Session 4: Building Towards Inquiry

Overview

This session starts with an overview of the essential features of inquiry—what it looks like in an elementary classroom, how it is reflected in the science standards, and the educational advantage of student-driven learning incorporating "subtle shifts" towards inquiry. Most of this session is focused on a "Kit Carousel." The goal here is for students to explore the kits and materials associated with the outreach portion of the course. In this part of the session, student pairs discover for themselves what an inquiry-based curriculum looks like as they rotate from kit to kit, pulling out the materials and checking the contents against the corresponding lesson synopses.

Background Information for the Presenter

Inquiry is a teaching and learning strategy in which students learn about science by actually doing science—asking questions, conducting investigations, evaluating evidence, and discussing their results with peers. Through inquiry, students not only learn science content, they also get first-hand experience with the nature and process of science, and have the opportunity to learn and apply many of the skills that go along with thinking and acting scientifically.

Inquiry comes in many forms, and it goes by many different names. Some synonyms for scientific inquiry include: investigations; question-based, problem-based, and project-based science; discovery learning; and science as practice. Education researchers may argue that there are subtle (and not-so-subtle) differences between these educational approaches. But at their core, these strategies involve kids learning science by doing science.

In an elementary classroom, inquiry might involve a six-week investigation of the effect of drought on the plants and animals of the Galapagos, via a software program that includes datasets and researchers' field notes. Students may make hypotheses and explore the data, looking for evidence and making explanations; they could then share their findings with classmates and debate each others' hypotheses (National Research Council 2008). Or, the inquiry experience might be more free-form and take less than one class period, like the Beach Buckets activity from Session 1 of this course.

The inquiry-based approach to science education has been around for years, and its merits are broadly recognized. The recent Conceptual Framework for New

Science Education Standards[1] (National Research Council 2010) advocates the use of scientific inquiry ("Scientific and Engineering Practices") in classrooms. The Framework highlights the many skills that students attain through inquiry, including testing and experimenting, making hypotheses, interpreting data using graphs and models, and communicating scientific ideas.

Scientific argumentation is another term commonly used in the education literature to describe the communication of scientific ideas. Articulating ideas clearly—and supporting those ideas with evidence—is often new to students. Likewise, debating the merits of one hypothesis versus another can be difficult. Students need to weigh the supporting evidence for each idea, defend their ideas using evidence, and be ready to change their ideas if they hear more compelling evidence. It is important that teachers facilitate these conversations, by asking meaningful questions and encouraging students to describe their evidence and explain their reasoning. In scientific discourse and discussion, as in many other elements of inquiry, teachers play a critical role in guiding students' experiences (National Research Council 2008).

For many students, learning via inquiry is challenging, and teachers need to scaffold (or structure) the students' progression. Often this involves sequencing the students' activities, so they learn skills as those skills become necessary. Scaffolding can also involve time for students to reflect on the work they've done and how their ideas have changed throughout an investigation. This reflective, meta-cognitive piece is an important part of inquiry (National Research Council 2007). However, though students' inquiry experiences may have a logical sequence, they should not be scripted. The inquiry process should not have a pre-ordained outcome. Rather, the experience should be just like "real" science—you need to do the study to find out the result.

Through inquiry, students can learn about many aspects of science: they can understand scientific concepts—often better than students who are learning the material in a non-inquiry (direct instruction) fashion (National Research Council 2007). Students develop an understanding of the nature and process of science, as an ongoing and collaborative pursuit. And, students' first-hand experience with scientific discovery can make science much more meaningful and engaging.

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[1] The Conceptual Framework for New Science Education Standards was developed by the National Research Council's Board on Science Education. The Framework identifies core concepts in science, which will be the basis for writing new science education standards. Partners in this project include Achieve, the National Science Teachers Association (NSTA), and the American Association for the Advancement of Science (AAAS). A draft was published in Summer 2010, and was open for public comment. The final Framework will be available in early 2011, and new science education standards will follow.

The curriculum materials used for the outreach portion of the course as described in this session are taken from *MARE* (Marine Activities, Resources & Education) and *GEMS* (Great Explorations in Math & Science), both from the University of California Berkeley's, Lawrence Hall of Science. All of these materials are inquiry-based, tested in many classrooms across the country, and are given high marks by teachers and students alike. You may decide to use a different set of curricula, with different content and grade level focus. That's up to you, but please keep in mind that it is important that the curriculum materials chosen for the participants to take into local classrooms and for use in the course as exemplars have the following characteristics:

- hands-on and inquiry-based
- trial tested by teachers in many classrooms
- the write-up is easily understood and followed
- kit-based with easily accessible materials
- activities generate high interest for K-12 students
- recognized as meeting relevant science standards

Session Objectives

In this session, participants:

— gain experience with kit-based curricula;
— are made aware of how inquiry science looks in the elementary and middle school classroom;
— experience inquiry-based, hands-on ocean science activities used in elementary school classrooms;
— determine which grade level they would like to teach at a local school for the outreach portion of the course;
— see examples of the kinds of materials that are available for use when designing their own lessons

Session Activities at a Glance

Quick Write
Participants are asked to write about their ideas about K-12 students doing inquiry science as described in the reading assignment.

Essential Features of Inquiry Science
Participants experience the Crayfish Investigation, a portion of a hands-on inquiry-based activity for third grade. This provides the participants with a common experience related to inquiry science. The essential features of inquiry are discussed and the advantages of subtle shifts toward student-directed classrooms are introduced.

Kit Carousel
Participants discover what an inquiry, kit-based curriculum looks like, as they rotate from kit to kit, pulling out the materials and checking out the activity against the synopses they have been given. The kits used here are those available for the outreach portion of the course so the participants gain familiarity with them. As they rotate through the kits, participants are asked to look for the presence of the learning cycle, inquiry, and student learning objectives.

Wrap up and Homework
Participants do a Quick Write about their overall impressions of the kits and curricula, which activity they thought was the most intriguing and why, and which grade level they want to focus on for the outreach portion of the course.

Time Frame

Total Workshop: 2.5 hours
- Quick Write (10 minutes)
- Essential Features of Inquiry Science (60 minutes)
  - Crayfish Investigation (40 minutes)
  - Overview of Essential Features of Inquiry (20 minutes)
- Kit Carousel (70 minutes)
- Wrap up and Homework (10 minutes)

What You Need

For the Quick Write

- "Inquiry Science" PowerPoint (page 15)

For Essential Features—Crayfish Investigation

For each group of 4-5 participants

- 1 clear plastic shoe box or similar aquarium
- clean, de-chlorinated water to fill plastic shoeboxes about 2–3" deep
- 1 crayfish (see ordering and keeping information page 36)

For the class

- 1 copy of "Class Rules" PowerPoint (page 24)
- 1 pkg. sentence strips
- colored markers
- 1 copy of Crayfish Information Cards (pages 29-35)

For each participant

- 1 copy of Crayfish Inquiry Journal (pages 16-23)

For Essential Features––Overview

For the class

- 1 copy each of the following PowerPoint slides:
  "Essential Features of Classroom Inquiry" (page 25)
  "Essential Features of Classroom Inquiry and Their Variations" (page 27)
  "Teacher Identified Benefits of Shifts" (page 28)

For each participant

- 1 copy of "Essential Features of Classroom Inquiry" handout (page 26)

For the Kit Carousel

For the class

- Outreach kits for each grade level
- Synopses of activities for each participant

For the Quick Write

- **"Reflect on Activities" PowerPoint (page 15)**

Getting Ready

1. Order crayfish. See page 36 for ordering and keeping instructions.

2. Make PowerPoints.

3. Make one copy of each of the following: "Crayfish Inquiry Journal," "Essential Features of Classroom Inquiry," and synopses of activities handouts for each participant.

4. Have outreach kits available for participants to investigate.

Instructor's Guide — Session Details

Quick Write

Participants do a Quick Write. Have participants do a Quick Write using the following prompts about inquiry science, referencing the assigned reading:

> For a K-12 student, what do you think the most difficult part (or stumbling block) of the inquiry process might be? Please refer to one or more of the inquiry processes discussed in the reading.

Introduction to the Essential Features of Inquiry Science

- **Participating in a hands-on inquiry-based activity.** Tell the students that they will have the opportunity to experience a portion of a hands-on, inquiry-based activity for third grade. The purpose of **doing** this activity is to help them become familiar with what an inquiry-based activity for elementary school might look like.

- **Activity modified for this classroom setting.** The overview below provides information on the entire activity, from the opening observations to the presentation posters and content synthesis. In today's session of the course, the students will be taken through only a small portion of the activity––just enough so they get the flavor of the inquiry experience.

Crayfish Investigations

Overview

In Crayfish Investigations, students are guided through a full open-ended inquiry in five sessions. (An alternate route provides students with a partial inquiry in three sessions.) In Session 1, students are introduced to the Inquiry Journal and focus on making observations, sketching and asking questions about crayfish in the I Notice... I Wonder activity.

Session 2 focuses on generating more questions and categorizing them as investigable or not investigable based on the "Class Rules About What We Can Investigate." Students are also provided with more background information about crayfish, on which they can base their investigations as they discover answers to the "Lookup" questions. This session ends with small groups of students choosing their investigation question, and planning the investigation to answer that question.

In Session 3, students actually do their crayfish investigation in their small investigation group, again using the Inquiry Journal to organize their record-keeping and guide them through the process. Session 4 provides the opportunity for students to make a presentation poster and participate in Part 1 of a poster session and gallery walk to present their results and hear about their classmates investigations. The second half of the class presents their posters in Session 5, which also provides the opportunity for synthesis of the content and process of the inquiry. Students discover that crayfish have many adaptations to survive and thrive in the wetland habitat. They also discover and practice the process of how scientists learn about the world.

Background note: One of the most successful groups of animals in the world are the members of the phylum Arthropoda, which means "jointed legs." There are three times more species of arthropods than all other animal species combined. This group of invertebrates (animals without backbones) includes the insects, spiders, mites, and the crustaceans such as crayfish, lobsters, crabs, barnacles, and shrimp. The crustaceans are almost entirely marine (living in salt water), but one notable exception is the incredibly successful crayfish, which lives in brackish and fresh water. By observing crayfish that live in wetlands and streams, we can begin to understand how their ocean relatives live as well.

Prologue

1. **Eliciting prior knowledge about crayfish.** Tell participants they will have the opportunity to observe a living organism called a crayfish. Ask them if they have ever caught or seen a crayfish before? What do they already know about crayfish? Tell the participants that they will have the chance to ask many questions about crayfish, and if they observe the crayfish very carefully, it may even answer the questions for us. We just need to be sure to ask the kind of questions that the crayfish can answer through their actions. Another word for questions is **Inquiry**. We are going to use the word inquiry to mean scientific questions we can figure out the answers to by **doing** an **investigation** right here in the classroom.

The Crayfish Inquiry Journal

1. **Using an Inquiry Journal.** Tell the participants that they will write in an Inquiry Journal, which directs them through the inquiry process as it helps them to organize their notes and observations. Remind them to keep good notes and sketches so that they can refer to them later, as scientists would. Distribute a journal to each participant. (This version of the journal is edited for the college course and consists of just the first eight of an 18-page journal.)

2. **Modeling the activity and management strategies.** Tell the participants that you will take them through the first part of this activity as if they were a third grade class. This approach models how the activity would go

in a classroom, and also models some of the management strategies that students may need to employ to maintain control in the elementary classroom.

I Notice... I Wonder (Inquiry Journal page 2)

1. **Participants work in small group of four to five. D**irect the participants' attention to the first two pages of their Inquiry Journal.

2. **Prepare to distribute crayfish.** Tell them that you are just about to distribute an aquarium containing water and a crayfish to each table. Remind them that they look like a giant to the crayfish and you will be able to tell by the actions of the crayfish whether or not it is feeling safe or scared. We want the crayfish to feel safe, so the participants need to keep their heads down low, with their eyes just peeking over the top of the aquarium. They should be careful not to pound on the table.

3. **Introduce signal for getting participants' attention.** Tell the participants that you will use a signal whenever you want to get their attention. You will say "Crayfish Eyes!" and everyone must immediately stop what they are doing and put their two index fingers on top of their head, just above their ears, as if they were eyes on stalks. Say, "Lets try it." "Crayfish Eyes!"

4. **Introduce the activity.** Tell the participants that as soon as they get their aquarium, they are to make observations and communicate those observations in their Inquiry Journal on page 2. Have everyone turn to page 2 and direct them to list their observations in the I Notice column and their questions in the I Wonder column. Remind them to use all their senses except taste and touch.

5. **Distribute the aquariums and crayfish to each small group.** Walk around the room encouraging participants to make observations and ask questions about what they observe.

6. **Record initial observations and questions.** After about 5 minutes, get the class's attention with "Crayfish Eyes" and have participants share what they observed as you record on the class I Notice chart. As you list their observations, ask questions such as: did everyone observed this, let's look again, does anyone disagree or have a different observation about it?

Each group may give a different answer about how many legs the crayfish have. Some might count the pincers, some might not and some may count all the abdominal legs

while others won't. In addition, some crayfish may have lost a leg during capture or confinement; if so, it will eventually grow back after several molts.

Sketching the Crayfish (Inquiry Journal page 3 and 4)

1. **Sketch the crayfish.** Now have the participants turn to page 3 of the Inquiry Journal and have one of them read the directions aloud to their small group. Have the participants sketch their crayfish and add more observations and questions to I Notice... I Wonder.

2. **Prepare to touch the crayfish.** After about 5 more minutes, have them turn to page 4 of the Inquiry Journal. Tell them that you will walk around to each group and show them how to carefully touch and pick up the crayfish to look at its underside. They will now be able to use their sense of touch so that they can draw the crayfish from this perspective. No one has to touch it or pick it up and no one is allowed to scare a classmate with the crayfish.

   If you have the crayfish in a transparent aquarium, one participant can hold up the aquarium, while others look at the underside of the crayfish through the container.

3. **Model how to pick up the crayfish.** Show the participants how to pick up the crayfish by squeezing its back with your thumb and forefinger, just behind their pinchers, with a firm, yet gentle grasp. Show the participants this technique and tell them that if they hold the crayfish like this, it cannot pinch them. It is as if someone were touching you in the middle of your back, just out of your reach. Model this on a participant by touching them in the middle of their back and daring them to reach your finger.

4. **Add to sketches.** Have the participants again observe and sketch their crayfish as you walk around and pick up each of their animals in turn.

5. **Participants add observations about underside of crayfish.** Remind the participants to add new observations and questions about the underside of the crayfish to their I Notice I... Wonder journal page.

6. **Share new discoveries.** After about 5 minutes, again get the participants attention with "Crayfish Eyes!" and have them share their new discoveries with the class as you add their observations to the class I Notice Chart.

7. **Collect crayfish.** Collect the crayfish and return them to their larger aquarium habitat.

Choosing Questions to Investigate

1. **Share "I Wonder" lists.** Have participants share and discuss their I Wonder lists with their small group. Distribute sentence strips and colored markers to each group and have them write their questions on the strips. Tell them to write only one question per strip, and not use a question more than once, even if more than one person in the group listed the question on their I Wonder list.

2. **Display and sort questions.** As groups finish writing their questions, have them tape the sentence strips up on the wall. Once every group has finished displaying their questions, read them aloud and ask the class to help you put them in categories. Ask them what some of the categories might be. Discuss and write their categories on the board. (Some possible categories that participants might suggest include: functions of different body parts, locomotion or movement, crayfish senses, feeding and food preference, habitat preference, defenses, life cycle.) Suggest other categories depending on their observations
3. **Add some of your "own" questions if participants don't include the following:**
   - who are crayfish related to?
   - where do they live?
   - how do they grow?
   - do they have gills?
   - how long can they stay out of water?
   - do they live in fresh or saltwater?
   - how do you tell the males from the females?
   - how do you care for them in the classroom?
   - why do they have so many different kinds of legs?

This marks the end of the modeled lesson. Describe to the participants how the rest of the lesson would go as detailed in the following steps.

1. **Name the question categories.** The next step would be to write the name of the categories on sentence strips and tape them up around the room. In the elementary classroom, the students help move each of the sentence strips under the appropriate category heading.

Class Rules for Investigations (Inquiry Journal Page 5)

1. **Determine criteria for investigations.** Before the classroom students can decide which question they would like to investigate, the class needs to decide on rules about what they **can** investigate. (This process is also called determining the Criteria for Investigations.)

2. **Discussion about criteria for investigations.** Small groups of students would be asked to discuss what they think would be good rules about what the class should be allowed to investigate. This is followed by a whole group discussion with the teacher recording their rules on a class chart.

3. **Choose rules for investigation.** The teacher would then circle those rules that everyone (including the teacher) can agree on. The following rules are displayed by the teacher as his/her contributions. A star is placed by any of these rules that the students also suggested. The teacher would go through each of the rules, and the students would help find examples on the sentence strips that fit and don't fit the rules.

4. **Display the following rules for the participants:**

Class Rules About What We Can Investigate

1. Animals are not harmed in any way.
2. The question isn't too big—it can be answered by just one investigation and within one class period.
3. The materials needed are easy to get, inexpensive or already available in the classroom
4. The investigation is a what-happens-if, comparison or measuring question, not a why or how.
5. The question is interesting to the investigator
6. The question is important (or relevant) to the crayfish in its real life.
7. The question isn't a "Lookup" question.
8. The question can be answered by something you can **do** in **this** classroom.

Note: You will probably want to spend a little more time on explaining why it is that "what-happens-if," "comparison" and "measuring" questions are usually investigable and the "why" and "how" questions are not. Usually the why and how questions are too big of a question to be investigated in the classroom, but it doesn't make them any less important. In fact, the "wondering why" questions have driven scientists to make important discoveries.

5. **Determine which questions are investigable and non-investigable.** The elementary students are told that if a question or investigation fits within the Class Rules then it is considered to be investigable. Questions that do not fit the class rules are not investigable. Some questions that are not investigable for this classroom would certainly be investigable in other settings with more time and equipment. The students write down the Rules on page 5 of their Inquiry Journal.

Choosing an Investigable Question

Choose an investigable question. The next step in the inquiry process is to determine which of the student-generated questions are investigable and which are not. The students will then attempt to transform some of the questions that are not investigable into investigable questions.

— The students travel around the room with a partner (or as a trio) and together pick two questions from the wall according to the following criteria:
— one question must be a lookup question
— one question must be not investigable according to the class rules.

The Lookup Questions (Inquiry Journal Page 5)
In this part of the activity, students use resources to learn more about crayfish so they have information on which to base their own investigations.

- **Information Cards are distributed to each group**. They are told that they will find the answers to some of the Lookup questions in the written material you have given them.

- **Discuss questions that have been answered.** Lead a class discussion about which questions on the wall they can now answer based on their research or what they already know. The students' answers to the questions are recorded and the students copy the information onto page 5 of the Inquiry Journal.

Our Question to Investigate (Inquiry Journal Page 6 and 7)

- ❑ **Students pick the question they would like to investigate.** If they pick a non-investigable question, and are able to turn it into an investigable question, they will be allowed to investigate it.

- ❑ **Students walk around the room looking at all the questions taped to the walls.** Once they have decided on a question or category, they are asked to stand in front of the category they chose.

- **Students select a category.** After all the students have self-selected a category, they discuss the questions with the other students who also selected that category. They sit down together and decide which of the questions in that category they are most interested in investigating.

- **Students revise and write their question.** Have students turn to page 6 and write down the question they have chosen to investigate and then revise the question to make it more focused and if needed, to make it investigable. They are also asked to describe their hypothesis.

  *Note: Meaningful hypotheses come from having firsthand experience interacting with a situation. A hypothesis isn't just a guess, but rather it is based on some prior knowledge. For example, if you were told that a space ship was coming, you could only make a **guess** about what the aliens would look like. You couldn't actually make a **hypothesis** about it because you have no experience or prior knowledge on which to base it.*

- **Determine if question fits the criteria for investigable questions.** On page 6 they are also asked to explain whether their question fits the Class Rules About What They Can Investigate and then explain why.

- **Describe the relevance of their chosen question.** When the elementary students complete page 6, they can go onto page 7, which asks them to explain why their chosen question is interesting to them. The students also need to describe what relevance the question has to the real life of the crayfish. Page 7 also asks the students to describe their feelings about the inquiry process thus far.

Materials and Procedure (Inquiry Journal Page 8 and 9)

- **List materials for investigations.** This session ends with the students listing the materials they will need for their investigation, and who will get the materials.
- **Describe investigations.** Tell the students that after their group has completed their materials list, planned the first few steps they will take, and sketched a diagram of their setup, they will describe their plan to another group and ask them for their opinions, ideas, and advice.

This brings to an end the inquiry experience for the participants. Tell them that the elementary students would continue with the actual investigation of their question.

Overview of Essential Features of Inquiry

1. Display "Essential Features of Classroom Inquiry" Powerpoint. Describe that these are the features as described in the National Science Education Standards book about inquiry. Briefly describe each of the features as detailed on the powerpoint for the participants.

2. Display the "Essential Features of Classroom Inquiry and Their Variations" powerpoint. Describe how this slide shows the variation in the amount of learner self-direction as inversely proportional to the amount of direction from the teacher or material.

3. Analyze where Crayfish Investigations falls on Classroom Inquiry continuum. Ask the participants where they think the Crayfish Investigation fell on this continuum. Assign each table group one of the five essential features and ask them to locate the crayfish investigation on the continuum for that feature.

4. Lead whole group discussion and introduce "subtle shifts." Tell the participants that even subtle changes along the continuum towards a more student-centered classroom can have a huge reward in terms of student understanding of content and investment in their own learning.

5. Display the "Teacher Identified Benefits of Shifts" powerpoint. (Cookbook refers to material or teacher directions, which tell the student what to do every step of the way.)

6. Discuss benefits and drawbacks of open-ended inquiry investigations. Tell the participants that the kits and curriculum they will be taking into the elementary classrooms are not full open-ended inquiries. However, the activities are inquiry-based. Ask the following questions:

––"Why do you think that the activities are not full open-ended inquiries?"

––"What do you think inquiry-based means?"

Encourage participants to keep these ideas in mind as they go through the next set of activities.

Optional: Display Framework for Science Education from the National Research Council.

Show participants a copy of the Framework for Science Education and tell them that this document represents what scientists and educators have deemed important for students to know at each grade level. Districts and states decide whether or not to adopt the recommendations of this document. Tell them that most states also have state standards, which can be similar or very different from these consensus standards.

Kit Carousel

1. Place kits around the room for exploration. Leave some kits in their boxes, and have other kits' activities set up before hand. Distribute synopses of the activities to each pair of participants. Tell them that they will spend the next 70 minutes rotating from kit to kit, looking at the materials and trying out some of the activities.

2. Participants investigate the activities and kits. Tell participants that their goal is to investigate the kits and look for evidence of the learning cycle, learning objectives (what students are expected to learn from the activity), and inquiry. Finally, at the end of the exercise, they will be asked to decide which grade level they would like to focus on for the outreach portion of the course.

3. Circulate around the room. Circulate around the room, answering questions and reminding participants to look for the presence of the learning cycle, learning objectives, and inquiry. After about 70 minutes, call time and have the participants return to their seats.

Wrap Up

Quick Write

Reflect on activities. Have participants take out a piece of paper and do a Quick Write for 10 minutes. Display the Quick Write powerpoint:

> What are your overall impressions of the kits and curricula, what was the most intriguing activity to you and why, and what grade level do you want to focus on?

Homework

Assign the reading from the course reader.
Bransford, J.D. & Donovan, S.M. (2005). Chapter 9: Scientific inquiry & how people learn. In S.M. Donovan & J.D. Bransford (Eds.), ***How students learn: History, mathematics, science in the classroom, (pp. 397-419).*** *Washington, D.C.: National Academy Press.*

Quick Write: Inquiry Science

For a K-12 student, what do you think the most difficult part (or stumbling block) of the inquiry process might be? Please refer to one or more of the inquiry processes discussed in the reading

Quick Write: Reflect on Activities

What are your overall impressions of the kits and curricula, what was the most intriguing activity to you and why, and what grade level do you want to focus on?

Page 1

My Crayfish Inquiry Journal

by _____

Page 2

I Notice	I Wonder

Page 3

Draw your crayfish here and draw it big! Label the parts you see with a word that describes how it looks or what it does. As you are drawing, go back and add more observations and questions to I Notice/ I Wonder.

Page 4

Draw the underside of the crayfish here and draw it big! Label the parts you see with a word that describes how it looks or what it does. As you are drawing, go back and add more observations and questions to I Notice/ I Wonder.

Page 5

Our Class Rules About What We Can Investigate

The LOOKUP QUESTIONS: What we found out about crayfish by looking up the answers

Page 6

Our Question to investigate as written on the wall:

We revised our question to make it investigable and our question is now:

My hypothesis:

Does My Question Fit Our Class Rules About What We Can Investigate? Write yes or no for each of the rules and why you think it fits or doesn't fit the class rules

Page 7

Why this question is interesting to me:

Why I think my question is important in the real world of the crayfish:

My Feelings about the Inquiry Process So Far:

Page 8

Our Plan

Materials We Need	Write whether the materials are already available in the room or if not, who will get this material

Here are the first few steps we plan to take:

Class Rules About What We Can Investigate

1. Animals are not harmed in any way.

2. The question isn't too big—it can be answered by just one investigation and within one class period.

3. The materials needed are easy to get, inexpensive, or already available in the classroom.

4. The investigation is a what-happens-if, comparison, or measuring question, not a why or how.

5. The question is interesting to the investigator.

6. The question is important (or relevant) to the crayfish in its real life.

7. The question isn't a "Lookup" question.

8. The question can be answered by something you can **do** in **this** classroom.

powerpoint

Essential Features of Classroom Inquiry

1. Learners are engaged by scientifically oriented questions.

2. Learners give priority to evidence, which allows them to develop and evaluate explanations.

3. Learners formulate explanations from evidence to address scientifically oriented questions.

4. Learners connect their explanations to scientific knowledge.

5. Learners communicate and justify their proposed explanations.

From ***Inquiry and the National Science Education Standards,*** **Ch. 2, pp. 24-27**

handout

Essential Features of Classroom Inquiry

1. **Learners are engaged by scientifically oriented questions.** Scientifically oriented questions center on objects, organisms, and events in the natural world; they connect to the science concepts described in the content standards. They are questions that lend themselves to empirical investigation, and lead to gathering and using data to develop explanations for scientific phenomena.

1. **Learners give priority to evidence, which allows them to develop and evaluate explanations.** Science distinguishes itself from other ways of knowing through the use of empirical evidence as the basis for explanations about how the natural world works. Scientists concentrate on getting accurate data from observations and measurements of phenomena. The accuracy of evidence gathered is verified by checking measurements, repeating observations, or gathering different kinds of data related to the same phenomenon. The evidence is subject to questioning and further investigation.

2. **Learners formulate explanations from evidence to address scientifically oriented questions.** Scientific explanations are based on reason and must be consistent with experimental and observations evidence. They provide causes for effects and establish relationships based on evidence and logical argument. Explanations build upon the existing knowledge base, but they go beyond what is already known and propose some new understanding.

3. **Learners connect their explanations to scientific knowledge.** Evaluation, and possible elimination or revision of explanations is one feature that distinguishes scientific from other forms of inquiry. Alternative explanations are reviewed as students engage in dialogues, compare results, or check their results with other scientific resources. Student explanations should ultimately be consistent with currently accepted scientific knowledge.

4. **Learners communicate and justify their proposed explanations.** Scientists communicate their explanations in such a way that their results can be reproduced. This requires clear articulation of the question, procedures, evidence, proposed explanation, and a review of

alternate explanations. This provides for further skeptical review and the opportunity for other scientists to use the explanation in their work on new questions.

From *Inquiry and the National Science Education Standards*, Ch. 2, pp. 24-27

Table 2.6 Essential Features of Classroom Inquiry and Their Variations

Essential Feature	**Variations**			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to science knowledge	Learner independently examines other resources and forms explanations	Learner directed towards sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies proposed explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use and sharpen communication	Learner given steps and procedures for communication

More----------Amount of Learner Self–Direction----------Less

Less----------Amount of Direction from Teacher or Material----------More

Powerpoint

Teacher Identified Benefits of Shifts Towards Inquiry

Shifted	Cookbook
Sense of freedom and focus when asked to design own data sheets	"Another Worksheet"
We didn't know what we were looking for so there was a broader range of what we could discover	Gives results before you even have the experience
Higher order thinking skills required	Didn't have to think, just look and write
Detailed descriptions, analysis and summarization	Record, list, describe
I wound up writing more than I expected	Four lines on the worksheet equals four sentences
Student ownership—empowering	Teacher ownership—"When the teacher tells you what to discover you don't have ownership"
Discovery oriented	Kids don't want to be told what to discover
Kids have to think for themselves	Not asked to think, just do
Anticipation kept us involved	"Oh, do we have to do all this work?"

Crayfish Information Cards

Crayfish are **invertebrates**. Invertebrates are animals without backbones. Worms, jellyfish, anemones, crabs, insects, and many many other animals are invertebrates. People and other mammals, reptiles, amphibians, fish, and birds are all **vertebrates** and have a backbone.

Crayfish have many senses that help them learn about their habitat. They find food, a mate, a hiding spot, and escape predators by using their senses. Crayfish have two pairs of **antenna,** which help them learn about their surroundings. One pair is very long and one pair is short. The shorter ones are called **antennules** and each is split into two so it looks almost like they have four short antennules. On the base of the antennules is an organ called a **statocyst**. The statocyst helps the crayfish to know which side is up and which side is down.

Crayfish also have a pair of long **antenna**, which to help them get information about their habitat. They use the long antenna for their sense of touch, to help them find their food when it is nearby. They can also use their antenna to taste or smell the water, to find food that is farther away. At the base of the antennas there is an organ called the **green gland**. This is where the urine or pee comes out.

Crayfish have eyes on stalks, which help them to see a very wide area around them at one time. They can probably tell the shape and size of objects and some color, but can't really see an image like we do. They are very good at seeing any movement around them though and will react very quickly.

Crayfish and their very close relatives including crabs, lobsters, and shrimp are part of a special group of animals called **Crustaceans**. Think of crustaceans as being the crusty, crunchy animals. This name refers to the hard exoskeleton that covers just about their entire body. Crustaceans and other arthropods wear their skeleton on the outside of their body instead of on the inside, like people do.

One of the most successful groups of animals in the world is the group called **Arthropoda**. The word Arthropoda means "jointed legs." It makes sense that a jointed-leg animal might be called an Arthropod because that word sounds kind of like the word arthritis—the disease where your joints hurt. There are three times more kinds of arthropods than all other kinds of animals in the world combined.

Arthropods include insects, spiders, mites, and crustaceans, such as crayfish, lobsters, crabs, barnacles, and shrimp. These animals all have an **exoskeleton**, which means they wear something like a skeleton on the *outside* of their body. The exoskeleton gives strength and support to their body and also gives their muscles a sturdy place to attach. It does something more too. The hard exoskeleton protects the arthropods' soft inner body from many predators or other dangerous things in their habitat.

Almost all crustaceans live in salt water. Crayfish are one of the exceptions. They live in freshwater or some kinds even live in water that is called **brackish**. Brackish water is kind of salty and kind of fresh. It is the kind of water found in wetland estuaries—where the freshwater flowing in from a river mixes with saltwater coming in from the ocean.

There are more than 500 species or kinds of crayfish and they are found throughout the world, but only in freshwater or brackish water. They live in swamps, marshes, wetlands, ponds, streams, and even cold lakes and fast-running rivers. They are found in all coastal areas of the United States, including Hawaii, and have been introduced in Costa Rica, Spain, France, Africa, and Japan.

All arthropods, which include crustaceans, are covered with a hard external skeleton (exoskeleton) that is jointed so they can move. It kind of like they are wearing a suit of armor. This exoskeleton does become a problem when the inner body grows. An exoskeleton doesn't grow or even stretch, so they must shed or **molt** it so their inner body can grow larger.

By the time a crustacean molts or sheds its exoskeleton so it can grow, a new, soft exoskeleton has already started to form underneath the old one. But before its new exoskeleton hardens around its soft body, the animal swells up with water to an even larger size. Then after the exoskeleton hardens, the animal can get rid of all this excess water. But by swelling up it has made sure that it has some room to grow before it has to molt again.

All crustaceans, including crayfish, have gills covered by a **carapace**. This is the shield-like part of the exoskeleton that covers the head and most of the back. The carapace also wraps around the sides of the body above the walking legs. In shrimp, lobsters, and crayfish, the tail section, or abdomen, extends back past the carapace and ends in the **telson** or fan-like tail.

Crustaceans can spend some time out of water, but must always keep their **gills** wet so they can breathe. Most crayfish can remain out of water for only about 10 minutes at a time. The gills of crayfish are located under the carapace and just above the walking legs.

Crayfish, crabs, and lobsters are called **decapod** crustaceans because they have ten large legs. The first pair of legs are pincers. Pincers are used to defend against predators, to help in competition with other crayfish, and to catch and tear food into smaller pieces. A crayfish can definitely pinch hard enough to really hurt, so keep your fingers out of its reach!

The mouth parts of decapods are legs which have been greatly changed. They are used kind of like fingers and teeth to sort and move food around after the pincers bring it to the mouth. The mouth parts are not counted as part of the ten legs of decapods.

Crayfish have four pairs of legs that are used mostly for walking, but also for handling food and cleaning itself. These walking legs have small pinchers, which they use to grasp onto things. The legs have many small hair-like structures, which they use to sense the habitat around them. If the hairs move, they can tell that they are touching something.

In female crayfish, the legs on the abdomen or tail section are used to hold the eggs until they hatch. They also are used as fans, to make sure the eggs have lots of oxygen. These abdominal legs are called **swimmerettes** because they help the crayfish swim. Crayfish are weak swimmers though, and they can't float. In male crayfish, the first swimmerette points towards the head and is usually white-tipped. In females, all the swimmerettes look very much the same.

The crayfish uses its strong tail to dart backwards rapidly by bending it towards the belly with lightening speed. This allows them to escape predators and to right themselves when they end up on their back. Crabs look very different from this. In crabs, the tail and abdomen are very small and are wrapped tightly underneath the body. Female crabs have a wide rounded abdomen used as a shelf to hold their eggs. Male crabs have a narrow abdomen shaped like a triangle.

Crayfish can be very aggressive towards one another. It is important that each crayfish be given a place to hide. Crayfish will eat almost any kind of fresh or frozen fish and can actually live for over a month without being fed. They will also eat live food, such as goldfish and water plants. Because these animals eat food, they must poop out the waste. The poop comes out in the place at the tip of the abdomen, just before the fan-like tail.

Crayfish have pincers like crabs and walking legs like shrimp. Also, like crabs, they can hang onto rocks and water plants so they aren't dragged away with strong water movement. Although they live only in fresh or nearly fresh water, crayfish have a lot in common with their saltwater relatives, but are easier to get and keep alive in the classroom. By observing crayfish that live in streams and ponds, we can begin to understand how their ocean relatives live as well.

Ordering Crayfish

Crayfish can be ordered from scientific supply houses such as Carolina Biological: (800) 547-1733. Order a few extra crayfish than you think you will need in case some die, are reluctant to move around, or have recently molted. When you order them we recommend you try to obtain the red eastern crayfish, which live in still water. These are the easiest to keep alive and don't require refrigeration or an air stone. The western brown crayfish are harder to keep alive, as they live in cold flowing water. To maintain these crayfish, keep them in an aquarium with an air pump (aerator).

Keeping Crayfish in the Classroom

Crayfish are quite hardy, but there are a few important procedures that should be followed to keep the crayfish healthy and alive.

- First of all, be sure to put dechlorinating drops (follow the package directions) in the fresh, clean water you use, and remember to change the water frequently.

- Feed the crayfish in a different aquarium than the one that is their habitat, so the water isn't fouled by old food. The exceptions are living tubifex worms and living feeder fish. You can put living prey directly into the crayfish habitat and they will live there. The crayfish can then eat them as they catch them. Dead food, like pieces of fish, catfood, crayfish chow, or even hamburger should never be put in their habitat—put these in an aquarium reserved for feeding.

- Give the crayfish plenty of hiding places because they are quite aggressive with each other and big ones are likely to eat the smaller ones if they get the chance. Sometimes, if you have a crayfish or two that are much larger than the others, you might want to separate them so the smaller ones don't become dinner. Broken clay flowerpots work well as hiding places.

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