Session 8: Inquiring Minds and Promoting Discussions

Overview

This session introduces and provides an overview of inquiry in informal environments. Participants conduct an investigation, then observe visitors and facilitators interacting as they engage in an inquiry on the museum floor. The second part of this session focuses on how educators can build upon learners' diverse responses to questions to engage them in learning through discussions and offers practical discussion-leading strategies.

Background Information for the Presenter

The term "inquiry" is used frequently in discussions of science teaching, in educational reform documents and in the research community. However, it is used in a variety of ways and means different things to different people—the term is pervasive, yet ill-defined. Most agree that inquiry is curiosity-driven. It involves wondering, posing questions, making observations. It involves reading books to find out what others have learned, planning investigations, gathering and analyzing information, reflecting on what was learned in the light of new evidence, and proposing explanations and predictions. Inquiry requires the use of critical and logical thinking, consideration of alternative explanations, and the ability to change one's ideas.

There are many models of inquiry that are presented in classroom settings to scaffold students as they learn about inquiry processes. These models typically characterize inquiry as a set or cycle of 5 or 6 steps, but this fails to capture the complexity and diversity of activity that is seen outside of the classroom as people—including scientists and museum visitors—practice inquiry. Depending on a person's interests, prior knowledge, the particular discipline, who and what is around to work with, and even their current frame of mind, inquiry will proceed in very different ways. The cyclic nature of inquiry is widely recognized; however, the scale of those cycles—from many years to just a few minutes—and the processes within vary greatly. The model of inquiry presented in this course focuses primarily on broader features of inquiry and does so in a way that does not focus on individual processes used in inquiry nor impose a sequence. We make no claim that it is the "right" or only model of inquiry, but rather a model that works well for describing, characterizing, and discussing natural inquiry endeavors seen in free-choice settings.

A portion of this session is focused on participants conducting an inquiry-based investigation, *Crayfish Investigations*. This investigation is based on

an inquiry unit designed for classrooms, and has been modified for this setting as an adult learning experience. The goal here is to have the participants share in a common inquiry science experience. The inquiry investigation described in the session has also been modified to be more suited as an activity presented in an informal setting. Additionally, the informal science education version of this activity is presented with visitors in this session so participants can compare the two versions. A *Note to the Instructor* in the "Comparing and Debriefing the Crayfish Investigation" portion of this session describes how the informal and the classroom version of the crayfish investigation differ.

Another focus of this session is for participants to observe how the facilitator interacts with visitors—specifically looking at responding strategies and promoting discussions. Perhaps the only thing as important to good teaching as questioning strategies—are ***responding*** strategies! From the learner's perspective, most of us only need to remember back to the humiliation of being told one's idea was wrong; the embarrassment of being singled out for an answer; the frustration of being constantly overlooked in favor of more vocal learners; or the feeling of being left behind in a discussion. From the educators' perspective, one learns very quickly how a few very vocal learners can dominate a discussion; how challenging it can be to engage the reluctant-to-speak learner in discussion; how off-track responses, if not handled well, can completely derail a discussion; and how tricky it can be to communicate correct information without discouraging participation by learners who contribute incorrect information.

Research on educator-learner interactions demonstrates that the ways that an educator responds to learners' questions and answers will set the tone for the learning environment and will influence learning outcomes. Is the environment one in which it is safe to share one's ideas and to ask what you don't know? Is critical and original thinking valued, or just right answers? Promoting discussions that draw in all learners help an educator understand what learners are thinking, and help create an open intellectual environment where they learn through discourse. Strategies as simple as waiting a few seconds after asking a question and before calling on someone to respond can make a huge difference in the number of learners who respond and the quality of the responses. Although an effective use of "wait time" in an informal setting may not look exactly the same as in a classroom setting, there are certain aspects of it that are relevant and should be included.

We've endeavored to present activities and interactions in this session that provide the participants with a "toolbox" to draw from. Depending on the activity, the educator, and the particular audience or group, interactions will sometimes be very conversational and other times very

instructional—there will be situations for all of the response techniques, but none is going to work all of the time. Museum educators are continually called upon to make some judgment calls on the fly.

Session Objectives

In this session, participants:

- are made aware of how inquiry science looks in informal settings;
- experience inquiry-based, hands-on ocean science activities used in informal settings;
- observe an experienced educator's use of questioning and response strategies with visitors;
- discuss the essential features of inquiry;
- learn about and analyze a variety of responding strategies to promote discussions between facilitator and visitors; and
- learn how to effectively:
    - draw in all learners to understand what they are thinking;
    - create an open intellectual environment where learners learn through doing and discourse;
    - build upon learners' diverse responses to questions to engage them in learning through discussions.

Session Activities at a Glance

Quick Write (5 minutes)
Participants are asked to describe what they think is involved in doing inquiry and to write about their personal experience with inquiry science in informal settings.

Introduction to Inquiry Science—Crayfish Investigation (45 minutes)
Participants experience the Crayfish Investigation, a modified informal version of a hands-on inquiry-based activity originally designed for the classroom. This provides course participants with a common experience related to inquiry science.

Inquiry on the Floor (20 minutes)
Participants have the opportunity to observe an on-the-floor version of the Crayfish Investigation. They take notes about the similarities and differences between the version they did in the classroom and the floor version. They also note the educator's use of questioning and response strategies.

Comparing and Debriefing Crayfish Investigations (10 minutes)
Participants revisit the crayfish inquiry investigation and discuss how leading the activity for general visitors in an informal setting differs from the classroom experience they had. Participants also contemplate and

discuss other possible venues to present inquiry activities (e.g., large aquarium tanks) and approaches for on-the-floor inquiry.

Responding Strategies and Ideas from Research: Promoting Discussions (20 minutes)
Participants are given a handout describing ideas from research about effective ways to respond to learner's questions and comments while encouraging discussions. They review the ideas then apply them to their own experiences.

Application of Responding Strategies (15 minutes)
This activity provides an opportunity for participants to apply what they've learned about responding strategies.

Overview of Essential Features of Inquiry (20 minutes)
The essential features of inquiry are discussed and common patterns of inquiry in museums described.

Adding More Inquiry into Participant-Designed Activities (10 minutes)
Participants spend some time discussing how to open their activities up to include more opportunities for learner-directed activities and inquiry. They complete this assignment for homework.

Science Content–Seaweed (20 minutes)
A presentation about seaweeds provides participants with content about seaweeds for their use as they present on the floor. This presentation is also used to model (1) how to present science content in an interactive way, and (2) how to effectively respond to questions and comments while encouraging discussions. (See Science Index on web site for the PowerPoint Presentation.)

Homework (5 minutes) *(Note – this homework is assigned as part of the UC Berkeley course; other institutions may decide to use these assignments or develop different assignments.)*

Reading:
Crowley, K., Callanan, M. A., Jipson, J. L., Galco, J., Topping, K., & Shrager, J. (2002). Shared scientific thinking in everyday parent-child activity. *Science Education*, 85(6), 712–732.

Cephalopod reading from textbook.

Activity Development:
Adding More Inquiry into Your Activities
Written Activity Plan due March 31st

Time Frame

Total Workshop: 2 hours 50 minutes
- Quick Write (5 minutes)
- Introduction to Inquiry Science–Crayfish Investigations (45 minutes)
- Inquiry on the Floor (20 minutes)
- Comparing & Debriefing Crayfish Investigations (10 minutes)
- Responding Strategies & Ideas from Research: Promoting Discussions (20 minutes)
- Application of Responding Strategies (15 minutes)
- Overview of Essential Features of Inquiry (20 minutes)
- Adding More Inquiry into Participant Designed Activities (10 minutes)
- Science Content: Seaweeds (20 minutes)
- Homework (5 minutes)

Materials Needed

For the Quick Write

- "Quick Write on Inquiry Science in Informal Settings" PowerPoint

For Introduction to Inquiry Science—Crayfish Investigation

For each group of 4–5 participants
- 1 clear plastic shoe box or similar aquarium
- clean, dechlorinated water to fill plastic shoeboxes about 5–10 cm deep
- 1 crayfish (see ordering and keeping information page in Getting Ready)

For the class
- 1 I Notice…I Wonder board
- 1 copy of "Investigation Rules" overhead or Investigation Rules poster
- 1 Question Board with categories
- 200 4x6" colored index cards (three colors)
- colored markers
- masking tape
- 1 copy of Crayfish Information Cards
- Optional: Various materials for conducting crayfish investigations (some interesting items include: sand, gravel, small clay pots for hiding, tubifex worms, fish flakes, bits of meat or fish, lettuce, large squares cut from black plastic garbage bags, large squares cut from white plastic trash bags, vegetable bags, strawberry baskets, mirrors, short lengths of transparent plastic tubing, and PVC pipes for hiding in, etc.)

For each participant
- 1 copy of Investigation Journal

Inquiry on the Floor

For the educator on the floor
- materials for the informal version of the Crayfish Investigation (see attached)

For each participant
- 1 copy of the informal version of the Crayfish Investigation (see attached)

For Overview of Essential Features

For the class
- PowerPoint presentation and digital projector

For each participant
- 1 copy of each of the following handouts:
  "Essential Features of Inquiry"
  "Inquiry and the National Standards"
  "Essential Features of Classroom Inquiry and their Variations"
  "Inquiry in Informal Settings"
  "Breakdown of Inquiry Emphases"

For Ideas from Research: Promoting Discussions

- 1 copy of "Ideas from Research: Promoting Discussions"

For Seaweed Science Content

- see Website Science Index for PowerPoint presentation

Preparation of Materials

1. Obtaining and keeping crayfish.

Ordering Crayfish

Crayfish can be ordered from scientific supply houses, such as Carolina Biological (800) 547-1733 or Niles Biological www.**niles**bio.com. 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.

- Use dechlorinating drops (follow package directions) in the fresh, clean water you use and 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 these 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, cat food, 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 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 great for hiding places.

2. Decide if you would like to do the Seaweeds Science Content or some other science presentation. The PowerPoint for the presentation can be found on the website in the Index of Science Content presentations.

3. Copy "Inquiry Journals," "Inquiry and the National Standards," and "Ideas from Research: Promoting Discussions" handouts for each participant.

4. Post "I Wonder…I Notice" Board. On one wall of the classroom (use an existing chalk or white board, bulletin board, or large sheets of paper taped to the wall) post the headings "I Wonder," " I Notice" and "Investigations" in colors corresponding to the respective colored index cards. Have available a means (such as tape) to attach the cards participants fill out under the appropriate headings.

5. Post "Questions" board. On a different wall of the classroom, post the word "Questions" in the color corresponding to the question index cards. Under this, list categories of questions (Some possible categories include: functions of different body parts, locomotion or movement, crayfish senses, feeding and food preference, habitat preference, defenses, life cycle). You may want to leave some open space to add new categories.

6. Write out sample questions to add to "I Wonder" list. Some questions could include:
   - 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?

Instructor's Guide–Session Details

Quick Write

1. Ask participants to do a Quick Write to explore their ideas about inquiry.

- In your opinion, what does doing inquiry involve?
- Describe what someone engaging in inquiry in an informal setting would be doing.

2. **Participants share ideas.** Have a few volunteers share their ideas and experiences with doing inquiry in informal settings.

Introduction to Inquiry Science—Crayfish Investigations

1. Participating in a hands-on inquiry-based activity. The purpose of ***doing*** this activity is for the class to have a shared inquiry experience and to help them become familiar with what an inquiry-based activity might look like.

2. Activity modified for this classroom setting. The inquiry investigation described below is based on an inquiry unit designed for third grade and has been modified as an adult learning experience for this setting.

Note to instructor: *You'll need to have an educator set up the informal version of the Crayfish Investigation with visitors on the floor as the course participants engage in the adult-learning version of the investigation in the classroom. Don't let participants know that the activity is also being presented on the floor at the same time. Course participants will join the crayfish investigation in progress on the floor later. The goal is for them to predict and then observe the differences and similarities of the two versions.*

Introducing Crayfish and Inquiry

1. Eliciting prior knowledge about crayfish. Ask participants if any of them have ever caught or seen a crayfish before? What do they already know about crayfish? Say that they'll have the chance to ask lots of questions about these very cool animals and that many of the questions they'll be asking will not be answered by the teacher or anyone else. They will be "answered" by the crayfish themselves. Tell them that by observing the crayfish very carefully, the crayfish will "answer" the questions for them. Participants just need to be sure to ask the kinds of questions that the crayfish can answer through their actions.

Background Note: *Members of the phylum Arthropoda (which means "jointed legs") are among the most successful groups of animals in the world. 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 the crayfish, lobster, crab, barnacle, and shrimp. The crustaceans are almost entirely marine (living in salt water), but one of the notable exceptions (living in brackish and fresh water) is the incredibly successful crayfish. By observing crayfish that live in wetlands and streams, we can begin to understand how their ocean relatives live as well.

2. Another word for questions is *Inquiry*. We're going to use the word *inquiry* to mean scientific questions about the natural world that we can figure out the answers to by **doing** an **investigation** right here in the classroom.

Making Observations and Generating Questions

1. **Participants work in small group of four to five.** Distribute a marker to each group and provide them with colored index cards.

2. Prepare to distribute crayfish. Tell them that you will distribute an aquarium containing water and a crayfish to each table. Emphasize a few rules for the groups to follow when observing the crayfish, including: don't put your hands in the tank or hold the crayfish yet—just use your eyes to observe.

3. Introducing activity. Tell participants that as soon as they get their aquarium, they should make observations and communicate those observations within their group. Have everyone hold up the two different colors of index cards and show them the "I Notice…I Wonder Board" at the front of the class. Ask them to list their observations (one per card) on the "I Notice" colored cards and their questions (one per card) on the "I Wonder" colored cards. Remind them to use all their senses except taste and touch.

4. Distribute aquariums and crayfish to each small group. Walk around the room encouraging participants to make observations and ask questions about what they observe. If you hear an interesting observation or question, encourage the group to write it down and post it on the board under the appropriate heading.

5. Post observations and questions on I Notice…I Wonder Board. After about 10 minutes, regain everyone's attention, collect and post any cards that are still out, and point out contributions to the board. As you go over the list, ask questions, such as—whether or not everyone observed this, let's look again, does anyone disagree or have a different observation about it?

Note to Instructor: *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 and 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.

Touching the Crayfish

1. Prepare to hold crayfish. Tell participants 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. Add that no one has to touch it or pick it up unless they are interested in doing so.

Note to Instructor: 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.

2. Teach participants to carefully hold crayfish. Show the participants how to pick up the crayfish by squeezing its back with your thumb and forefinger, just behind the pinchers, with a firm, yet gentle grasp. Teach participants this technique and tell them that if they hold the crayfish like this, it can't pinch them.

3. Show each group underside of crayfish. Have participants again observe their crayfish as you walk around and pick up each of their animals in turn.

4. More observations and questions added to cards. Remind participants to add new observations and questions about the underside of the crayfish to their I Notice I Wonder cards.

5. Share observations. After about 5 minutes, again get participants' attention and have them share their new discoveries with the class and add their observations and questions to the class I Notice I Wonder Chart.

6. Collect crayfish. Return the crayfish to their larger aquarium habitat.

Choosing Questions to Investigate

1. Determining the question to investigate. Before participants can decide which specific question they would like to investigate, they need to be aware that there are rules that determine what kind of investigation they can actually do in this situation.

2. Display the rules for investigation. Call their attention to the display of the following rules.

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 building.
4. The investigation is a what-happens-if, comparison, or measuring question, not a "why" or "how" question.
5. The question is important (or relevant) to the crayfish in its real life.
6. The question can be answered by something you can **do** and not just by looking up the answer.

Note to Instructor: *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 complicated to be investigated in the classroom, but it doesn't make them any less important. In fact it has been the "wondering why" questions that have driven scientists to make discoveries.*

3. Determining if questions are investigable or not investigable. Tell the participants that if a question or investigation fits within the Rules then it is considered to be investigable. Those questions that do not fit the rules are not investigable. Some questions that are not investigable for this situation would certainly be investigable in other settings with more time and equipment.

4. Provide an example of an investigable and a not-investigable question. Tell participants that the question, "What is a crayfish's favorite food?" is certainly an interesting and important one, but it's probably not investigable here. Lead a brief discussion about why it might not be investigable. [We are not able to try every food in the entire world to determine its favorite] Ask, how might we turn that question into one that is investigable? Ask for ideas and if it doesn't get brought up by participants, mention that we might ask, "Does the crayfish prefer hot dogs or lettuce?" This is a question about food preference that we can find the answer to, can investigate.

5. Adding questions from previous visitors. Add some sample questions to the I Wonder board. Some of these might include:

- 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?

Note: *Some possible question categories include: functions of different body parts, locomotion or movement, crayfish senses, feeding and food preference, habitat preference, defenses, life cycle.*

6. Discussing possible Investigation Questions. Have participants look at the I Wonder list and discuss, within their group, ideas for questions they would like to investigate.

7. Choosing their Investigation Question. Have each small group pick the one question they'd like to investigate. Have them write this question on an Investigation Card (this will likely be a re-phrasing of an I Wonder card). If they pick a not investigable question from the I Wonder list, and are able to turn it into an investigable question, they will be allowed to investigate it. Have them post their Investigation Card on the board in the column labeled Investigations.

8. Crayfish Information Cards. Participants may wish to use resources to learn more about crayfish so they have information on which to base their own investigations. They will find the answers to some of the look-up questions in the written material you've given them.

Investigation Journals

1. Record questions in Investigation Journal. Distribute Investigation Journals to each participant. Explain that they will only do page 1 because of time constraints. Have them write down the question they've chosen to investigate.

2. Participants describe hypotheses. Each group should generate at least two hypotheses for their question that includes both a prediction and a rationale.

> ***About Hypotheses.*** *Meaningful hypotheses come from having had some firsthand experience interacting with a situation and include a prediction (I think that…) and a rationale (I think that because…).*
> *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 extraterrestrials 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.*

Including multiple hypotheses is essential to a good experimental design. An experiment should gather data to determine the best hypothesis, not to prove or disprove a single one. By considering all of the possible (or at least plausible) outcomes, one thinks more deeply about their question, there is less likelihood of bias, and there are fewer problems with unanticipated results.

3. Investigation groups share plans with each other. Ask each small investigation group to join with another investigation group and take turns sharing ideas. Encourage them to describe in detail the steps they plan to take to complete their investigation. Also encourage them to be "critical friends" and to give thoughtful feedback that will help the other group to be successful.

Optional, depending on you time constraints

Page 2 of Investigation Journal: Making Observations and Recording Data

1. Reminder to record data and conclusions. Review the data collection section of the Investigation Journal and remind participants they need to describe what happened and what their results tell them about crayfish (their conclusion).

2. Start investigation. Encourage participants to get started on their investigations right away. They need to complete their investigation, including all of the questions in the Investigation Journal, by the end of 30 minutes.

3. Clean up work station. After participants have completed their data collection, tell them to clean up their work space and return the crayfish to its habitat.

4. Participants share discoveries. Ask for volunteers to share their investigation and what they discovered about crayfish. Also ask the participants if they made any discoveries about *doing inquiry*.

Inquiry on the Museum Floor

1. Consider investigations for museum floor. Ask participants to think about the crayfish investigation they just designed, and, if there was time, completed. Ask the following question and lead a whole group discussion. You may want to record some of their ideas to refer back to later.

"What changes do you think you would need to make to facilitate this activity on the floor?"

2. Introduce opportunity to observe crayfish investigation in progress. Tell participants that they have the chance to go and check out a crayfish investigation already in progress on the museum floor. Ask them to bring note-taking materials to record observations—about both the investigation and the interactions between the facilitator and the visitors. They should look for evidence of inquiry, similarities and differences between the floor version of the investigation and the version they just did, and how the facilitator encourages and responds to visitors.

3. Participants observe investigation. Have participants observe the activity on the museum floor for about 20 minutes. Circulate and encourage them to take notes on what they see both the visitors and the educator doing and saying.

4. Participants return to classroom for debrief. After about 20 minutes return to the classroom to debrief the experience.

Comparing and Debriefing Crayfish Investigations

1. Discuss participant observations of on-the-floor inquiry. Lead a discussion using the following prompts:

What did you notice about the floor version of the inquiry?
Did others notice the same thing?
Do others have a different viewpoint?
Were you surprised by anything you saw?
What changes were made from the classroom version?
Did you see the educator responding to visitor's incorrect answers?
If so, what did s/he do? Was it effective?

***Note to Instructor**: Here are some of the changes between the classroom and the informal version of the activity that the participants might observe or mention. Visitors have the option to choose an investigation question, and begin planning an investigation to answer that question, move forward with a previously-designed experiment, or review data already collected. Another difference is that visitors to an informal science setting would not complete the Investigation Journal as used in this session. Instead, a centrally-located binder with investigation journal pages for each question under investigation would allow different visitor groups to add to or revise the journal as they pick up an investigation. Over time, many groups could collect enough data about a single question to make generalized conclusions. A complete write-up of the informal science education version is included with this session.*

2. Discuss other possible venues and approaches for on-the-floor inquiry. Lead a discussion about other possible venues and approaches for on-the-floor inquiry using some or all of the following prompts:

> "Could an activity similar to the crayfish investigation be presented with other types of live animals?"
> "Which ones might be good to use and why?" "What are some issues that might come up?"
>
> "Can you envision an inquiry that visitors might be able to do by watching sharks or fish in a large aquarium tank?" "How might an educator facilitate that?"
>
> "How do you think visitors' experiences might be affected by engaging in an inquiry?"

Responding Strategies

1. Small groups discuss Facilitators Responding Strategies. Ask participants to think back to the way the facilitator responded to the visitor questions and comments. Use the following prompts and have participants discuss their ideas with their table group:

- Describe an interaction you remember between the facilitator and a visitor (or yourself if you participated in the activity) involving the visitor asking a question or making a comment and the facilitator responding.
- How would you describe the way the facilitator responded to the visitor? How did the visitor respond to what the facilitator said? Did a discussion start?

2. Whole group discussion about responding strategies. Lead a whole group discussion about the way the facilitator responded to what the visitors said or did and how the visitor then responded to the facilitator's response. Remember to use the Discussion Map to encourage sharing of different ideas and supporting evidence.

Ideas from Research: Promoting Discussions

1. Distribute "Ideas from Research: Promoting Discussions." Tell participants this handout describes some suggestions to encourage discussions between facilitators and visitors. Distribute it and have individuals read silently for a few minutes. Then have table groups discuss the ideas using the following prompts:

- Which of these ideas have you tried or have you seen someone else do? Describe the situation and what you thought of the interaction.

- Which of these ideas to promote discussion are you most interested in trying and why?

2. Lead whole group discussion about ideas from research. Lead a whole group discussion using the Discussion Map to encourage the sharing of different ideas and supporting evidence.

3. A toolbox of response strategies. Share with participants that, depending on the activity, the educator and particular audience or group, interactions will sometimes be very conversational and other times very instructional—there will be situations for all of the response techniques to promote discussion, but none is going to work all of the time. Museum educators are continually called upon to make some judgment calls on the fly.

> ***For example****: If there is one family or person there and they want to tell a personal story or go off on a tangent, let them...it is* ***their*** *time and* ***their*** *visit (it may also give you insight into how to get them involved in the activity). However, if there is a big crowd there, you need to use strategies to keep the group as a whole on track.*

Application of Responding Strategies

1. Introduce learner responses to sink-float question. Tell participants you are about to show them a slide with learner responses to the question: "What can you tell me about things that float?" Share with them that the learners had just participated in the sink/float activity where they had the chance to explore sinking and floating of various objects in a tub of water.

2. Display the "Learner Responses about Things That Float" slide. Read each of the responses aloud and then have the participants discuss in small groups how **they** might respond to each of the learner responses.

> **Learner #1:** Spoons float**.**
>
> **Learner #2:** The moculas they're moving. But then they stop. And when they stop, it floats.
>
> **Learner #3:** Light things float.
>
> **Learner #4:** Things that are less dense than water float.
>
> **Learner #5:** My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn't like to fish, 'cause he thinks they're gross.

3. Groups share response ideas. After about 10 minutes, regain the attention of the whole group. Tell participants you'd like them to "share out" ideas they had for responding to each of the learner's answers, and their reasons for doing so.

4. Lead discussion of how participants would respond to learners' answers. Go through the first two questions one by one, then add any of the suggestions listed below if they do not mention them. Help them to identify each response as passive, active or empathic.

> **Learner response:** "Spoons float." An inaccurate statement, probably based on limited testing.
>
> **Possible educator response:** Empathic response: "This spoon floats, and so does this one. I wonder if all spoons will float? Let's test some more." Or: "Oh, I see why you think that all spoons float, because look at all these spoons—they all float."
>
> **Learner response:** "The moculas they're moving. But then they stop. And when they stop, it floats." A confused and convoluted sounding response, including what's probably a mispronounced "molecules." The learner may have some understanding of molecules, or may just be using a "science word."
>
> **Possible educator response:** May choose an active response to probe more to find out what they're thinking., such as, "What do you mean by 'moculas?' Why would it float if the 'moculas' stop?" If time is an issue, you may need to write the word "moculas" (or a corrected "molecules") on the board and tell the learners you'll come back to this idea to discuss it (and improve upon it) more later. Sometimes, if the statement seems really convoluted and you have no idea what they're talking about, you may need to use a passive response, such as, "could be," or "Hmm, interesting idea," then move on in the discussion.

5. Continue discussion of learner responses and educator strategies. Continue going through the learner responses and possible educator strategies:

> **Learner response:** "Light things float." Could be a commonly held misconception. Could also be that they understand that light *materials* float, but haven't used the most accurate phrasing.
>
> **Possible educator response:** Could use an empathic response: "This light thing does, and so does this one. I wonder if all light things will float? Let's do some more testing. Would you call this grain of sand light? Let's test to see if it will float."

Learner response: "Things that are less dense than water float." A statement showing apparent understanding (by one learner in the group) of a key concept of density.

Possible educator response: If you wish discussion and thinking to continue, don't get too excited in your response and don't announce to the child that she or he is "right." Other learners may then stop participating for fear of being "wrong," and may be afraid to let you know that they do not understand the concept. For an active response, you may want to ask what the learner means by "less dense," to check his/her understanding, and also to give other learners the opportunity to listen and perhaps improve their understanding. Ask for examples of items they think are less dense than water. Be sure to continue to take other responses too. You can always come back to the idea later and let that learner know that's what scientists think too.

Learner response: "My uncle has a boat. And when we go fishing, we catch lotsa fish, but my brother doesn't like to fish, 'cause he thinks they're gross." This seems to be a statement by a learner seeking some attention, rather than joining in on discussion of the topic.

Possible educator response: Sometimes a response like this one needs to be gently cut off, otherwise the learner may dominate the time, while the other learners become bored and distracted**.** You can also use an active response to highlight the one piece of relevant content in the statement: "So you're saying that boats float? Does anyone have any ideas on why boats float? Do boats ever sink? Why?"

Overview of Essential Features of Inquiry

1. Display overhead "Essential Features of Inquiry." Explain that these are features of inquiry distilled from various models and descriptions of inquiry in science education literature. The model is based on the idea that different inquiry processes (collecting data, drawing conclusions, providing explanations, etc.) reside in different, interconnected "spaces," and that, as shown in the diagram four of these spaces describe inquiry as a whole—Exploration, Investigation, Explanation, and Generalization. The layout of the model serves not only to illustrate the four spaces and the *non-linear* nature of inquiry—where participants can transition from one space to any other—but also to highlight the central influence that *exploration* and *questions* have in any inquiry process. As a person or group engages in inquiry, participants will move between the spaces. Although no order is imposed, participating in a "full inquiry" involves using processes from each of the four categories.

2. Display overhead "Inquiry and the National Standards." Explain that this is how inquiry is described in the *Inquiry and the National Science*

Education Standards book. Briefly describe each of the features as detailed on the participant handout.

3. Display "Inquiry in Informal Settings" overhead. Describe how this overhead summarizes findings from studies that look at what visitors do at exhibits.

4. Display the "Breakdown of Inquiry Emphases" overhead. Explain that this represents the emphasis that the *National Science Education Standards* puts on inquiry, as well as the actual practices visitors undertake. The *sizes* of the words are directly proportional to the emphasis by the two groups. Discuss how the two differ and suggest that one role of facilitators could be to help visitors move further toward "deeper" inquiry processes.

5. Ask how the Crayfish Investigation contributed to scaffolding and guiding visitors through an inquiry. Did it promote engagement in different categories of inquiry? Lead a class discussion about their ideas.

6. Discuss *guided* versus *open-ended* inquiry. Explain that the outreach activities and kits used in the course are inquiry-based, but the activities are not open-ended inquiry. Display the "*Essential Features of Classroom Inquiry and their Variations"* chart from page 29 in *Inquiry and the National Science Education Standards*, and point out how each of the features can be more or less teacher directed.

7. Introduce the idea of "subtle shifts." Tell participants that even subtle changes along the continuum toward a more learner-centered, and therefore a deeper inquiry experience, can have huge rewards for the visitor. The more agency they have in the experience, the greater their content understanding and investment in their own learning.

8. Participants discuss benefits and drawbacks of open-ended inquiry investigations. Ask, "How would you describe what inquiry-based means compared to open-ended inquiry?" Lead a discussion with the whole group sharing their ideas.

Adding Inquiry into Designed Activities

Participants apply inquiry ideas. Have participants apply some of these ideas about inquiry to their own designed activities. Ask them to discuss with their partner how they might include more inquiry in the design and/or delivery of their own activity. Remind them that they don't have to include a completely open-ended inquiry, but think about the "subtle shifts" and how they could give the visitors more room to make their own decisions and discoveries. Tell them that for homework they will add their ideas into their Written Activity Plan due next class session.

Science Content: Seaweeds

We have chosen to introduce science content about seaweeds to model how science content can be presented through an interactive series of discussions, demonstrations and PowerPoint slides. The purpose of the science content presentation is threefold: (1) provide background about important concepts participants may choose to develop activities about; (2) show how to make content presentations interactive and discursive; and (3) model how to present science content using a learning cycle.

Note: *If you're interested in using this or other science content presentations, please see the Science Content Index on the website.*

Note: If you are continuing to add to the "Key Characteristics of Exemplar Activities" chart started in *Session 4: Designing an Activity*, add the following points that were addressed in this session:
__ Gives visitors a sense of authority/ownership of their own learning
__ Has a specific purpose and focuses on important ideas, concepts or objectives
__ Includes opportunities that explicitly address nature and processes of science
__ Allow opportunities for visitors to engage in inquiry including exploration and investigation, but also in making explanations and application
__ Is "minds-on" (not just hands-on), interactive, fun, and contains a "hook"
__ Visitors ***do*** something
__ Encourages questions from visitors and follows the interests of the learner
__ Uncovers/makes connections with visitors' current/prior understanding
__ Encourages and provides opportunities for discussion/discourse and other social interactions between visitors or family/group members
__ Includes opportunities to engage with and manipulate objects, experiences and conversations in a social setting
__ Includes opportunities for learners to engage in various teaching approaches including some or all of the following: free exploration, guided and open inquiry and problem solving
__ Includes opportunities for visitors to make meaning individually, with peers and with someone more knowledgeable (e.g. facilitator/knowledgeable visitor)
__ Presents the science content accurately

Homework

Reading:

Crowley, K., Callanan, M. A., Jipson, J. L., Galco, J., Topping, K., & Shrager, J. (2002). Shared scientific thinking in everyday parent-child activity. *Science Education*, 85(6), 712-732.

Squid/cephalopod reading from textbook and Internet.

Activity Development:

Adding More Inquiry into Your Activities

Written Activity Plan due March 31st

Investigation Journal

1. Our Question to investigate:

2. Our Hypotheses-- possible answer(s) to our question and a rationale that explains why we think that. (Generate as many plausible hypotheses as you can):

3. Our Plan. Here are the steps we plan to take:

4. Describe your plan to another group. What changes did they suggest you make to your plan? Record their feedback.

Page 2: Optional, depending on time

5. Results--Here's what we observed:

6. Conclusion--The hypothesis that is best supported by the results:

7. This is what our results tell us about *this* crayfish:

8. Here are the New Questions we have:

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 building.

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

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

6. The question can be answered by something you can **do** and not just by looking up the answer.

Ideas from Research: Promoting Discussions

Using Wait Time

The concept of "wait-time" as an instructional variable was first articulated by Mary Budd Rowe (1972). The "wait-time" periods she found—periods of silence that followed teacher questions and students' completed responses—rarely lasted more than 1.5 seconds in typical classrooms. She discovered, however, that when these periods of silence lasted at least 3 seconds, many positive things happened to students' and teachers' behaviors and attitudes. To attain these benefits, teachers were urged to "wait" in silence for 3 or more seconds after their questions, and after students completed their responses (Casteel and Stahl, 1973; Rowe 1972; Stahl 1990; Tobin1987).

Positive outcomes for learners given 3 or more seconds of undisturbed "wait-time":

- The length and correctness of responses increase.
- The number of "I don't know" and no-answer responses decreases.
- The number of volunteered, appropriate answers by more learners greatly increases.

Positive outcomes for educators' practice when they wait for 3 or more seconds:

- Questioning strategies tend to be more varied and flexible.
- A decrease in quantity and increase in quality and variety of questions they ask, including increase in questions requiring higher-level thinking on the part of learners.

Handling Dominating Learners

As reported in "The One or Two Who Talk Too Much" (1988), researchers Karp and Yoels found that in classes with fewer than 40 students, four or five students accounted for *75* percent of the total interactions per session. In classes with more than 40 students, two or three students accounted for 51 percent of the exchanges. Here are some ways to handle dominating students:

- Break the visitors into small groups or assign tasks to pairs of learners.
- If one learner dominates the discussion, ask others whether they agree or disagree with the ideas.

Calling on Boys versus Girls

Current research confirms that educators call on boys more often than girls, accept more call out responses from boys than girls, give boys more wait-time to respond, and give boys more praise and remediation than girls (Sadker & Sadker, 1994; Biklen & Pollard, 1993). Educators usually are not aware that they favor the boys in their classroom over girls and are genuinely surprised when they learn of these inequities as they conference with trained observers or watch videotapes of their teaching. (Wellhousen & Yin, 1997).

Encouraging Learners

(Adapted from *Tools for Teaching* by Barbara Gross Davis, Jossey-Bass Publishers: San Francisco, 1993.)

Use nonverbal cues to encourage participation. For example, smile expectantly and nod as learners talk. Maintain eye contact and look relaxed and interested.

Draw all learners into the discussion. You can involve more learners by asking whether they agree with what has just been said or whether someone can provide another example to support or contradict a point: "How do the rest of you feel about that?"

Give quiet learners special encouragement. Quiet learners are not necessarily uninvolved, so avoid excessive efforts to draw them out. Some quiet learners, though, are just waiting for a non-threatening opportunity to speak. To help these learners, consider the following strategies:

- Arrange small group (two to four learners) discussions.
- Pose casual, broad questions that don't call for a detailed correct response: "What about this is interesting to you?" or "What would you like to learn more about?" or "What do you notice?" (McKeachie, 1986).
- Assign a small specific task to a quiet learner: "Would you help us to put these things into groups?"
- Reward participation with a smile and make eye contact.
- Bolster learners' self-confidence by writing their comments where others can see them or repeating them to make them public (Welty, 1989).

Provide accepting responses that encourage further thought and interaction. One of the effects of giving accepting responses is creating a safe climate for a variety of learner responses. Such responses also allow learners to be responsible for deciding what to do for themselves, take risks and learn about the consequences of their actions. There are three general types of accepting responses:

- **Passive Acceptance**: A response that does not indicate agreement or disagreement with the learner's answer. Examples: "Could be" or "Interesting idea." Allows the educator to acknowledge the contribution made by the learner. Can be useful to use when a learner gives a really convoluted answer, and the educator wants to encourage continued discussion.

- **Active Acceptance**: Restating the learner's answer in a way that shows understanding. Example: "So Sara is saying that the wood floats." Lets the learner know that the idea has been received and understood.

- **Empathic Acceptance:** Educator attempts to explain the reasoning behind the learner's answer. Example: "Oh I see, why you think that… because look at all these examples of it." Lets the learner know the educator understands what they're saying as well as the evidence behind it.

What to Do After Learners Respond to Your Questions

How to handle accurate (and sometimes complicated) learner responses. This could mean the learner has an excellent grasp of the subject matter, but could also mean that they have memorized some terms or scientific phrasing that they don't really understand.

Do: Ask follow-up questions to try to find out what they really understand; point out technical terms, ask what they think they mean, and what evidence these statements are based on, to give other learners the opportunity to listen and perhaps improve their understanding. Ask other learners for evidence supporting or disputing the idea. Don't let on that one idea is "the answer," but facilitate discussion and tests that will allow the rest of the learners to evaluate and investigate a variety of ideas for themselves. If you want discussion and thinking to continue, don't get too excited in your response and announce "that's right." Other learners may then stop participating for fear of being "wrong," or be afraid to let you know that they do not understand the concept. Be sure to continue to take other responses too. You can always come back to the idea later and let the learner know that's what scientists think too.

Don't Do: Don't tell them they are correct and brilliant. Although such a response would likely make that learner feel good, it could cut off the rest of the group from being willing to put forth their own ideas, for fear of being wrong. Even without such a "glowing" response on your part, a statement like this from a learner can have the effect of shutting down the rest of the group's thinking and participation. They may simply nod their heads in agreement with a "sophisticated" sounding response that they very likely do not understand. It's also not fair to the learner herself, as she may or may not comprehend the terminology she used.

How to handle partially accurate learner responses.

Do: Ask them for their evidence: "Can you show me what you mean?" Ask other learners what they think. Retest the evidence with the group. Give the learners an opportunity to alter their statement to make it more accurate, either during the discussion or with further tests.

Don't Do: Don't tell them that they are wrong or right. Don't make them feel bad for not providing a completely correct response. But also don't allow the inaccurate ideas to go completely unchallenged.

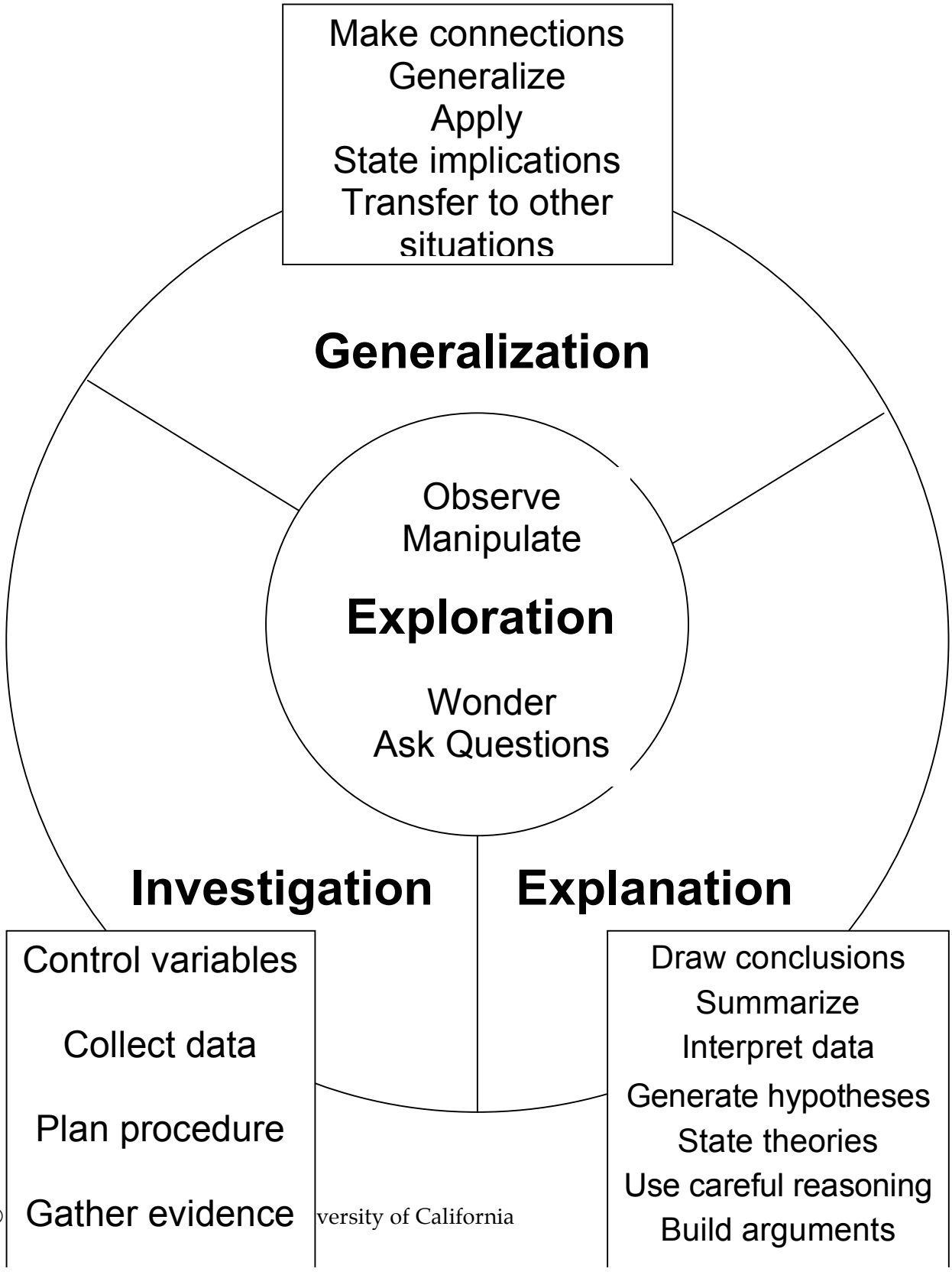
How to handle inaccurate learner responses.

Do: Without placing judgment on the response, ask other learners what they think. Through follow-up questions, try to figure out their point of view and the "evidence" it's based on. It is likely that other learners in the group might have similar ideas. Note that leaving even a couple of minutes time between the learner's statement and evidence that disproves it allows the learner's ego to be less attached to the idea.

Don't Do:

Don't tell them they're wrong, or immediately provide evidence that proves them wrong, embarrassing them in front of their peers.

Essential Features of Inquiry



overhead

Inquiry and the National Standards

- **Learners are engaged by scientifically oriented questions.**
- **Learners give priority to evidence, which allow them to develop and evaluate explanations.**
- **Learners formulate explanations from evidence to address scientifically oriented questions.**
- **Learners connect their explanations to scientific knowledge.**
- **Learners communicate and justify their proposed explanations.**

From ***Inquiry and the National Science Education Standards,*** **Chapter 2, pp. 24–27**

(handout)

Inquiry and the National Science Education Standards

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.

2. **Learners give priority to evidence, which allow 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.

3. **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.

4. **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 participants engage in dialogues, compare results, or check their results with other scientific resources. Student explanations should ultimately be consistent with currently accepted scientific knowledge.

5. **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*, Chap. 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

Overhead

Inquiry in Informal Settings (What Visitors Actually Do)

1) **Visitor questions typically focus on the physical display, not underlying phenomena or concepts.**

2) **Visitors are generally successful at answering their questions through manipulation and observation.**

3) **Conclusions and explanations seldom generalize past the exhibit.**

4) **Situations involving alternative explanations or using evidence to support claims are rarely seen.**

Handout

Inquiry in Informal Settings (What Visitors Actually Do)

1) **Visitors' questions typically focus on the physical display, not underlying phenomena or concepts.** When engaging with exhibits, activities and live displays, visitors approach with questions such as "What is in this one," "What does this do," "What is that called," and "What is this about." Deeper questions pertaining to underlying mechanisms, relationships, and principles are rare.

2) **Visitors are quite successful at answering their questions through manipulation and observation.** Most museum-goers are adept at answering questions such as those listed above by reading text, watching or listening to others, and, in the case of hands-on exhibits, "playing" with the exhibit until they are satisfied that they know what it does.

3) **Conclusions and explanations seldom generalize past the exhibit.** When visitors do generate explanations, they are typically focused on the specific exhibit, and do not generalize to other exhibits or situations outside of the museum.

4) **Situations involving alternative explanations and using evidence to support claims are rarely seen.** Using evidence to support claims is the inquiry-related activity least frequently observed in visitors. Presentation and consideration of alternative viewpoints, perspectives, and explanations is a close second. Visitors appear satisfied with any explanation (whether from text panels, docents, or family members) and do not require evidence to support it.

Handout and slide

Breakdown of Inquiry Emphases

NSES	Visitors
Exploration	Exploration
Investigation	Investigation
Explanation	Explanation
Generalization	Generalization

Crayfish Investigations
Lawrence Hall of Science

This activity outline was developed for use in a variety of informal venues. By design, it provides the content, pedagogy and strategy necessary for implementation by both the novice and experienced informal educator. It is expected that this outline will be adapted and improved upon by the user. We welcome your feedback!

Synopsis of the Activity
Visitors are invited to interact with crayfish while facilitators guide them to make observations and design investigations to learn more about crayfish. If they wish, visitors can set up an investigation to answer their question(s) and/or collect data to provide evidence for a previously asked question. Visitor observations and questions are added to a public board, and results to a notebook where others can read and build on them.

Audience
The general public of all ages. Suited for 1–3 small groups of participants.

Setting
Open areas on the floor, or in a classroom setting; recommend avoiding high-traffic areas. At times, this can be a very demanding activity for facilitators and having more than one facilitator is recommended.

Activity Goals
Learners will become familiar with the processes of inquiry. Learners will also be encouraged to take a closer look at the world around them and to help focus them on the types of questions they can ask, how to answer those questions, and how their answers can be applied beyond the specific situation. Learners also gain an understanding of the structures and function of crayfish.

Concepts
This activity is primarily process-oriented, so the concepts and vocabulary deal with inquiry, not crayfish. The activity could be done with a variety of organisms, such as hermit crabs, shrimp, etc. and appropriate life science concepts and vocabulary developed.

- Scientists try to answer questions they have about the world by doing investigations where they make observations and gather data.
- Scientists predict what they think will happen in an investigation and describe their reasons for why they think that. Together these two things are a hypothesis.
- Evidence is used to support an explanation or idea.
- Certain findings can be generalized to other situations.

Ocean Literacy Principles
7. The ocean is largely unexplored.
b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Materials
For each group:
- 1 clear plastic shoe box or similar aquarium
- clean, dechlorinated water to fill plastic shoeboxes about 5 – 10 cm deep
- 1 crayfish

For the table or cart:
- I Notice/I Wonder/Investigation board
- 100 colored index cards (three colors)
- colored markers
- 1 copy of Crayfish Information Cards
- Various materials for conducting crayfish investigations (e.g. sand, gravel, various-sized/colored/shaped clay pots, pipes, and/or containers for hiding, tubifex worms, fish flakes, bits of meat or fish, lettuce, large squares cut from black plastic garbage bags, large squares cut from white plastic trash bags, vegetable bags, strawberry baskets, mirrors, flashlights, blocks, or other barriers, etc.)
- Notebook with copies of Investigation Journal

Preparation and Set-up
- Prepare I Wonder/I Notice/Investigations Board. Using chalk or white board, bulletin board, or large sheets of paper taped to the wall, post the headings "I Wonder," "I Notice," and "Investigations" in colors corresponding to the respective colored index cards. Have available a means to attach the cards visitors fill out under the appropriate headings.

- Gather all materials; place crayfish information cards and a tub with a crayfish or two on the table. Have all other materials near the table or cart for easy access when needed.

Guiding Questions
What do you see or notice about the crayfish?
What is it doing?
What does it look like?
How is it moving around?
What do you want to know about the crayfish?
What do you wonder about the crayfish?
How could we answer that question?
Would that be true for all crayfish? All crustaceans? All animals? How do you know? What evidence do you have?

Activity Description

Introduction: Invite visitors to come and observe the crayfish in their aquariums. Visitors are often very attracted to the opportunity to observe and touch living organisms. Also, noting that they can actually design and participate in an actual scientific investigation could help gain visitor interest. For instance, you could say, "Have you ever seen a living crayfish? Do you have a question about crayfish that you would like to investigate? Come over and find out what you can discover about them."

> ***Focus on Inquiry***
> *There is no order in which the explorations need to be done, and visitors do not need to do every exploration. The common goal across all of the explorations is the process of inquiry. Thus the facilitator does need to encourage visitors to observe, question, and investigate, and also to help visitors make connections between the explorations if visitors do more than one exploration and are not making the connections on their own.*
>
> ***Multiple Entry Points***
> *While facilitators may progress from Free Exploration, to I Notice/I Wonder, to Investigation etc, the reality is that visitors may not want to or be able to explore in that order. Acknowledging this, the design of the activity is open enough that each subsequent section in the write-up is a mini-activity/task within the whole activity, and the facilitator can weave a series of mini-tasks for visitors while keeping the goal of the activity in mind.*

Free Exploration (Observe, Question): Invite visitors to come close and observe the crayfish in the aquarium tanks. Encourage them to make observations and ask questions about what they wonder about. As visitors freely explore, ask them questions about their observations of the crayfish to encourage them to think about the biology of the organism, and what they notice about how it uses its different body parts. Encourage visitors to ask questions and talk with others in their group.

Suggested questions:

- Have you seen crayfish before? Where?
- Can you tell me something you know or have heard about them?
- What do you notice about the crayfish?
- Can you describe more about that?
- What else do you notice?
- What kinds of things do you wonder about the crayfish?
- What is really interesting to you so far about the crayfish?
- Would you like to do an investigation or design an experiment to see if you can figure out the answer to your question?

Key ideas to address in this conversation:

- Crayfish live in freshwater ponds, lakes, and streams.
- They are related to crabs, lobsters, and shrimp.
- Scientists find out about living organisms by observing them very carefully in their natural habitat.
- These aquariums are not the crayfish natural habitat, but we can find out some interesting things about them by observing them carefully in these model ponds.
- Scientists do investigations to find answers to their questions.

Form, Function, and Feeding (Observe): Let visitors know that, just like scientists, they can find the answers to many questions they wonder about. Invite visitors to take a closer look at the body parts of the crayfish, and challenge them to share something they notice about the crayfish. Remember to encourage visitors to explain and provide evidence for their observations and ideas.

Suggested Questions:

- What does it seem to be doing?
- What makes you think that? What's your evidence?
- How is the crayfish moving around?
- What body parts is it using?

Key ideas to address in this conversation:

- Engage the visitor in a conversation about the crayfish based on what they find interesting about the structures, function, and life history of the crayfish.
- If they are interested and can read the Crayfish Information Cards, consider choosing one of the cards that addresses what they are interested in and, after reading the card, have them share the information with other visitors at the cart.

I Notice, I Wonder (Observe, Question): Encourage visitors to write down as many observations on the cards about crayfish as they like (one observation per card) and place it on the board under the heading "I Notice." Also challenge them to share one or more questions they wonder about. Encourage them to pick at least one of the questions to write on a card and post it on the board under the heading "I Wonder."

Suggested questions:

- What would you like to find out about the crayfish?
- What do you wonder about?
- Do you think you know the answer?
- How sure are you? How could we be more sure?
- What could we do to find out the answer to your question?

Holding the crayfish (Observe): Show visitors 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. Emphasize that no one has to touch it or pick it up, and that the crayfish must be treated very, very gently. Show them the difference between male and female crayfish.

Suggested questions:
- What do you notice about the underside of the crayfish?
- What does the crayfish do when it is held out of water for a few seconds?
- What does it do when it is put back in the water?
- Looking at two different crayfish, what do you notice is the same and what is different?

Choosing a question to investigate (Question, Investigate): Encourage the visitors to choose one of their questions to investigate, or you may suggest some already prepared investigations for visitors to consider (see Attachment B at end of this activity). You can also invite visitors to look at the board or talk to other visitors for ideas of questions to investigate.

Suggested questions:
- What would you like to find out about the crayfish?
- What do you wonder about?
- Do you think you know the answer?
- How sure are you? How could we be more sure?
- What could we do to find out the answer to your question?
- What do you think might happen if we do that investigation?
- What makes you think that?
- What kind of materials will you need to do the investigation?

Doing an investigation (Investigate, Observe, Question): If the materials are available, help the visitors set up their experiment (groups with older kids can write in an investigation journal, or the facilitator may summarize the investigation at a later time—see journal pages at end of this activity).

Suggested questions:
- What question about the crayfish are you investigating?
- What do you think will happen when you do that investigation?
- What makes you think that?
- What happened when you did the investigation? What are your results?
- What does that tell you about this crayfish?
- Did you answer your question? What's your evidence?
- Do you think you figured out something about all crayfish or only this one? What makes you think that?

Related Activities/Extensions/Modifications

The Crayfish Investigations activity can be done with animals other than crayfish as long as they are hardy and interesting—mole crabs and brittle stars have been used successfully. Posting an "I Wonder/I Notice" Board and guiding visitors to make observations and ask questions (and to a lesser extent do some investigations) can also be done using animals in a tank.

Additional Resources
Books about crayfish and their relatives as well as photographs are helpful to include for those visitors wanting to learn more. The Crayfish Information Cards are a great resource for visitors to find answers to questions about life cycle, how long they live, where they live, etc.

Background

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 the crayfish, lobster, crab, barnacle, and shrimp. The crustaceans are almost entirely marine (living in salt water) and many live at the rocky seashore. One of the freshwater exceptions is the incredibly successful crayfish.

There are more than 500 species of crayfish and they are found throughout the world in swamps, marshes, 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. Although they live only in brackish or freshwater, crayfish are ideal to represent the crustaceans living at the rocky seashore because they have so much in common with their marine relatives and yet are much easier to obtain and keep alive in the classroom.

All arthropods (which include crustaceans) have several features in common. They are all covered with a hard external skeleton (exoskeleton) that is segmented so they can move. Arthropods must shed or molt the exoskeleton in order to grow because it cannot grow as the inner body does. By the time a crustacean molts, a new, soft exoskeleton has already started to form underneath the old one. As soon as it molts, the animal inflates its new exoskeleton to a larger size by swelling itself with water. This allows for some growing room before the next molt is necessary.

Crustaceans are very successful living between the rise and fall of the tides in the wetlands and these same adaptations allow the crayfish to live in very diverse freshwater systems. All crustaceans have gills covered by a carapace—the shield-like part of the exoskeleton that covers the head and most of the back, and 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 fanlike tail. Crustaceans can stay out of water for varying lengths of time, but must always keep their gills moist so they can breathe. Most crayfish can remain out of water for only about 10 minutes at a time.

Crayfish, crabs, and lobsters are called decapod crustaceans because they have ten large legs. The first pair of legs are modified into pincers, which are used to defend against predators, help in competition with other crustaceans, and catch and tear food into smaller pieces. Actually, even the mouth parts of decapods are modified legs (not counted among its ten) and are used to sort and manipulate food after the pincers bring it to the mouth.

The next four pairs of legs are used primarily for walking, but also for handling food and cleaning itself. In crayfish, the legs on the abdomen or tail section are used in reproduction to hold masses of dark, spherical eggs until they hatch. They also are used as fans to keep the eggs oxygenated. These abdominal legs are called swimmerets because they help the crayfish to swim, although they are weak swimmers and cannot float. The crayfish uses its strong tail to dart backwards rapidly by flexing it towards the belly. This allows them to escape predators and to right themselves when they end up on their back. In crabs, the tail and abdomen are very much reduced and are wrapped tightly underneath the carapace. Female crabs have a wide rounded abdomen used as a shelf to hold their eggs. Males have a narrow, triangular abdomen.

Crayfish can be very aggressive towards one another. It is important, if you are keeping them for any length of time, 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.

Crayfish have to contend with fast moving rivers, whereas its seashore relatives, crabs and shrimp, have the changing tides and crashing waves to deal with. Crayfish have pincers like crabs and walking legs like shrimp. Also, like crabs, they can hang onto rocks and water plants so it isn't dislodged with strong water movement. By observing crayfish that live in streams and ponds, we can begin to understand how their ocean relatives live as well.

1. 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).

You can also collect your own crayfish if there is an appropriate wetland, stream or pond nearby. In some areas crayfish can be bought from bait shops, or even from pet stores, which is usually the most expensive option. Most supply houses also provide several other preserved or live crustaceans for comparison, such as hermit crabs, brine shrimp, barnacles, crabs, etc.

You can keep crayfish in the refrigerator for up to two days if you wrap them in wet newspaper or pond plants. But you must keep their gills wet, so they can breathe.

2. Keeping Crayfish
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 these live 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, cat food, 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 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 great for hiding places.

3. Designing the Crayfish Habitat
Crayfish survive very well in an aquarium that is large enough for each of them to find a hiding place and not foul the water too quickly with their wastes. There also needs to be enough surface area of water so that an adequate supply of air in the water is available. The ideal habitat is a small wading pool, filled to a level of about 8 - 10 centimeters and housing 10 or so animals. Smaller aquariums call for fewer crayfish, with a rule of thumb being about 5 crayfish for a 40-liter aquarium. Fill the aquarium about 8 – 10 centimeters deep with dechlorinated water, add clean gravel to cover the bottom, add the broken flower pots for shelter and finally add 10 or so Elodea sprigs to provide oxygen to the water.

4. Obtaining other supplies for the crayfish
Elodea plants, dechlorinating liquid, feeder goldfish and live tubifex worms can all be purchased from a supply house like Carolina Biological, or they are usually easily and inexpensively obtained at your local aquarium store.

Crayfish Information Cards

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

Crayfish have two pairs of **antenna, which** help them to sense their habitat. 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 have a long pair of **antenna**, which they use to help them sense their habitat. They use them 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 like crabs, lobsters and shrimp are a special group of animals called **Crustaceans**. 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 are the animals in 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 the crayfish, lobster, crab, barnacle, 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. The hard exoskeleton protects the arthropod's soft inner body from many predators or other dangerous things in the 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 (a mixture of salty and fresh). 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. Pinchers 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 that 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. They can tell that they are touching something if those hairs are moved.

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 to swim. 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. 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 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 wastes. The place the poop comes out can be found 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.

Vocabulary

- Investigation - a process of gathering information or ascertaining facts through detailed or careful examination to answer a question.
- Investigable question - questions that can be answered by gathering data.
- Observation – A close or careful examination; the noting of a fact or occurrence often involving measurement
- Hypothesis - A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation; includes both a prediction or explanation and rationale.
- Data - Factual information, especially information derived from scientific experiments and organized for analysis or used to reason or make decisions.
- Evidence – Information or data that can serve to prove or disprove something.
- Finding - A conclusion reached after examination or investigation.
- Generalizable – able to infer or form a general principle, opinion, conclusion, etc. from only a few facts, examples, or the like.

Attachment A

Investigation Journal

I Notice…	*I Wonder…*

This is the question I want to investigate:

These are the materials that I need:

This is what I think will happen and why I think so:

This is what happened when I tried my investigation:

This is what my results tell me about this crayfish.

Here are the new questions I have:

Attachment B
If visitors are having trouble coming up with an investigable question with the crayfish, here are a few investigations to suggest. You can laminate the cards and keep them to the side to show to individuals or you can keep the list as reference for the facilitator.

Do crayfish prefer to be in the open or to hide? Think about what you would need to conduct this investigation then ask the facilitator to help you collect the materials you would like to use. What do you think will happen and why?

Which type of substrate (stuff on the bottom of the tank) do crayfish prefer? Think about what you would need to conduct this investigation, then ask the facilitator to help you collect the materials you would like to use. What do you think will happen and why?

What kinds of food will crayfish eat and which do they seem to prefer? Look at then items available on the table and think about what you would need to conduct this investigation. Then ask the facilitator to help you collect the materials you would like to use. What do you think will happen and why?

Do crayfish prefer to be in the light or in the dark? Think about what you would need to conduct this investigation then ask the facilitator to help you collect the materials you would like to use. What do you think will happen and why?

If two different sized crayfish (or a male and female) are put together, will the smaller one hide out? Think about what you would need to conduct this investigation then ask the facilitator to help you collect the materials you would like to use. What do you think will happen and why?