Session 6: Questioning Strategies

Session Overview

This session focuses on two main categories of questions—"broad" and "focused" questions—also referred to in some education literature as "open-ended" and "closed." The interactive activities in this session introduce the appropriate use of both types and are not intended to portray either type as "good" or "bad." The emphasis is on analyzing the impact of both kinds of questions on student thinking and behavior, and using this information to help decide how and when to best use them. In addition, we explore the effects of sequencing questions, both to lead students through learning cycle-based explorations, and to help guide discussions. We also explore typical approaches teachers can take when answering questions ("sage on the stage" or "guide on the side") and how these approaches can either draw out student questions or, in the extreme, shut them down. Finally, participants are introduced to a lesson exploring sink/float concepts and use what they've learned about questioning strategies to plan a series of questions they will ask their own students during the next session.

Background Information for the Presenter

Questioning is a vital and powerful teaching strategy, and a crucial component of just about any teaching situation. This is especially the case when learning situations derive from student experience, where questions and reflections about that experience are used to develop and refine concepts. Questions can open doors at every stage of the learning experience—inviting students into activities and ideas by creating interest in a new topic; helping guide students' active explorations; stimulating reasoning and sense-making of new concepts; and encouraging students to apply their ideas to different situations. Well-sequenced questions can initiate the sharing of ideas, encourage development of multiple hypotheses or alternative explanations, help students recall prior knowledge, allow them to synthesize new information, and help guide logical thinking.

There's an art to employing questioning strategies and to balancing the amount of asking and telling used in a teaching situation. There is no one formula for what this balance should be, and it changes from situation to situation. Experience and practice can hone teachers' expertise and questioning know-how. Skilled instructors use questions to find out what students think, encourage discussion, and draw attention to diverse viewpoints and interpretations. However, one can also observe veteran teachers who do not take advantage of questioning strategies that could elevate their classes to interactive learning experiences, but instead resort to perfunctory question-and-answer drills. Research indicates that teachers who are specifically trained to ask high-quality questions show significant improvement in constructing and using such questions in the classroom (Angletti 1991, as quoted by Cecil 1995). Reflection and analysis of the effect on learning of various kinds and sequences of questions is essential for teachers to develop this type of expertise.

Questions that Encourage or Discourage Discussion

An analysis of questioning strategies can begin with noting the effects of using focused and broad questions during a discussion. The model lessons in this session demonstrate how using focused questions, which have specific, prescribed answers, can shut down a class discussion by requiring students to try to guess what the teacher is thinking. In contrast, beginning the conversation with broad questions, which have multiple acceptable answers/responses, can encourage more students to participate and offer various ideas for the discussion. Of course, if consensus has been reached as the result of a discussion, it can be appropriate to wrap-up with focused questions that help students summarize their ideas and conclusions. Once an instructor develops a feel for how these questions affect learners, they can then make thoughtful adjustments to their questioning strategies during their teaching.

Considering Goals When Asking Questions

When planning for questions, another thing to consider is the instructor's purpose or possible goals for engaging the learner in a particular teaching situation. When beginning a new activity or science topic it's often useful to engage students in observing and noticing details. Questions such as, "What did you notice when…?" can be used to guide students to make certain observations, but should be broad in order to encourage multiple points of view. Questions such as, "What do you think will happen if…?" can be used to stimulate productive activity during an investigation. Once students have explored a phenomenon or performed an investigation, questions can then be used to guide students to make comparisons or quantify their observations. Given adequate experience and exploration of a topic or phenomenon, students may then be ready to draw conclusions and make sense of their investigations, responding to questions, such as, "What do you think is the explanation for…?" or "Why do you think this happened?" can be used to encourage sense-making. Questions can be used to challenge students to apply what they've learned in order to generalize their knowledge or test their hypotheses. Asking students to reflect on their thinking and investigation processes helps them become more aware of their own strengths and weaknesses in the subject area, as well as encourages them to take charge of their own learning.

Role of the Instructor

The final factor considered during this session, which can definitely impact an instructor's questioning strategies, is how the instructor views his or her role in the classroom. A "sage on the stage" type of instructor has the point of view that it is their responsibility to impart or transmit knowledge directly to students and that the teacher or text must provide the necessary information for understanding. This view of the learning process can emphasize rote memory and regurgitation of ideas from sources other than the students themselves. A "guide on the side" type of instructor embodies a more constructivist view of learning—one which accepts that students must be encouraged to create their own personal frameworks through discussion and interactions with materials and various sources—so they can develop a deeper understanding that can be flexibly applied to different learning situations.

Session Objectives

In this session, participants:

— experience and reflect on the different effects that focused and broad questions have on student thinking and discussions;
— note teacher behaviors that reflect when a teacher sees his/her role as either "guide on the side" or "sage on the stage" and the impact this may have on students;
— participate in a sink/float activity they will help present to students in the next session;
— apply what they've learned about questioning strategies as they prepare their own set of questions to guide visiting students when they take part in sink/float investigations during the *Question Lab* session; and
— participate in *The Great Plankton Race* to model an activity that they may take into the classroom when they teach.

Session Activities at a Glance

Describe the Object Activity
This session starts off with a brief activity in which the presenter asks participants a series of guiding questions. The participants are then asked to notice the different effects that broad and focused questions had on their own thinking and participation in discussion. The effects are quite striking, as discussion emerges naturally when broad questions are used, and tends to end abruptly with focused questions.

Considering the Role of the Instructor
Two brief dramatizations are presented, depicting the interactions between a professor and a student who has come for help during office hours. The first illustrates the instructor taking a "sage on the stage" role, while the second portrays the "guide on the side" role. During a discussion, participants learn how a teacher's view of their role and their assumptions about learning may influence the types of questions they ask students.

Introducing Discussion Map
The class is then introduced to the idea of using a "map" to lead successful discussions in which they learn to:

- Ask a broad question
- Listen to response and thinking
- Ask for evidence or explanation
- Ask for alternative opinions or ideas
- Lead back to the main topic
- Help to organize and summarize the ideas

Sink/Float Activity and Planning Sink/Float Questions
Next, participants plunge into an activity exploring sink/float concepts. Participants apply what they've learned about questioning strategies as they work in small groups to plan a series of questions to ask students who will take part in the next session—

when participants will guide students through the same sink/float activity they've just experienced.

Challenge Activity: Great Plankton Race
As a follow-up to Sink/Float and to model an activity that participants may present in a classroom, participants are challenged to design a planktonic organism that will neither float like a cork nor sink like a stone. They are given pictures of planktonic organisms and simple materials. The best model of a planktonic organism will sink slowly or be neutrally buoyant. After designing with their team mates, students test and race their plankton in a simulated ocean. ***Please note**: This exercise is designed to give students an opportunity to apply observations and concepts in an engaging way. It is not a biomechanics exercise, and thus Reynolds Number issues are ignored.*

Concluding the Session and Homework
The session ends with participants reflecting on what they have experienced and how this may influence their teaching.

Time Frame

Total Workshop: 2 hours 50 minutes
- Describe the Object Activity (20 minutes)
- Role of the Instructor and Debrief Discussions (35 minutes)
- Introducing the Discussion Map (10 minutes)
- Sink/Float Activity (30 minutes)
- Planning Sink/Float Questions (20 minutes)
- Great Plankton Race (40 minutes)
- Concluding the Session and Homework (10 minutes)

Materials Needed

For the class:

- ❑ 1 overhead transparency or PowerPoint slides of each of the following sheets:
  - — "?"
  - — "Questions for Discussion" questionnaire
  - — "Types of Questions"
  - — "Discussion Map"
  - — "Discussion Map Example"
  - —"Quick Write"
- ❑ 1 overhead or LCD projector

For each participant:

- ❑ 1 copy of the "Questions and the Learning Cycle" sheet
- ❑ 1 copy of the "Types of Questions Defined" sheet
- ❑ 1 copy of the "Discussion Map" sheet
- ❑ 1 copy of the "Questions Planning Worksheet"
- ❑ 1 copy of the "Sample Questions" sheet

For the *Describe the Object* Activity:

For the class:

❑ 3 distinct and interesting items, such as a large shell, a skull, and a bone.

Note: *These are three different items you'll hold up for all to see as they briefly discuss their observations in teams of two. These can be any items you have handy, as long as they are large enough to be visible to the group and interesting to discuss and compare. These items could also be topically related to each other, such as a shell, a skull, and a bone (to inspire discussion about the hard parts of organisms), or a rock, a piece of plastic, and a shell (to inspire discussion about natural and man-made objects) or simply three containers, one with a solid, one with a liquid, and one with air inside.*

For the Skits:

For the class:

❑ 3 copies of the Scripts—one for yourself and one for each of the two role play participants

For the Sink/Float stations:

For each group of 4–6 participants:

❑ approximately 9 ft. of yarn or string to make sorting circles
❑ one dishtub
❑ a diverse collection of sink/float test objects, such as:
— small and large pieces of wax
— wooden objects
— metal objects
— crayons (for younger children, do not use crayons, as some colors sink and some float, which can be confusing)
— fresh egg (in the shell of course)
— balloon
— aluminum foil
— soda can (unopened) diet and non-diet
— full bottle of water with cap
— paper clips
— plastic film canister with lid
— sponge
— sand
— marble
— spoon
❑ salt (*optional*) This would be useful for high school or university age groups—not as a sink/float item—but in case any choose to increase the density of the water.

For the Great Plankton Race:

For the class:

❑ water to fill aquarium
❑ 2 stopwatches
❑ a knife for cutting corks
❑ Award Ribbons (See Preparation of Materials)

- ❑ 1 sheet each of red, blue and white paper
- ❑ 28 sheets yellow paper (or another color not red, blue or white)
- ❑ Diversity of Plankton overhead
- ❑ Video and VCR or pictures of plankton (optional)

For each small group of 5–6 participants:

- ❑ one to several gallon jars or clear plastic shoeboxes (e.g. plastic mayonnaise jars)
- ❑ water to fill the gallon jars or plastic shoeboxes
- ❑ container or plastic bag filled with the following found materials: recycled Styrofoam packing "peanuts," corks (whole and half), toothpicks, paper clips, metal washers, colored yarn, split-shot fishing sinkers, 1–2" square pieces of sponge
- ❑ 2 pairs of scissors
- ❑ sponge to mop up drips

Preparation of Materials

1. Assemble materials for Describing Object activity. Gather and set out the objects for the activity.

2. Prepare PowerPoint slides. You'll need one of each of the following slides:

— "?"
— "Questions for Discussion"
— "Types of Questions"
— "Questions and the Learning Cycle"
— "Discussion Map Example"
— "Discussion Map"
— "Quick Write"

3. Duplicate handouts. For each participant you'll need one of each of the following handouts:

— "Questions and the Learning Cycle"
— "Types of Questions Defined"
— "Discussion Map"
— "Question Planning Worksheet"
— "Sample Questions"
— "Features that Planktonic Organisms Share"

4. Duplicate scripts. Make three copies of the Skit scripts, one for yourself and two for the role-play participants.

5. Prepare sorting circles. Cut pieces of yarn or string, about 3 feet long, and tie the two ends together to make circles. Each group will lay 3 yarn circles out on the table—one to designate items that float, one for those that sink, and the third for groups who decide they need a third category. Each group of 4–6 participants will need three sorting circles.

6. Set up sink/float stations. You'll need one sink/float station for each group of 4–6 participants. For each station, set aside:
— a dishtub half-filled with water
— three sorting circles
— a collection of sink/float test objects

7. Set up Great Plankton Race. Fill large aquarium/tub for the race. Fill individual tubs for testing designs. Lay out building materials for students to collect.

8. Review Great Plankton Race activity. This activity is one of those that students may take into classrooms during the outreach portion of the course. This activity comes from the *MARE Teachers Guide to Open Ocean Habitats*. There is enough information to lead the activity within this session write-up—the entire activity provides more background if you are interested.

Important Note to Presenter: You will need to plan to recruit some students for the next session, the *Question Lab* session. In that session, course participants each have the opportunity to present a brief activity to a small group of students and try out their questioning strategies—with real live students. This experience is invaluable. It provides a safe and controlled context for participants to gain firsthand experience trying out different questioning strategies, without the pressure of needing to do so with a large or high-stakes group. They gain the further advantage of being able to reflect on what worked and what didn't with their fellow participants and you. **We strongly recommend that you make the effort to recruit students for the Question Lab.** If you do decide to skip the *Question Lab* session, go ahead and have your participants prepare questions in this session, as if they would be presenting sink-float activities to students, to provide at least some practice with this important exercise.

Instructor's Guide — Session Details

Introducing Questioning (20 minutes)

1. Display "?" slide (or transparency). Project the transparency or PowerPoint slide that shows a large question mark—to intrigue students as they enter the room, and as the lesson begins.

2. Explain importance of questioning strategies. Explain that teaching is a language-based profession, and that the ability to lead/facilitate successful meaning-building discussions, to inspire higher-level thinking, and to find out how students are developing their understanding are all grounded in the teacher's ability to ask questions.

3. Describe how skillful questioning can enhance an educational experience. While the topic of "how to ask questions" may seem unimportant to some, developing good questioning strategies is what elevates teachers to the level of being an "artist of discourse" in the classroom. To put it another way, a lack of good questioning strategies can seriously undermine a teacher's effectiveness. Even the best activities can lead nowhere if they do not involve the thoughtful use of questions.

4. Carefully planned questions used in the course. Point out that in previous sessions of this course, carefully thought-out questions were used to inspire higher-level thinking and further investigation.

5. Statements requiring a response can be categorized as questions. Tell participants that a question can be defined broadly as any utterance that requires a response. Show how a question can be re-phrased as a directive statement, and alternatively how a directive statement can be re-phrased as a question. Refer to the examples below.

> Question: What did you observe when you used the moon balls in the phases of the moon activity?
> Statement: Describe what you observed when you used the moon balls in the phases of the moon activity.

Explain that in this session you will be using this broader definition of question—as any statement requiring a response.

Describe the Object Activity

1. Ask partners to describe first object. Hold up the first object. Ask, "What do you observe about this object?" and "How might you describe this object to your partner?" Tell each team of two to observe and describe what you are holding up to their partner.

2. Ask partners to describe second object; compare with first. After about one minute, hold up the second object with your other hand. Ask, "What do you observe about **this** object?" and "How might you describe **this** object to your partner?" Tell them to observe and describe what you are holding in this hand, and compare it with what you are holding with the other hand. Ask, "How is this object the same or different from the other object?"

3. Ask partners to describe third object; compare with first and second. After another minute, set down the first two objects where they can be easily seen by the group, and hold up the third object. Ask them to observe and describe this object, and compare it to the other two objects.

4. **Ask what each object is in succession.** After about one minute, hold up the first object again and ask the fourth question: "What is this object?" Do this with each of the three objects in succession.

5. Ask other focused questions about the objects. Ask any other focused questions that seem appropriate, such as:

> Which of these is from inside the body of an animal?
> What kind of animal is this object from?

Introducing Broad and Focused Questions

1. Display "Two Types of Questions" slide.

2. Introduce broad and focused questions. Explain that the questions you just used can be put into the two general categories—**broad** and **focused** questions.

3. Each type generates a different kind of response. Emphasize that neither type of question should be considered "good" or "bad," but that the two different types tend to generate different types of responses. For this reason, teachers need to be aware of the particular circumstances in which it's best to use different types of questions.

4. Identify Questions 1–3 as *broad* questions. Display *Questions for Discussion* transparency or slide, and say questions 1–3 fall into the category of *broad* questions:

Questions 1–3:
1. What do you observe about this object?
2. How might you describe this object to your partner?
3. How is this object the same or different from the other object(s)?

5. Discuss how broad questions influenced discussion. Ask participants to reflect on how these broad questions influenced them in their discussions. Allow ample wait time for participants to begin sharing their thoughts and observations. Their ideas may include the following:

- encouraged interacting with or observing the materials
- evoked more than one acceptable response
- opened up the discussion
- encouraged divergent thinking or different points of view

6. Identify Questions 4 and beyond as *focused* questions. Tell them that Questions 4–6 are in the category of *focused* questions:

> **Questions 4 and beyond:**
> 4. What is this object?
> Any other focused questions you asked, such as:
> 5. Which of these is from inside the body of an animal?
> 6. What kind of animal is this from?

7. Discuss how focused questions influenced discussion. Ask about the effect of these focused questions on the small group discussions. Again, allow for a few participants to share their reflections. Among other responses, they may say:

- required recall of specific information
- focused responses on the topic of types of organisms
- kept the interchange short and to the point
- encouraged single, correct responses

Discussing How Teachers Use Broad and Focused Questions

1. Display research quotes. Have participants read the quotes and discuss with a partner what they think of these ideas.

> True dialogue occurs when teachers ask questions to which they do not presume to already know the correct answer (Lemke, 1990, p. 55).
>
> Seventy-five percent of the questions teachers ask are of a factual or literal nature (Bromley, 1992, p. 139).
>
> Teachers ask an average of seventy literal or factual questions in an average thirty-minute lesson (Bromley, 1992, p. 139).

2. Share what they discussed. Ask if anyone would like to share with the group any thoughts that were discussed. Take several responses and encourage a dialogue among participants.

3. Explain disadvantage of focused questions for initiating discussions. Suggest to participants that, in general, focused questions are not good for starting discussions. A common mistake made by educators is to attempt to begin a discussion by asking a focused question. When students do not readily respond, the teacher may then reword the initial question and provide hints about the specific response they expect. This clearly communicates to students that there are "wrong" ways of participating in the discussion and may discourage those who are not so certain about the answer from joining in.

4. Ask several focused questions. In order to graphically illustrate the effects of focused questions, ask the following questions, fairly rapidly, one right after the other:

- What kind of question usually works best for starting a discussion? [a broad question]
- What kind of question usually doesn't work well for starting a discussion? [a focused question]
- Am I using broad questions right now? [no]
- A discussion isn't starting, is it? [no]

5. Ask a broad question. Now pose a broad question and allow some time for participants to respond.

- What are some situations or goals for which narrow questions might be appropriate?

6. Participants notice effects of different questions. Point out that the first four questions you just asked were obviously all focused questions, and the last one was a broad question. Once again, ask participants to describe the different effects that the questions had on the class discussion.

7. Emphasize importance of using questions appropriately. Introduce the idea that, just as focused questions are generally inappropriate for initiating discussion, teachers should not ask a broad question if they are looking for a specific answer or want to wrap-up a discussion. The important thing for a teacher to consider is the purpose for posing the question. Emphasize that focused questions are not inherently bad, but it seems that most educators under-utilize broad questions in the classroom.

8. Focused questions are not necessarily easier to answer. In thinking about why teachers ask so many focused questions, we should consider how a teacher's perspective can influence his or her choice of questions. To a teacher, it may seem as though a focused question is simpler and safer for students to answer than a broad question. Therefore, they may think they are making it easier for students to respond. The problem with this premise is that students may have differing abilities for remembering specific kinds of factual knowledge. For example, some may be very capable at recalling "big picture" ideas relating to a topic, but not be very good at remembering specific details. Focused questions can be more difficult for these students.

9. Teachers may not feel comfortable with open discourse. Another reason teachers may avoid using more broad questions could be their worries about fielding student responses that may be inaccurate or unpredictable. Many teachers also view the classroom environment as a place where it's necessary for the teacher to maintain control at all times. They see focused questions as a way to ensure that students engage in a briskly-paced exchange with the teacher, presumably helping to avoid behavioral disruptions. They may also be worried that open-ended discourse may lead to topics they themselves do not understand or that the discussion may range away from the main topic they seek to teach.

10. Importance of encouraging student discussions. However, the disadvantage of preventing students from raising divergent viewpoints and engaging in authentic discussion is that it may deprive students of the opportunity to exercise their critical thinking skills while participating in an open exchange of ideas. If we accept that students need to discuss and weigh new ideas to fully construct knowledge and understand science in a meaningful way, then we must provide opportunities in the classroom for this type of discussion to occur.

11. Display Karen Gallas quote. Call attention to the quote and explain that it's from a book that promotes what she calls "Science Talk" sessions with students, where they freely discuss their ideas without a lot of intervention from the teacher.

> "Inquiry alone does not suffice. Children can construct rich meanings when presented with rich materials, but the meanings they construct, without reflection and discussion, are often diffuse, mysterious and laden with misconceptions." (Karen Gallas, *Talking Their Way Into Science*, 1995, p. 54)

Considering the Role of the Instructor (35 minutes)

Enacting and Discussing Skit #1

1. Introduce importance of teachers' role identification. Tell participants that in addition to being aware of how different types of questions can influence classroom discussion, it's also very important to consider the impact of how instructors see/perceive their role, as related to student learning.

2. Introduce skits. Let them know that they will now watch two skits involving the interactions between a university astronomy professor and a student seeking help during office hours. Each skit illustrates a different viewpoint regarding the instructor's role, as well as some examples of both broad and focused questions.

Note: *Volunteers for the skits should be recruited before class, so that especially "the professor" has a chance to read the script ahead of time and prepare. When recruiting, select students you think able to project their voices and present the skit as per the written instructions. Or, the instructor of the class or an assistant can play the professor.*

3. Volunteers present first skit. Ask the two volunteers who were assigned to the roles of professor and student to come to the front. Give them their scripts for Skit #1 and keep one for yourself. Remind the volunteers to read their parts loudly and clearly, and to refer to the "acting" instructions in the script. Ask them to begin when they are ready.

> ***Note****: Since you will later be using the questions from the following discussion as examples of a "discussion map," it's important to ask the following first four questions exactly as in the script.*

4. Discuss the first skit using scripted questions. Lead a discussion with the students asking the following questions:

- **How would you describe the interaction between the professor and student in the first role play?**
- **What about what the professor said or acted makes you think that?**
- **Does anybody have a different idea or opinion?**
- **How do you think the professor saw his/her role as an educator?**

5. Focus on behavior of professor. Consider bringing up some of the following points about the professor in Skit #1, as is appropriate:

- The professor's attitude was intimidating and condescending, i.e., "That's easy," "You mean *you're* confused," "Nope. Pay attention in the next lecture and you'll get it," and "Well, that's your problem. If you would just stop thinking and would listen, you'd understand."

- The professor did not attempt find out what the student was thinking by using probing questions.

- The professor used a barrage of focused questions that could be "parroted back" without evidence of any real understanding:
  Professor #1: That's when we see the full Moon, right?
  Student: Right.
  Professor #1: So do you see that during the full Moon the Moon is always on the opposite side of the Earth from the Sun?
  Student: Uh yeah. Yeah I see it. That's when it's full.

- The professor used a broad question when they were expecting a particular answer.
  Professor #1: So now, knowing that, give me an explanation for tides on Earth.

- When the student responded to the broad question "incorrectly," the professor gave a potentially demoralizing response:
  Professor #1: Nope. Pay attention in the next lecture and you'll get it.

Enacting and Discussing Skit #2

1. Volunteers enact second skit. Tell participants they'll now see how the same situation might play out with a different approach. Either use the same volunteers or ask for two new volunteers. Give them the scripts for Skit #2 and keep one for yourself. Remind the volunteers to read loudly and clearly, and have them begin.

2. Use same questions to discuss second skit. Following the skit, ask students to describe the interaction between the professor and student in the second skit, and how they think the professor saw his/her role as an educator. Use the following series of questions:

- **How would you describe the interaction between the professor and the visitor in the first skit?**
- **What about what the professor said or did makes you think that?**
- **Does anybody have a different idea or opinion?**
- **How do you think the professor saw his/her role as an educator?**

3. Focus on behavior of professor. Consider bringing up some of the following points about the professor in Skit #2, as is appropriate:

- The professor made an effort to validate the student's point of view so as not to intimidate them:

Professor #2:"That's understandable. Everybody gets confused, because it's difficult."
and
Professor #2: "You'd think that's what it would be called."

- The professor acted as a collaborator in investigating the answer:
  Professor #2: "Let's try to figure this out."

- The professor handed the marker to the student:
  Professor #2: "What side of the Moon do you think would be lit up?"
  and
  Professor #2: "What do you think the Moon would look like to us on Earth?"

- The professor provided a guided opportunity for the student to figure out the ideas for themselves:
  Professor #2: "So where do you think the Moon would be when it appears full to us?"

- The professor acknowledged the reasonable nature of the student's less than accurate idea:
  Professor #2: "A lot of people get confused by that, and sometimes it does. That's what we call a lunar eclipse."

- The professor asked questions that were appropriately focused, since the student's question was about a specific piece of information with a clear "right" answer.
  Professor #2: "If the Sun is shining from this direction, and the Moon was here, what side of the Moon would be lit up?"

- The professor also asked a broad question to encourage thinking, but without expecting a particular response:
  Professor #2: "Looking at the position of the Moon and Sun in relation to the Earth in this drawing, how do you think they might affect tides on Earth?"

- The professor replied to the student's response to the broad question with an accepting response, encouraging the student to continue grappling with the ideas.
  Professor #2: "Again, that seems to make sense. It's more complicated than that but keep thinking about it, and we'll get to it in class."

Discussing the Role of the Instructor

1. Introduce "guide on the side" and "sage on the stage." Explain that an educator's use of questions in learning situations is often based on the role they adopt as an instructor. Share two well-known expressions used as shorthand to describe two possible roles—an instructor can act either as a "guide on the side," or as a "sage on the stage."

2. Point out how "sage on stage" sees her/himself as transmitter of knowledge. The first skit represents the "sage on the stage" instructor role, admittedly in an extreme version. The instructor sees him/herself as the ***transmitter of knowledge***. The teacher sends out the information—the student receives it. There is a sense that the instructor is the recognized authority and the repository of information on whatever subject is being taught. This attitude can be described as, "I know about this and you don't, so I'm going to tell you the right answer." This reflects an idea of education as a process of an expert (the teacher) directly providing their knowledge to the novice (the student).

3. Point out how "guide on side" sees her/himself as facilitator of learning. The second skit represents the "guide on the side" instructor role. The instructor's attitude in this case is one of shared inquiry, or of collaborators in an investigation, trying to figure out something together. In this role the instructor is a ***facilitator of learning.*** This mode of teaching focuses on the thinking, or cognition, of the student—the instructor allows students to express their ideas, encourages them to identify and confront any obstacles or conflicts, and then guides them to reinforce, alter, or replace their ideas.

4. Pose question about whether it might ever be useful to be a sage on the stage. Ask participants to turn to a partner and discuss this question:

> Can you think of any situation when it might be appropriate to be a sage on the stage?

5. Participants share ideas. After partners have a few minutes to discuss the question, ask them to report any interesting ideas that came up in the discussion.

Note: *The above distinction is useful to get a very important point across, but in a fuller discussion it of course needs to be qualified and placed into non-stereotypical context. It's also not intended to imply that these two approaches are mutually exclusive. Teaching takes place along a continuum that combines many approaches. Even the most seemingly straightforward classroom situation is made up of many complex learner-educator interactions. As with questions, there is a time and a place for many different pedagogical approaches.*

Introducing the Discussion Map (10 Minutes)

1. Introduce discussion map. Educators have studied effective strategies for leading discussions, and have developed the idea of a "discussion map" to reflect how skilled discussion leaders tend to guide and encourage discourse. This map can be applied to discussions with any age group.

2. Display discussion map. Project the overhead transparency or slide, *Discussion Map*, and read each step aloud:

> • Ask a broad question
> • Ask about the evidence for their explanation
> • Ask for alternative opinions or ideas
> • Lead students back to the main topic
> • Help organize and summarize ideas
>
> Listen carefully to each student response and try to figure out their thinking.

3. Point out importance of listening carefully after each response and following students' line of thinking. Explain that these steps represent a useful ***sequence*** of questions a teacher can use, but they don't show how a teacher determines ***which exact questions*** to ask. The questions that are asked depend on carefully listening to each student response and doing your best to understand their thinking. The purpose is to raise ideas and encourage students to discuss their thinking. The most important factor in discussion-leading is following (and guiding) the natural flow of the exchange of ideas.

4. Relate discussion map to the skit discussions. Explain that the discussions you just led with them about the skits were structured using this map. Display the Discussion Map Example and review how they follow the discussion map.

> **Ask a broad question**:
> How would you describe the interaction between the professor and student in the first role-play?
>
> **Ask about the evidence for their explanation:**
> What about what the professor said or acted makes you think that?
>
> **Ask for alternative opinions or ideas:**
> Does anybody have a different idea or opinion?
>
> **Lead students back to the main topic**
> How do you think the professor saw his/her role as a teacher?

5. Discussion map modeled throughout course. Point out that other discussions from previous sessions of the course were also designed with this kind of discussion map in mind. Suggest that this discussion map model is well-suited for a teacher who seeks to facilitate students in constructing their own conceptual understanding. It allows for diverse ideas to emerge and for students to compare evidence for varying points of view.

6. Describe flexible use of discussion map. The discussion map idea is very useful, but it's not intended to be a full description of discussion-leading strategies. It works best when used as a flexible model to guide discussions, rather than a rote procedure to be followed step-by-step. Often each step of the cycle can involve multiple student responses, and student-to-student exchanges without the teacher intervening between each response.

Sink/Float Activity (30 minutes)

Introducing the Activity

1. Describe plans for next session. Say that a group of "questioning experts" will attend the next session to help them practice their questioning skills. Reassure them that the "experts" will actually be students (of whatever age is appropriate for your participants to teach). Tell participants they will have a chance to practice guiding student investigations using thoughtful questions.

2. Explain rationale for doing activity themselves. Emphasize that before the students visit, it's important for participants to engage in the activity they will facilitate with the visiting students. Afterward, they will write up a plan for the questions they will use to guide their students' explorations.

3. Explain the science content of the activity. Tell participants that the fundamental idea students will explore in their sink/float investigations involves testing different objects in a tub of water. Objects dropped in the air will usually fall to the ground, but when some objects are placed in water they float. Students will investigate which types of objects float—and how an object's shape, size, or composition may affect whether an object floats or sinks.

4. Point out different levels of access to science concepts. Explain that this sink/float activity provides an opportunity for students of all ages to grapple with concepts relating to density, buoyancy, and surface tension. Point out that the science content can be approached at different levels—this seemingly simple activity can be used to initiate young children's thinking about characteristics of floating and sinking objects, or it can involve older students in exploring more complex scientific concepts about forces that counteract gravity's pull on objects.

5. Explain purpose of leading activity with students. Testing objects in water will intrigue younger students who can investigate and explain it at an observational level, and it may also inspire them to explore and expand on their foundational understandings about surface tension, buoyancy, and density. Because the activity can be approached from different levels of experience and understanding, as a facilitator you'll be challenged to try figure out "where" your students are. **The goal is to focus on questions that *facilitate taking students further in their explorations and understanding.***

Demonstrating the Activity

1. Gather participants. Ask all participants to gather around a sink/float station. Make sure they are standing in a large enough arc or circle so the materials are visible to everyone.

2. Explain first steps. Tell them that their first task in their small groups will be to decide on a definition for sinking and floating. In other words, they need to develop the criteria that they will use to judge if an object sinks or floats.

3. Demonstrate making predictions. Show participants how they will take turns picking up an object, predicting if it will float or sink, asking others in the group

for their predictions, and then placing it in one of the sorting circles on the table depending on whether they think it will float or sink.

4. Suggest what to do if they disagree. Let them know that group discussion is encouraged, but if there is a disagreement about where an object should be placed, the person holding the object gets to decide where it belongs.

5. Demonstrate testing objects. After they've made predictions about every item, they will receive a tub of water to test each one. They will take turns picking up an item, testing it in the water, and deciding how to sort it. Depending on the results of their tests, they may choose to place objects in the circle they predicted, or they may change their decision. Multiple tests may be necessary before deciding where to place an object.

6. Caution against students testing objects too quickly. Point out that children are often tempted to simply toss all the items in the water, and test them all at once. It can be challenging to get them to slow down and think about each item, but this will be important for students to do to get the most out of the activity.

7. Explain they may use a third sorting circle if necessary. Point out that there is a third circle provided in case their group decides they need another classification grouping. Let them know that in their groups, they may also need to adjust or refine their definitions for sink and float as they perform their tests.

Experimenting at Sink/Float Stations

1. Form small groups and begin investigating. Divide students into small groups so they are equally distributed at each station. Say they can begin exploring the objects as soon as they are assigned to a group and station. (A convenient method is six stations with groups of five to six participants at each.)

2. Model using guiding questions to encourage investigations. Circulate among the participants and pose questions to help guide their investigations. Some sample questions are:

- What kinds of things float?
- What kinds of things sink?
- Do small things float?
- Do large things sink?
- Will wax float?
- Will a large and heavy piece of wax float?
- Will metal float?
- Will a metal paperclip float?
- Will aluminum foil sink or float? Can you figure out a way to make it sink?
- How can a large and heavy ship float?
- What do you notice when you press down on something that is floating?
- Which seems more important, the material an object is made of, or its size?
- Why will some containers float when closed, but sink when open?

3. Provide more challenges. If any groups finish the task, challenge them to try to:

- Make sinkers float

- Make floaters sink
- Make an object "flink" (remain suspended between the surface of the water and the bottom of the container)
- Explain why certain items float and others sink.

4. Conclude sink/float activity. After most of the small groups have finished testing and sorting their objects, either ask them to gather at a separate discussion area or collect the sink/float materials from their tables.

Planning Sink/Float Questions (20 minutes)

1. Describe preparing for the session with students. Tell participants that they will spend the last part of this session preparing questions for the students who they will be interacting with in the next session.

2. Emphasize reasons for planning questions. Explain that when working with any students, it's important to be able to think on your feet and improvise questions and responses, but it's also a good idea to have an overall plan for questioning. Add that this exercise is helpful for several reasons:

- Studies show that most teachers ask broad and focused questions randomly, or use only one type at a time.
- Students can derive more meaning from a lesson when questions are thoughtfully planned to address specific learning objectives.
- Without a plan, teachers often fall back on teaching in the manner in which they were taught.

3. Display the Questions and the Learning Cycle slide. Refer to the *Questions and the Learning Cycle* handout to describe how specific questions can work well for different parts of the learning cycle. Remind participants that each phase of the learning cycle has specific goals and thoughtfully asking questions can help students to achieve those goals. Explain that, for the most part, the visiting students will be in the invitation and exploration phases of the learning cycle while investigating the sink/float materials.

4. Explain task. Tell participants that, for the next 15 minutes or so, they will come up with a list of questions they will try out with students while they are doing the sink/float activities. Encourage them to focus on the goals for the earlier stages of the learning cycle (invitation and exploration), as well as using the discussion map as they plan their questions. They should also remember to include ample broad questions to encourage divergent thinking

5. Distribute handouts. Give participants the following handouts:

Questions and the Learning Cycle
Types of Questions Defined
Discussion Map
Question Planning Worksheet
Sample Questions

6. Explain recording questions. Tell them they should describe their plan for questions on the *Question Planning Worksheet* provided. They can use some of the questions from the sample sheet, or write their own original questions.

7. Provide time for writing questions. Give participants a chance to work on the assignment in their groups. If there's not enough time, they can finish planning their questions as a homework assignment.

The Great Plankton Race (40 minutes)

Introduce Great Plankton race challenge. Now challenge the students to use what they know from Sink/Float to design their own planktonic organism. Questions give meaning to this activity. In an activity such as this or *Sink/ Float*, meaning comes from shared discussions elicited by questions facilitated by the teacher. Think about how you would ask focused and broad questions if you were doing this activity in a classroom.

Introduction to Plankton

Plankton Video

1. Watch video. Have participants pair-up to watch a plankton videotape such as the Monterey Bay Aquarium "Treasury of Ten Aquarium Videos" (Alternatively, show photos, pictures or posters to illustrate the diversity of plankton.) Distribute one sheet of blank paper and two pencils to each pair of students.

Sidebar: This is a very cool video clip of plankton—no voice over, just a very fun and catchy musical soundtrack. Students and teachers find it intriguing and very interesting to watch.

2. Participants discuss video with partner. While watching the videotape, have participants quietly discuss with their partner what they observe. Suggest that they look at the colors, shapes, spines, and kind of motion (if video available).

3. Pairs sketch plankton. Have each pair work together to sketch at least two different plankton species as the video is playing.

4. Label sketches. After the video clip, have them label in their own words, some of the interesting features they noticed on the plankton they sketched. Remind them to again think about the colors, shapes, spines, and kind of motion.

5. Share sketches with table group. Now have them share their drawings with another pair of students. Tell them they can add to or modify their drawings based on any new information the additional pair introduces.

6. Lead class discussion and record ideas. Lead a class discussion as groups share their drawings and observations. Record their ideas on a class chart labeled About Plankton. *[Some of their observations about similarities may include the following: many are transparent; lots of legs or appendages; weird-looking; spiny; weak-swimmers; red coloration; connected in chains, beating cilia (hair-*

like structures). Differences may include: lots of different shapes; some are stationary; some look like worms; some look like jellyfish; some have long and some short spines].

Questions to use at this stage of the activity include:
Have you ever seen...?
What did you observe?
Did you notice...?

Diversity of Plankton Cut-outs

1. Display Diversity of Plankton cut-outs. Show the Diversity of Plankton transparency cut-outs on the overhead projector and have participants help you find similarities and differences between all the various samples shown. Ask the question: "What do you observe?" Have participants raise their hands and then call on a few to give their ideas. Ask follow-up questions such as: "Who has a different idea?" and "Did you notice?"

2. Volunteer does secret sort of plankton. Then ask participants to think to themselves about how they might sort the pictures. After a minute or so, ask for a volunteer to do a secret sort of the pictures on the overhead and have everyone else try to guess what criteria they were using to sort. After a few participants answer, have the volunteer describe the criteria they used. Ask if anyone has a different way to sort them. Depending on time, you may have another volunteer sort the pictures.

3. Participants describe structures. Now have participants describe some of the structures they can see in the drawings. Call on a few students and have them share in words, or come up and point to the structures. [Structures they might observe include: spines, chains, hairy-looking, many legs, etc.]

4. Group discussion about benefits of structures. Then ask the question: "How might some of those structures help the plankton survive in its environment?" Have participants discuss the question with a partner, then call on a few students who raise their hands. Give noncommittal yet encouraging responses and ask if anyone has a different idea. [Camouflage, predator avoidance, prey capture, flotation.]

5. Group discussion about how to slow sinking rates. Ask: what are all the ways plankton might be able to slow down how fast they sink? Call on a few participants. Remain noncommittal, yet encouraging in your responses and ask for other ideas. [Possible answers include: flattened appendages, small bodies, long spines, gas or oil floats, chains, etc.]. Now ask a volunteer to group all of the transparency drawings together that they think show structures that might help to keep the plankton from sinking. Ask if someone would like to modify and change the sort.

6. Participants discuss benefits of slow sinking with table group. Have participants discuss the following question with their table group. "Why would flotation adaptations or at least a slow rate of sinking be important to plankton?" After a minute or so, repeat the question and call on a few participants who raise their hand. Ask for other ideas and explanations. [Phytoplankton need to stay near the surface sunlight and zooplankton need to stay near their food—the phytoplankton.]

7. Lead a whole group discussion about confirming ideas. Finally, ask how they might be able to confirm their ideas about ways to slow sinking rates. [Possible answers: library research, field or aquarium observations, modeling, etc.]

Designing and Building Plankton

1. Introduce activity. Tell students that each of them will now get to try out their ideas about sinking rates of plankton. They will design and build a plankton model from materials with different densities. Show the class the materials they can use to make their plankton and the gallon jar of water they will use for their pre-race testing. Remind students that each model should be constructed to sink as **slowly** as possible, but must not float at the surface *(in nature some plankton species do live at or on the surface, but most drift beneath it).*

2. Provide directions. Tell them that they will try out how well their plankton does in their small group aquarium and then once they have made a model that they like, they will have the opportunity to race it against another student's model in the large aquarium at the front of the room.

3. Form groups around materials. Form the students into small groups gathered around a few desks pushed together. Place a pile of available materials, a gallon jar of water, and a sponge in the center of each group.

4. Circulate as students work. Circulate around the room to check on the students' progress. Questions to ask at this point include:

What happened when...?
What did you discover?
What do you think will happen if...?
What questions do you have?
What could we do to find out?

5. Lining up for race. Once an individual has made a plankton model and tested it in their group gallon jar, they can queue up behind the large aquarium at the front of the room.

6. Students explain adaptations and conduct race. Have pairs of students take turns explaining the adaptations of their plankton

and then conduct preliminary heats in the large aquarium. Have two students at a time place their models just below the surface. Have two other students stand ready with stopwatches to record the time each takes to sink to the bottom of the aquarium (25 cm). At the "go" signal (consider using a toy cap pistol for effect) each contestant releases his or her plankton and the race is on. Have two additional students record each student's name and time on the board.

Sidebar: Starting the race with the plankton just below the surface avoids the problem of surface tension that can keep some models of plankton from sinking.

7. Conduct semi-final races. After all students have raced their plankton, select the four students with the slowest times for semi-final sink-offs. Winners of the two semi-final heats face off for the championship.

8. Students describe winning plankton's adaptations. Have the winners describe the adaptations that led to their plankton's success.

Questions to use at this point in the activity include:
What did you find out about...?
How is this the same or different from...?
Can you compare this to something else?
What do you now know about the characteristics of...?

9. Present awards at Awards Ceremony. Have an awards ceremony and distribute cut-out paper trophies to the slowest racers and participant ribbons to all.

10. Distribute "Features that Planktonic Organisms Share" handout.

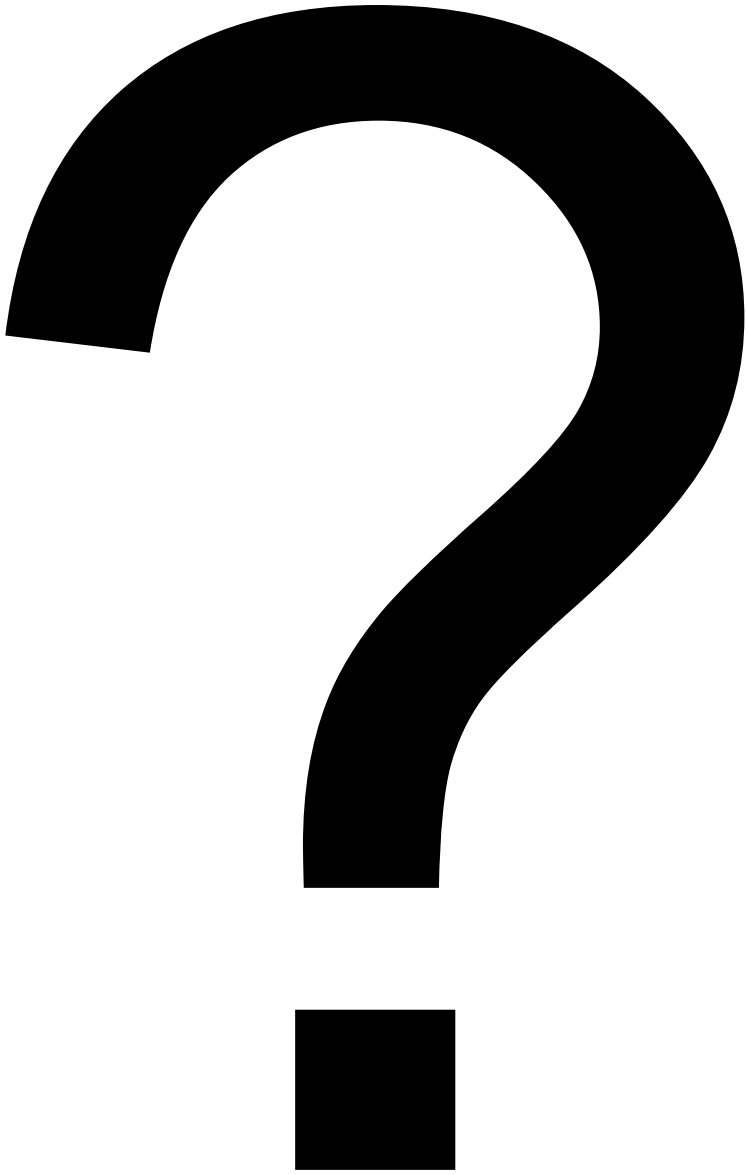
Concluding the Session (5 minutes)

1. Participants write a Quick Write response for the session. Tell each participant to take out a piece of paper and write their thoughts about how the session has affected their ideas. Display the following slide:

Summarize your thinking about questioning strategies, leading discussions, and the role of the instructor.
If you can, please include:
- How have your ideas changed?
- What do you think made your ideas change?
- How might you use this in your science teaching?

Homework (5 minutes)

Assign the reading in the course reader.



Two Types of Questions:

- Broad
- Focused

Questions for Discussion:

1. What do you observe about this object?
2. How might you describe the object to your partner?
3. How is this object the same or different from the other object(s)?
4. What is this object?
5. Which of these is from inside the body of an animal?
6. What kind of animal is this from?

Research Quotes:

True dialogue occurs when teachers ask questions to which they do not presume to already know the correct answer.

(Lemke 1990, p. 55)

Seventy-five percent of the questions teachers ask are of a factual or literal nature.

(Bromley 1992, p. 139)

Teachers ask an average of seventy literal or factual questions in an average thirty-minute lesson.

(Bromley 1992, p.139)

"Inquiry alone does not suffice. Children can construct rich meanings when presented with rich materials, but the meanings they construct, without reflection and discussion, are often diffuse, mysterious and laden with misconceptions."

—Karen Gallas from *Talking Their Way Into Science*, 1995, p. 54

Discussion Map

- Ask a broad question
- Ask about the evidence for their explanation
- Ask for alternative opinions or ideas
- Lead students back to the main discussion topic
- Help to organize and summarize ideas

Listen carefully to each student response and try to understand their thinking

Discussion Map Example

Ask a broad question:

- How would you describe the interaction between the professor and student in the first role play?

Ask about the evidence for their explanation:

- What about what the professor said or acted makes you think that?

Ask for alternative opinions or ideas:

- Does anybody have a different idea or opinion?

Lead students back to the main discussion topic:

- How do you think the professor saw his/her role as an educator?

Questions and the Learning Cycle

- **Invitation Stage**
- **Exploration Stage**
- **Concept Invention Stage**
- **Application Stage**
- **Reflection Stage**

Broad Questions

- Have more than one possible answer
- Invite students to interact with materials and/or ideas
- Open up discussion and analysis
- Encourage divergent thinking and multiple points of view
- Involve higher-level thinking

Focused Questions

- Have a certain response that is expected
- Help students recall specific information
- Focus discussion on a particular topic
- Keep discussion short and to the point

Quick Write Prompt

Summarize your thinking at this point about questioning strategies, leading discussions, and the role of the instructor.

If you can, please include:

- How have your ideas changed?
- What do you think made your ideas change?
- How might you use this in your science teaching?

Questions and the Learning Cycle (handout)

Consider the possible purposes for asking questions during different phases of learning.

Invitation Stage: Use questions to help generate interest, and help students focus on observations. Help students to connect past experience to a new topic of study.

Have you ever seen...?
Have you ever wondered...?
What did you observe?
Did you notice...?

Exploration Stage: Use questions to encourage students to explore new materials, properties and events. Guide students to engage in productive investigations.

What happened when...?
What did you discover?
What do you think will happen if...?
What do you think made that happen?
What questions do you have about…?
What could we do to find out?

Concept Invention Stage: Use questions to help students synthesize new understandings and make sense of investigations. Help students classify, categorize, quantify or order their observations. Have students use evidence from investigations to make explanations. Help students to draw conclusions, and make connections.

What did you find out about...?
How is this the same or different from...?
Can you compare this to something else?
What do you think is the explanation for…?
Why do you think that...? What is your evidence?
What might another explanation be?

Application Stage: Use broad questions to encourage reasoning and analysis. Involve students in authentic problem-solving situations and critical thinking. Help students to generalize their knowledge and test their hypotheses. Encourage students to apply new learning to other situations.

What do you now know about the characteristics of...?
What other factors do you think might be involved?
Can you find a way to...?
How can we use what we found out to solve a problem?
How could you be more sure about…?

Reflection Stage: Use questions to encourage students to think back on what they have done and how they have made sense of what they have explored.

How did you arrive at your solution or conclusion?
Did you change any of your initial thinking?
What caused you to see things differently?
How did you figure out…?

Types of Questions Defined (handout)

Broad Question — A statement or question that anticipates a variety of acceptable and generally unpredictable responses.

When an instructor asks such questions, they are hoping for unplanned, divergent outcomes. These questions require that the students utilize thinking processes in ways that are unique to the individual rather than planned by the instructor. Broad questions allow the student to make sense of and explore their own ideas freely, in their own terms, without restrictions and with only minimal guidance by the instructor. These questions are useful to encourage students to synthesize ideas, extend ideas, deduce and predict, or organize elements of what they've learned into a fresh pattern. Broad questions encourage students to share various ideas during a discussion and to value other students' ideas as they are expressed.

Focused Question — A statement or question that anticipates a particular, predictable response planned by the instructor.

A specific "correct" response or set of responses is anticipated when a teacher asks a focused question. Focused questions can require the student to remember information or recognize information that is readily at hand. This is useful to help students to recall a fact, define a term, identify something, or review a topic that has been learned. Focused questions can be used to confirm previous classroom experiences in order to help establish a base of information for new experiences. Focused questions can also help students to synthesize information in a particular way as guided by the instructor. Focused questions that ask students to integrate what they have previously learned are useful if you want students to compare, contrast, associate, explain, state relationships, or arrive at particular conclusions. "Compare," "tell," and "explain" can begin these kinds of integrating statements. Even though a predictable answer is asked for, students may give an explanation in their own words.

Discussion Map

A teacher encouraging students to construct their own conceptual understanding can use a structure for questioning that encourages discussion and helps to "unpack" their ideas.

- Ask a broad question
- Ask about the evidence for their explanation
- Ask for alternative opinions or ideas
- Lead students back to the main discussion topic
- Help to organize and summarize ideas

Listen carefully to each student response and try to understand their thinking

Roles for Teachers

***Guide on the Side*:** Teachers who see themselves as facilitators of student learning, helping to direct individual student discoveries and acting as co-collaborators while investigating topics together.

***Sage on the Stage*:** Teachers who see themselves as the primary bearers of information and understanding, experts whose role is to fill students' "blank slates" with correct information.

Question Planning Worksheet

Invitation Stage —

Example: What kinds of things do you think will stick to a magnet?

Exploration Stage —

Example: Do you think this object will stick to a magnet?

Concept Introduction Stage —

Example: Why do some things stick to magnets and others don't?

Application Stage —

Example: Can you figure out a trick to get paper to stick to a magnet?

Sample Questions (handout)

What is the first object you will test at the station?

What do you predict will happen?

Is that what you thought would happen?

Did any of the objects do something different than what you guessed?

What surprised you?

What have you discovered?

Is that what you thought would happen to the object?

Do you think this ball will float in water?

Do you think it will float if we try the same test again?

Are there more sinkers or floaters so far?

How many floaters are there?

Can you figure out a way to make the spoon float?

Why do some things float, and others don't?

Do you think all metals sink?

Do you think all soaps float?

Do you think all waxes float?

Do you think all wood floats?

Script for Skit #1

Student: There are a couple of things I didn't understand about the phases of the Moon.

Professor #1: Why do you think you're having such a hard time with it?

Student: Uh, I dunno. The lecture was confusing.

Professor #1: You mean *you're* confused. OK, What didn't you understand?

Student: Well, when the Moon is full, what position is it in relation to the Sun?

Professor #1: *(Draws diagram of the Sun and Moon, and explains.)* When the Moon is between the Earth and the Sun, that's the new Moon, when all we see is the dark side. As the Moon moves away from the Sun it waxes—we can see more of the Sun's reflected light. As it moves around to the side of the Earth opposite from the Sun, that's when we see the full Moon, right?

Student: Right. But wouldn't the Earth's shadow...

Professor #1: So do you see that during the full Moon the Moon is always on the opposite side of the Earth from the Sun?

Student: Uh yeah. Yeah I see it. That's when it's full.

Professor #1: Do you have any other questions?

Student: Yeah, when is it a quarter Moon and a half Moon?

Professor #1: That's easy. We call it a quarter Moon when it's here or here. It's called a quarter Moon because it's a quarter of the way around the Earth. Got it?

Student: Uh, yeah. Sure.

Professor #1: So now, knowing that, give me an explanation for the tides on Earth.

Student: Um. I don't know. I guess when it's a full Moon it would be high tide?

Professor #1: Nope. Pay attention in the next lecture, and you'll get it.

Student: But I thought that...

Professor #1: (*Spoken gently*) Well that's your problem. If you would just stop thinking and would listen you'd understand.

Script for Skit #2

Student: There are a couple of things I didn't understand about the phases of the moon.

Professor #2: Well, that's understandable. Everybody gets confused, because it's difficult. What's your question?

Student: Well, when the Moon is full, what position is it in relation to the Sun?

Professor #2: Let's try to figure this out. *(Draws Moon between the Earth and Sun.)* If the Sun is shining from this direction, and the Moon was here, what side of the Moon do you think would be lit up?

Student: The side towards the Sun.

Professor #2: And what do you think the Moon would look like to us on Earth?

Student: We would be looking at the dark side, so it would be a new Moon.

Professor #2: So where do you think the Moon would be when it appears full to us?

Student: Oh, on the opposite side of the Earth?

Professor #2: That seems to make sense.

Student: But wouldn't the Earth's shadow make it look dark?

Professor #2: A lot of people get confused by that, and sometimes it does. That's what we call a lunar eclipse. But usually all three are not exactly in the straight line necessary for the Earth to block the light from the Sun.

Student: Oh, I get it.

Professor #2: So what do you think the Moon would look like to us on Earth if it was here? *(Draws moon in quarter moon position.)*

Student: Hmm. I guess we'd see half of it lit up. Is that a half moon?

Professor #2: That is what you see, and you'd think that's what it would be called, but how far around the Earth is the Moon from the full Moon position to here?

Student: It's a quarter of the way around.

Professor #2: That's why it's called a quarter Moon. A little confusing, I know.

Student: No, I think I get it now.

Professor #2: Great. Now in our next class, we'll be talking about tides on Earth. Looking at the position of the Moon and Sun in relation to the Earth in this drawing, how do you think they might affect tides on Earth?

Student: I don't know. I guess the gravity of the Moon and Sun affects it somehow. Would it be higher tides on the sides the Moon and Sun are on?

Professor #2: Again, that seems to make sense. It's more complicated than that, but keep on thinking about it, and we'll get into it next class.

FEATURES THAT PLANKTONIC ORGANISMS SHARE

2 themes

1. staying up in water—avoid sinking to bottom
2. avoid being lunch—avoid predators

1. small size
   —reduce sinking
   —harder for predators to see and/or capture

2. spines (e.g. diatoms, crab larva or zoea, dinoflagellate, Fig. A), fins, wing-like body extensions (e.g. arrow worms or chaetognaths; pteropods or planktonic snails)
   —increase drag like parachute, decrease sinking
   —also predation defense —spines and extensions increase effective body size
   —make it hard for predator to capture/eat organism

3. shell and body coverings
   —have no shell—reduces weight and reduces sinking, but makes organism more vulnerable to predators
   —have thin shell—add as little weight as possible

4. some ability to swim (vertical—up and down in the water)
   —swim to counteract sinking
   —swim to escape predators (but swimming by prey actually helps vibration-sensitive predators like arrow worms find prey)
   —vertical migration
   —swim up to surface to feed at night and down to depth during day
   —feeding at night and hiding in darker depths during the day helps avoidance of visual predators (like larval fish)

5. high water content of body—be as much like drop of water as possible

6. buoyancy and flotation regulation
   —oil droplets—copepods (Fig. B) store oil drops & use for energy during winter months; drops have dual purpose for energy and increase in buoyancy
   —gas-filled floats—Portuguese man of war (Fig. C)

7. transparent, jelly-like body—body less dense and harder for predators to see

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