: Summarized

- Start by having the students select interesting (and possible) questions to investigate
- At the beginning, provide a model of inquiry instruction (such as the scientific investigation model)
- *Guide* the students, do not *tell* the students (this may mean a change in *your* behavior as a teacher)
  - Think about whether you want the inquiry to be "directed" or "open"
- Celebrate successes and discuss frustrations, but do not give up easily – both teachers and students need time for inquiry to be successful

Inquiry Instruction Implementation Curve



Inquiry: The Case of Bubbles

- Students can learn much about chemistry and physics by studying bubbles
- Challenge students to make the BEST bubbles from water, glycerin and soap
- What questions will students have to answer and what scientific skills will they practice?

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Inquiry and the Nature of Science

- The typical school laboratory is “cookbook-style.” Students are given the exact steps to follow and are asked to confirm known results.
- Many typical laboratory learning experiences use the stereotypical ‘scientific method’ which portrays the work of scientists as following a rigid, linear path.
- These are *not* accurate views of how science works and are *not* inquiry.