Session 6: Conversations and Questions

Overview

This session focuses on conversations and questions, and the key role they play in facilitating learning and meaning-making of ideas and concepts for learners. For educators, conversation can be a window into learners' prior knowledge, skill-level, personality, previous experience, and ability to articulate ideas. Three patterns of talk are introduced through role plays that depict typical interactions between educators and learners, followed by discussions about the impact on learners when an educator sees his/her role as either "sage on the stage" or "guide on the side." Participants then discuss how educators may influence the types of conversations they have with their learners through the questions they ask and how they follow up on those questions.

Background Information for the Presenter

Learning Occurs through Conversation

Constructivism is a theoretical perspective on learning grounded on the premise that *we construct (build, create) our own understanding of the world we live in through our experiences and interactions*. Learning, or *construction* of understanding, results from a combination of reflecting on and making connections between prior experiences, new experiences and content, motivation to learn, and social interactions. As many have experienced in their own learning and teaching, conversation plays a key role in facilitating social interactions around learning and assisting in meaning making for ideas and concepts. This observation is supported by and detailed in theory and research. From the sociocultural viewpoint within constructivism, learning occurs through discourse within social interactions (Rogoff, 1998; Vygotsky, 1978).

"Meaning emerges in the interplay between individuals acting in social contexts and the mediators that are employed in those contexts" (Schauble, Leinhardt, & Martin, 1997, p. 4). Tools, language, signs, symbols, and peers and experienced individuals are mediators. In other words, human thinking is shaped by the social activities and use of the materials and symbols invented by culture, which in turn are temporally and geographically influenced. Vygotsky (1978) detailed the importance of discourse further by arguing that higher mental functions have social origins that are first expressed between individuals before they are internalized within the individual. In other words meanings are rehearsed and made explicit as a result of conversations and interactions between

people before becoming internalized by the individual. In the sociocultural viewpoint, learning relies on conversation. For learners, engaging in conversations can foster more generative thinking and enable them to practice dialogic skills, such as asking questions and communicating ideas in an effective manner. It can be a way for them to process information and make social connections. These thinking and dialogue skills form the basis of active, analytic, individual thought, and allows individuals to develop their ability to communicate their ideas. In museums, educators negotiate this interplay within the social activities and rely extensively on conversations as a key form of mediation. For educators, conversation can be a window into their learners' prior knowledge, skill-level, personality, previous experience, and ability to articulate ideas.

It's important to keep in mind that talking about conversation starts us thinking about other aspects of a learner's culture that can influence learning. The culture of the learner can be the culture of a society, ethnic group, or a country and also includes the culture of the classroom, family, group of friends and the resulting activities, routines and common experiences that people in each of those communities has. An additional aspect of the influence of social activities on human thinking is the use of the materials and symbols invented by its culture, which are temporally and geographically influenced (Schauble, et al., 1997; Vygotsky, 1986) and can influence the ways that ideas are conceptualized, modeled, and understood.

Patterns of Facilitated Conversations

In informal learning environments, conversations occur between educators and learners, as well as between learners themselves—as peer-to-peer conversations and parent(s)-child (ren) conversations. Educator-learner conversations are considered to be facilitated conversations. To aid analysis of conversations, researchers look at who is talking and what they are saying—how they contribute to the conversation, and then identify patterns in this exchange. There are three patterns of talk that are most common, and will be explored further in this session (Dawes, 2004; Scott, 1998; Scott, Mortimer, & Aguiar, 2006). Most of the literature on educator talk and discourse is drawn from research in schools simply because there are more studies available. There is some research that explores interactions in informal environments, and these investigations provide evidence that informal educators also use these three patterns of talk (see for example, King, 2009; Tal, 2006; Tran, 2007). So for now, we borrow from classroom research as we consider the applicability of the findings

and ideas on practice in informal environments. Descriptions of the three patterns of talk follow.

1. Educator monologue. Educator explains, describes, clarifies, identifies, and questions. In an Educator Monologue, the educator is doing most of the talking, though the turn taking (i.e., whose turn it is to talk) may alternate between educator and learner. In either case, the educator's turn is usually longer than the learner's, and the educator ends up doing most of the explaining, describing, clarifying, identifying, and questioning. The educator dominates the conversation with scientific views and explanations. It is perceived as an efficient way of communicating scientific knowledge, though it is criticized for expressing only one viewpoint and not allowing learners to articulate their understanding of the ideas.

2. IRE or IRF. There are two variations to this pattern. In the IRE variation, the educator **initiates** the conversation with a question or comment, the learner **responds**, the educator **evaluates** the response, and then repeats the pattern with another question (Lemke, 1990; Mehan, 1979). Also, the learner's response may be short answers, while the educator's evaluation may be long and elaborate on the learner's response. The second variation to this pattern is IRF, the educator **initiates** the conversation with a question or comment, the learner **responds**, the educator solicits for **follow up** ideas and comments from the learner, and then the pattern repeats with **response** and **follow up** (Sinclair & Coulthard, 1975). In both cases, the turn-taking switches back and forth between educator and learner regularly, and the educator directs the conversation and makes knowledge public. This pattern, and the IRE variation in particular, has been criticized for failing to provide learners with an opportunity to articulate their own understanding and express themselves in the language of the discipline (Alexander, 2005 ; Wellington & Osborne, 2001). On the other hand, it has been argued that such dialogues can serve as a way to extend the learner's answer, to draw on its significance, or to make connections with other parts of the learner's total learning experience (Wells, 1999)

3. Reflective Discourse. Educator facilitates a conversation where learners and educators pose questions, respond to one another's comments and questions, and learners seek to understand each other. In a Reflective Discourse pattern, the educator and the

> learner are talking back and forth, and both are initiating, responding, and following up on each other's comments. The learner is expressing her or his own thoughts, ideas, and questions. If there is more than one learner, they are also talking with each other and trying to understand the thinking of another. The educator and learner engage in a back-and-forth exchange, asking and answering one another's questions, and trying to understand the thinking of the other person (van Zee & Minstrell, 1997). It offers the learner the opportunity to voice her or his everyday views of the world in common language, but requires the assistance and guidance from more knowledgeable individuals to make connections between everyday views and scientific views (Scott, et al., 2006).

These patterns of talk are not intrinsically good nor bad; their merits and demerits derive from the reasons for and ways they are used to support and achieve intended goals. In teaching science, there's often a tension between directing the conversation to communicate the views of science and being an equal contributor to the conversation to encourage everyone to voice their views. The opportunity for learners to talk and share their thinking is necessary for learning science, but learning science also requires understanding and speaking the language of science, which educators need to model for learners. It's important for learners to have the opportunity both to make explicit their everyday ideas and to apply and explore newly-learned scientific ideas through talk and other actions *for themselves* (Scott, et al., 2006).

The fundamental point here is that "meaningful learning involves making ***connections*** between ways of thinking and talking…between everyday and scientific views" (Scott, et al., 2006, p. 622). For instance, an educator may begin with Reflective Discourse to give learners a chance to express their everyday views in order to motivate and encourage them to be engaged, to legitimize their ways of thinking, and probe their prior knowledge. The educator may then shift to IRF to draw out more of learners' thinking and guide the expressions of their understanding toward scientific views. The educator may then transition into Educator Monologue to model how to voice and connect learners' everyday ideas in scientific language, and then finish with more Reflective Discourse to give learners the opportunity to practice using scientific language.

Questioning Strategies

Questioning is a vital and powerful teaching strategy, a crucial component of just about any teaching and learning situation. This is especially the case when learning situations derive from firsthand experience, and reflection on that experience is used to develop and refine concepts. Questions can open doors at every stage of the learning experience—inviting learners into activities and ideas by creating interest in a new topic, helping guide explorations, introducing new concepts, and encouraging learners to apply their ideas to different situations. Skilled instructors use questions to find out what learners think and draw attention to conflicting ideas. Well-sequenced questions can initiate the sharing of ideas, encourage divergent thinking, help learners recall prior knowledge, allow them to synthesize new information, and help guide logical thinking.

There's an art to questioning strategies and to balancing the amount of asking and telling used in a teaching situation. There's no one formula for what this balance should be and it changes from situation to situation. Experience and practice can hone educators' expertise and questioning know-how. Skilled educators use questions to find out what learners think, encourage discussion, and draw attention to diverse viewpoints and interpretations. However, one can also observe veteran educators who do not take advantage of questioning strategies that could elevate their teaching to interactive learning experiences, but instead resort to perfunctory question-and-answer drills.

Research indicates that educators who are specifically trained to ask high-quality questions show significant improvement in constructing and using such questions in teaching situations (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 educators 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 lesson in this session demonstrates how using focused questions, that have specific, prescribed answers, can shut down a discussion by requiring learners to try to guess what the teacher is thinking. In contrast, beginning the conversation with broad questions, that have multiple acceptable answers/responses, can encourage more learners 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 learners 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, it is also important to consider is the educator'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 learners in observing and noticing details. Questions such as, "What did you notice when…?" can be used to guide learners 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 learners have explored a phenomenon or performed an investigation, questions can then be used to guide learners to make comparisons or quantify their observations. Given adequate experience and exploration of a topic or phenomenon, learners 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 learners to apply what they've learned in order to generalize their knowledge or test their hypotheses. Asking learners 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 encouraging them to take charge of their own learning.

Role of the Educator

The final factor considered during this session, that can definitely impact an educator's questioning strategies, is how they view their role in the learning process. A "sage on the stage" type of educator has the point of view that it is their responsibility to impart or transmit knowledge directly to learners and that the educator 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 learners themselves. A "guide on the side" type of educator embodies a more constructivist view of learning—one which accepts that learners must be encouraged to create their own personal frameworks through discussion and interactions with materials and various sources—in order for them to develop a deeper understanding that can be flexibly applied to different learning situations.

Although education researchers have identified many categories and subcategories of questions, we've chosen to focus on two main groups.

These two groups are "**broad**" and "**focused**" questions, also referred to in some education literature as "open" and "closed," or as "broad" and "narrow." By this distinction, we in no way intend to classify these question types as either good or bad. The activities in this session focus on the appropriate use of both types of questions. The emphasis is on analyzing the impact of both question types on the thinking and behavior of learners, and using this information to help decide how and when to best use such questions. In addition, we focus on the appropriate *sequencing* of questions, both to guide learners through learning cycle-based explorations, and to help lead discussions. We also explore the effects of an educator's perceived role on how to approach questioning.

Session Objectives

In this session, participants:

––discuss the purpose and value of conversations in the learning process;

–– read short excerpts from the research literature to become aware of such ideas as, IRE (Initiate, Respond, Evaluate), and the value of (1) peer to peer conversations, (2) dialogue in learning, and (3) guidance in learning science;

—experience and reflect on the different effects of focused and broad questions on thinking and discussions with learners; and

—note the impact on learners when an educator sees his/her role as either "guide on the side" or "sage on the stage."

Session Activities at a Glance

Quick Write and Discussion (15 minutes)
Participants do a Quick Write for about 5 minutes, and then discuss their responses in a whole group discussion as a means to develop a shared understanding of the role of conversations in learning and determine key characteristics of learning conversations.

- What is the role of conversation in learning? i.e., why is talking important for learning?
- Describe a time when you felt you were engaged in a learning conversation in a class or in an informal environment. What were the characteristics of the conversation that made you feel it was a real learning opportunity? (i.e. who was talking, what kinds of questions were used and what responses were elicited?)

Ideas from Research—Talking and Learning (30 minutes)
In groups of four, each person is responsible for quickly reading and taking turns presenting to their group the information from one research card on the topic of talking and learning. They include their own reactions to the information and questions they have about it, leading a discussion on the topic within their group.

Introduction to Kinds of Questions (10 minutes)
Participants are introduced to broad and focused questions as very important parts of learning conversations and that each type of question generates a different kind of response. Emphasis is placed on educators thinking strategically and purposefully about the questions they ask.

Types of Conversations, Skits and Debrief (45 minutes)
Three brief skits are acted out, depicting the types of conversations between an educator and museum visitors. The first illustrates the *Educator monologue*, the second demonstrates *IRE (Triadic dialogue)*, and third portrays *Reflective discourse.*

Role of the Educator (10 minutes)
Participants discuss the impact on learners when an educator sees his/her role as either "guide on the side" or "sage on the stage

Research Discussion: Questions, How Educators Use Them, and the Discussion Map (20 minutes)
Participants discuss how educators may influence the types of conversations they have with their learners through the questions they ask and how they follow up on those questions.

Discussion Map

- Ask a broad question
- Listen to response and thinking
- Ask for evidence or explanation
- Ask for alternative opinions or ideas

Exemplar Activities (Choose one of the following):

Skull Cart Activity and Debrief (30 minutes)
Participants observe visitors on the floor of the museum interacting with the *Skull Cart Activity*—the educator asks both focused and broad questions, while also modeling the discussion map.

Adaptation: Interactive Science Presentation (30 minutes)
Participants learn about adaptation and evolution as they participate in an interactive PowerPoint presentation highlighting questioning strategies, the discussion map, and the interplay between different kinds of conversations (monologue, IRE/IRF, and reflective discourse). (See index of Science Presentations on the web site if you're interested in obtaining the PowerPoint for this presentation.)

Concluding the Session (5 minutes)
Participants reflect on what they learned in the session.

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.)*

- Online discussion
- Reading:
  - Baker, Beth. Recruiting Minorities to the Biological Sciences. Bioscience, 50.3 March 2000.
  - Jolly, Eric J. Confronting Demographic Denial: Retaining Relevance in the New Millennium, Association of Science – Technology Centers, January/February 2002.
- Activity Development
  - Content paper (2 pgs, 1 paper per person) about the science content and concepts in your activity. Upload to Bspace by March 5.

Time Frame

Total Workshop: 2 hours 50 minutes
Quick Write & Discussion (15 minutes)
Ideas from Research: Talking and Learning (30 minutes)
Introduction to Questions (10 minutes)

Types of conversations, Skits & Debrief (45 minutes)
Role of the Educator (10 minutes)
Research Discussion: Questions (20 minutes)
- How Educators Use Questions
- Discussion Map

Exemplar Activities (Choose one of the following):
- Marine Skull's Cart Activity and Debrief (30 minutes)
- Adaptation Interactive Science Presentation (30 minutes)

Concluding the Session (5 minutes)
Homework (5 minutes)

Materials Needed

For the class:

- ❑ PowerPoint presentation for Session 6: Conversations & Questions
- ❑ 1 digital projector
- ❑ Copy of Marine Skull's Cart Activity write-up
- ❑ Materials to do Marine Skull's Cart Activity (see activity write-up)

For each participant:

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

For each small group of 4–5 students:
1 set of the following research cards:

- ❑ Research Card #1: The Value of Dialogue
- ❑ Research Card #2: IRE (Initiate, Respond, Evaluate)
- ❑ Research Card #3: Peer to Peer Discourse
- ❑ Research Card #4: Value of Guidance in Learning Science
- ❑ Research Card #5: Reflective Discourse and Monologues

For the Skits:

- ❑ 4 copies of each of the three different Skit Scripts—one for yourself and one for each of the three skit participants
- ❑ Optional:
  - 1 magnifying lens
  - 1 square cm piece of cardboard
  - sea otter pelt
  - picture of sea otter
  - 1 abalone and 1 mussel shell

Preparation of Materials

1. Duplicate handouts. For each participant you will need one of each of the following handouts:

— "Types of Questions Defined"
-- "Discussion Map"
--"Questions and the Learning Cycle"

2. Duplicate scripts. Make four copies of the three different Skit scripts— one for yourself and three for the skit participants. For each role-play, highlight the lines for the respective actors.

3. Marine Skull Cart Activity. Decide if you will do the Marine Skulls Cart, or a different activity you are familiar with, or the Interactive Science Presentation. If you choose to do the Marine Skull's Cart, become familiar with activity focusing on using it as an exemplar of strategically using broad and focused questions. If you'd prefer to use a different activity, just be sure it provides ample opportunities to engage visitors in a discussion using broad and focused questions, a combination of IRE/IRF and reflective discourse types of conversations, and the Discussion Map. **A copy of the Marine Skulls Cart activity is included near the end of this document.**

4. **Prepare the Jigsaw Research Cards**

Groups will need one copy of each:
Research Card #1: The Value of Dialogue
Research Card #2: IRE (Initiate, Respond, Evaluate)
Research Card #3: Peer-to-Peer Discourse
Research Card #4: Value of Guidance in Learning Science
Research Card #5: Reflective Discourse and Monologues

Instructor's Guide–Session Details

Quick Write. 15 minutes

1. **Participants do a Quick Write.** Participants write for five minutes on the following questions:
   - What is the role of conversation in learning? i.e., why is talking important for learning?
   - Describe a time when you felt you were engaged in a learning conversation in a class or informal environment. What were the **characteristics of the conversation** that made you feel it was a real learning opportunity? (e.g., who was talking, what kinds of questions were used, and what kind of responses were elicited?)

2. **Facilitate a whole group discussion.** This discussion builds on participants' Quick Write responses with the goal of sharing ideas and identifying characteristics of conversations that support learning. Prepare two columns on the board; title them "Role of Conversations" and "Characteristics of Conversations."

3. **What is the role of conversation in learning?** Ask participants to share their responses to the first Quick Write question: What is the role of conversation in learning? In other words, why is talking important for learning?

4. **Record their ideas.** As participants share their ideas, record their responses on the half of the board titled "Role of Conversations."

   Remember to encourage participants to: (1) share multiple viewpoints; (2) agree and disagree; (3) provide evidence and clarifications for their viewpoints and dis/agreements; (4) respond to one another's comments.

Note: here are some responses your participants may offer:

ROLE OF CONVERSATIONS

- arguments can be helpful to clarify ideas
- opportunity to realize what I (the learner) don't know
- organizes ideas about a topic
- reiterates or rephrases information to make it understandable
- opportunity to articulate first thoughts on a topic
- opportunity to add ideas into the mix and build off of one another
- mechanism to help remember what you know about a subject
- helps participants create their own understanding of ideas

- allows for disagreements and sharing of multiple viewpoints
- opportunity to share in "safe" environment
- provides opportunity for everyone to contribute and be included

Ideas from Research—Talking and Learning. (30 minutes)

1. Introduce Jigsaw. Tell participants each small group will receive a few research cards. Each card features a piece of information research has found out about talking and learning. Each member of their group is responsible for carefully reading one of the cards. Then they will take turns explaining the information from their card to their small group. Like a jigsaw puzzle, each member of the team is in charge of one of the "pieces."

Research Card #1: The Value of Dialogue
Research Card #2: IRE (Initiate, Respond, Evaluate)
Research Card #3: Peer-to-Peer Discourse
Research Card #4: Value of Guidance in Learning Science
Research Card #5: Reflective Discourse and Monologues

2. Each member leads a brief discussion about one research card. After each group member shares the information from a research card, they should tell the group their thoughts about the card. They should also invite group members to discuss the topic on the card, including:

- anything they find confusing about it.
- questions or issues they have about the topic on the card.
- how classroom teaching might be structured to take this piece of information into account.

During this discussion, each member should hold onto, and be in charge of their research card. They should continue the sharing and discussing process until you tell them to stop.

3. Large group share. After about 15 minutes of discussion, ask each group to share out any issues, ideas, or questions that came up during their small group discussion.

4. Explaining rationale behind jigsaw activity. Tell participants that this type of jigsaw activity is meant to encourage collaboration and discussion in small groups. Having each member responsible for the information on their card, and leading the discussion about that information, can help keep everyone involved in the discussion, and prevents any one person from dominating the group.

Note to Facilitator: Remember to encourage participants to:

- Share multiple viewpoints
- Agree and disagree

- Provide evidence and clarifications for their viewpoints and dis/agreements
- Respond to one another's comments.

Introducing Kinds of Questions. 10 minutes

1. Kinds of questions. Let participants know that, generally speaking, questions are a very important part of learning conversations. They can be grouped into two categories: broad and focused. Emphasize that each type generates a different kind of response—that neither type of question should be considered "good" or "bad," they tend to prompt different types of responses. For this reason, it's important for the educator to be able to recognize these types of questions and think strategically and purposefully about the questions they ask.

2. Broad and focused questions. Display the slide "kinds of questions" and explain broad and focused questions. Provide some examples.

- Focused questions ask for a specific answer, usually a short response.
  - Can you see it?
  - Do you want to touch it?
  - Do you think it's an animal?
  - What's that part called?
  - How many arms do you see?
  - What is that?
- Broad questions ask for a range of answers, usually an extensive response.
  - What's your theory so far?
  - What do you think?
  - Why did they make it like that?
  - What does it look like to you?
  - Tell me more about your idea.

3. Small group discussion. Ask participants to discuss in their table groups the following questions:

- What are advantages and disadvantages of broad and focused questions?
- Provide examples for when in teaching it would be effective to use each type of question.

4. Whole group discussion. Invite participants to share their discussions. Use the Discussion Map as a suggested guide to facilitate this discussion.

Discussion Map:

- Listen to their responses.
- Ask for evidence, explanation, or clarification.
- Ask for agreements, disagreements, and alternative opinions and views.
- Synthesize their ideas as you reference their comments.
- Restate/summarize the participants viewpoints.
- Ask them about discrepancies in their ideas.
- Bring forward points that may not get mentioned, such as the importance of questions asked by the learners.

Note to facilitator. Key points to address:

Focused questions

- Require learners to recall specific information
- Focus learners' responses on the topic specified by the educator.
- Keep the interchange short and to the point

Broad questions

- Encourage learners to interact with the materials
- Open up the discussion for more viewpoints and contributions from learners
- Encourage divergent thinking

Activity: Role-plays. 45 minutes

Introduce the Activity

1. **Highlight questions.** Point out that, as they have identified, questions are an important part of learning conversations. There are two parts to a question that are helpful for thinking about the role of questions in a conversation: who is asking the question and what is the question prompting the other person (or people) to do.

2. **Introduce the role-plays.** Let participants know that in this next activity they will observe (or participate in) three role-plays. These role-plays simulate teaching moments in informal science institutions.

   Their task is to pay attention to the ***talk*** that takes place between the educator and learners. We will focus on the questions:
   - Who is asking questions?
   - What is the question prompting from the other person?

3. **Draw three columns.** Draw three columns on the board, one for each role-play. Record "who is asking questions" and "what is the question prompting" from the debrief of each role-play in each column.

Role-play 1: Educator Monologue

1. **Ask for volunteers for first role-play.** Ask for three volunteers to be in the first role-play. Distribute a highlighted script to each volunteer and instruct him or her to read his or her highlighted lines when appropriate.

2. **Debrief first role-play.** Use the following prompts as a guide to discuss the pattern of talk. Ask groups to share their observations and explanations, encourage them to comment on each other's explanations, and remind them to provide evidence for the comments as you debrief the role-play. Record the patterns they identify on the board so everyone can see them.

   - How would you describe the interaction between the educator and the learners in the first skit?
   - What about what the educator said or did makes you think that?
   - Does anyone have a different idea or viewpoint?
   - Who was asking the questions?
   - How would you describe the questions being asked? (broad or focused?)
   - What were the questions prompting from the other person? Was this different depending on the speaker?
   - How do you think the educator saw his/her role as an educator?
   - How do you think the educator used questions to facilitate the conversation?

   CAUTION. As participants begin discussing the talk in the role-plays, be careful that the discussion does not focus on placing judgment and value on one skit over the other, or that any one is "good" or "bad." The focus should be on recognizing the questions and what the educator is doing with the questions.

   Note to facilitator: This role-play features an Educator Monologue pattern. Some of the characteristics of this role-play that participants may point out include: the educator is doing most of the talking, although the turn-taking may also alternate between

educator and learner. In either case, the educator's turn to talk is usually longer than the learner's and the educator ends up doing most of the explaining, describing, clarifying, identifying, and questioning.

Role-play 2: Initiate-Respond-Evaluate (IRE)

1. **Ask for volunteers for second role-play.** Ask for three volunteers to be in the second role-play. Distribute a highlighted script to each volunteer, and instruct him or her to read his or her highlighted lines when appropriate, once everyone gets a copy of the script.

2. **Debrief second role-play.** Use the following prompts as a guide to discuss the pattern of talk. Ask groups to share their observations and explanations, encourage them to comment on each other's explanations, and remind them to provide evidence for the comments as you debrief the role-play. Record the patterns they identify on the board so everyone can see them.
   - How would you describe the interaction between the educator and the learners in the second skit?
   - What about what the educator said or did makes you think that?
   - Does anyone have a different idea or viewpoint?
   - Who was asking the questions?
   - How would you describe the questions being asked? (broad or focused?)
   - What were the questions prompting from the other person?
     i. Was this different depending on the speaker?
   - How do you think the educator saw his/her role as an educator?
   - How do you think the educator used questions to facilitate the conversation?

   CAUTION. As participants begin discussing the talk in the role-plays, be careful that the discussion does not focus on placing judgment and value on one skit over the other, or that any one is "good" or "bad." The focus should be on recognizing the questions and what the educator is doing with the questions.

   Note to facilitator: In an IRE pattern, the educator ***initiates*** the conversation with a question or comment, the learner ***responds***, the educator ***evaluates*** the response, and then repeats the pattern with another question. The turn-taking switches back and forth between educator and learner regularly, although the educator is directing the conversation because they are asking the questions and determining the correctness of the response. Also, the learner's response may be short answers, while the educator's evaluation may be long and elaborate on the learner's response.

A variation to IRE is IRF. In this case, the educator ***initiates*** the conversation with a question or comment, the learner ***responds***, and the educator solicits a ***follow up*** response from the learner for further ideas and clarifications. The turn-taking switches back and forth between educator and learner regularly, although the educator is directing the conversation because they are asking the questions and soliciting follow up responses.

Role-play 3: Reflective Discourse

1. **Ask for volunteers for third role-play.** Ask for three volunteers to be in the third role-play. Distribute a highlighted script to each volunteer, and instruct volunteers to read their highlighted lines when appropriate, once everyone has a copy of the script.

2. **Debrief third role-play.** Use the following prompts as a guide to discuss the pattern of talk. Ask groups to share their observations and explanations, encourage them to comment on each other's explanations, and remind them to provide evidence for the comments as you debrief the role-play. Record the patterns they identify on the board so everyone can see them.
   - How would you describe the interaction between the educator and the learners in the third skit?
   - What about what the educator said or did makes you think that?
   - Does anyone have a different idea or viewpoint?
   - Who was asking the questions?
   - How would you describe the questions being asked? (broad or focused?)
   - What were the questions prompting from the other person? Was this different depending on the speaker?
   - How do you think the educator saw his/her role as an educator?
   - How do you think the educator used questions to facilitate the conversation?

   CAUTION. As participants begin discussing the talk in the role-plays, be careful that the discussion does not focus on placing judgment and value on one skit over the other, or that any one is "good" or "bad." The focus should be on recognizing the questions and what the educator is doing with the questions.

   Note to facilitator: In a Reflective Discourse pattern, the educator and the learner are talking back and forth—both are initiating,

responding, and following up on each other's comments. The learner is expressing her or his own thoughts, ideas, and questions. If there is more than one learner, they are also talking with each other and trying to understand the thinking of another.

Discussing the Role of the Educator (10 minutes)

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 roles—an instructor can act 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 educator sends out the information—the learner receives it. There is a sense that the educator 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 educator) directly providing/transmitting their knowledge to the novice (the learner).

3. Point out how "guide on side" sees her/himself as facilitator of learning. The educator'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 educator is a ***facilitator of learning.*** This mode of teaching focuses on the thinking, or cognition, of the learner—the educator allows learners to express their ideas, encourages them to identify and confront any obstacles or conflicts, then guides them to reinforce, alter, or replace their ideas.

4. Pose questions. Ask participants to turn to a partner and discuss these questions:

- How do you think the educators in each of the skits saw themselves—as a "sage on the stage" or as a "guide on the side"?
- Can you think of any time when it would be appropriate to be a sage on the stage?

5. Participants share ideas. After partners have a few minutes to discuss the questions, 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 a 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.

Research Discussion: Questions. (20 minutes)

1. Consider questioning in skits. Ask participants to consider the following set of key ideas from research in regard to how the questions asked in the skits helped or hindered the learning process**.**

2. Display Key Ideas from Research—Questions. Distribute or display the following statements and have partners read and discuss what they think of these ideas.

- Inquiry-oriented teaching is driven by learner questions.
- The opportunity to generate questions places the learner in an active, initiating role in the learning process (Palincsar & Brown, 1984), and situates them as producers of knowledge, not just consumers.
- True dialogue occurs when teachers ask questions to which they do not presume to already know the correct answer (Lemke 1990, p. 55).
- Asking questions in discussions (whole or small group) develops a good habit of mind that is practiced in the social space and can become part of individual thought (Chin, 2007; Scott, 1998).
- Seventy-five percent of the questions teachers ask are of a factual or literal nature (Bromley 1992:139).
- Teachers ask an average of seventy literal or factual questions in a thirty-minute lesson (Bromley 1992:139).

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

Discussing How Teachers Use Broad and Focused Questions

1. Explain disadvantage of focused questions for initiating discussions. Suggest 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 learners do not readily respond, the educator may then reword the initial question and provide hints about the specific response they expect. This clearly communicates to learners 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.

2. Emphasize importance of using questions appropriately. Introduce the idea that, just as focused questions are generally inappropriate for initiating discussion, educators should not ask a broad question if they're looking for a specific answer or want to wrap-up a discussion. The important thing for an educator 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.

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

4. Educators may not feel comfortable with open discourse. Another reason educators may avoid using more broad questions could be their worries about fielding learner responses that may be inaccurate or unpredictable. They may also be worried that open-ended discourse may lead to topics they do not understand, or that the discussion may range away from the main topic they seek to teach.

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

6. 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 learners, where they freely discuss their ideas without a lot of intervention from the educator.

"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)

7. Summarize discussion about broad and focused questions. Share these points with participants:

— In general, focused questions are not good for starting discussions. A common mistake educators make is to begin a discussion by asking a focused question and, when learners don't readily respond, trying to reword the same question and give hints about the specific response they expect.

— In general, broad questions are not good to wrap-up a discussion, or if the educator is looking for a specific answer.

— Remember, broad questions lead to divergent answers, and focused questions lead to specific answers.

8. Being purposeful about asking questions. Suggest some reasons for asking questions in the first place. Educators may ask questions to:

- stimulate learners' thinking
- generate feedback for them about learners' understanding
- evaluate what learners know
- elicit what learners think and encourage learners to extend their ideas
- scaffold learner thinking as they help learners build knowledge

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

10. Describe how skillful questioning can enhance an educational experience. While the topic of "how to ask questions" may seem unimportant to some, a lack of good questioning strategies can seriously undermine an educator's effectiveness. Even the best activities can lead nowhere if they do not involve the thoughtful use of questions.

Introduce the Discussion Map

1. **Introduce map.** Researchers 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 *Discussion Map slide,* and read each step aloud:

- Ask a broad question
- Listen to responses and thinking
- Ask for evidence or explanations
- Ask for alternative opinions or ideas
- Ask a question leading back to the main topic
- Help to organize and summarize the ideas

3. Point out importance of listening carefully after each response and following learners' thinking. Explain that these steps represent a useful ***sequence*** of questions an educator can use, but they don't show how an educator determines ***which exact questions*** to ask. The questions asked depend on carefully listening to each learner response and doing one's best to understand their thinking. The purpose is to raise ideas and encourage learners 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 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 educator and the visitors in the first skit?

Listen to response and thinking.

Ask for evidence or explanation:
- What about what the educator said or did makes you think that?

Ask for alternative opinions or ideas:
- Does anybody have a different idea or viewpoint?

Ask a question leading back to the main topic
- How do you think the educator saw his/her role as a educator?

• How do you think the educator used questions to facilitate the conversation?

Help to organize and summarize the ideas

5. Discussion Map modeled throughout course. Point out that discussions in previous course sessions were also designed with this kind of map in mind. This discussion map model is well-suited for an educator who seeks to facilitate learners in constructing their own conceptual understanding. It allows for diverse ideas to emerge and for learners 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 can involve multiple learner responses, and learner-to-learner responses, without the teacher intervening between each response.

Present one of the following two activities as an exemplar of the pedagogy presented in this session.

Marine Skull's Cart Activity and Debrief (30 minutes)

1. Model Skull Cart activity with museum visitors. Tell participants the class will go to the museum floor to observe a cart activity—the educator will be modeling both focused and broad questions, as well as the discussion map. Have participants take note-taking materials with them and record specific questions asked by the facilitator.

2. Debrief Skull Cart activity. Ask participants what they noticed specifically about the types of questions asked by the facilitator. Were they able to note the use of a discussion map? In what ways did it seem to be a useful tool to use with visitors?

3. Distribute *Questions and the Learning Cycle* Handout. Distribute *Questions and the Learning Cycle* handout to participants and give them a moment to review. Describe how the types of questions asked can also be mapped to the use of the learning cycle. Were they able to note the use of the learning cycle during the Skull Cart activity? In what ways did it seem to be a useful tool to use with visitors?

Adaptation Interactive Science Presentation (30 minutes)

Participants learn about adaptation and evolution as they participate in an interactive PowerPoint presentation highlighting questioning strategies, the discussion map, and the interplay between different kinds of conversations (monologue, IRE/IRF, and reflective discourse). (See index of Science Presentations on the web site if you're interested in obtaining the PowerPoint for this presentation.)

Concluding the Session (5 minutes)

1. Participants write a Quick Write response for the session. Tell each participant to get 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?

Note: If you're continuing to add to the "Key Characteristics of Exemplar Activities" chart begun in *Session 4: Designing an Activity*, add the following points that were addressed in this session:

__ Encourages questions from visitors and follows the interests of the learner
__ Is sensitive to the visitors' prior ideas and knowledge about this topic
__ Encourages and provides opportunities for discussion/discourse and other social interactions between visitors or family/group members
__ Includes opportunities for visitors to make meaning individually, with peers and with someone more knowledgeable (e.g. facilitator/knowledgeable visitor)
__ Includes opportunities to engage with and manipulate objects, experiences and conversations in a social setting

Homework (5 minutes)
Online discussion

Reading:

- Baker, B. (2000). Recruiting Minorities to the Biological Sciences. *Bioscience, 50(3)*, 191-195.

- Jolly, E.J. (February 2002). Confronting Demographic Denial: Retaining Relevance in the New Millennium. *ASTC Dimensions.* Association of Science and Technology Centers, Washington, DC. (Reprinted in Journal of Museum Education, 27.2-3).

Activity Development:

- Content paper (2 pgs, 1 paper per person) about the science content and concepts in your activity. Upload to Bspace by March 5.

Research Card #1:

The Value of Dialogue

Human thinking is shaped by the social activities and use of the materials and symbols invented by culture, which in turn are temporally and geographically influenced (Schauble, Leinhardt, & Martin, 1997, p. 4). Vygotsky (1986, 1978) further detailed the importance of discourse by arguing that higher mental functions have social origins that are first expressed between individuals before they are internalized within the individual. In other words, meanings are rehearsed and made explicit as a result of conversations and interactions between people before becoming internalized by the individual. In the sociocultural viewpoint, learning relies on conversation. For learners, engaging in conversations can foster more generative thinking and enable them to practice dialogic skills, such as asking questions and communicating ideas in an effective manner. It can be a way for them to process information and make social connections. These thinking and dialogic skills form the basis of active, analytic, individual thought, and allow individuals to develop their ability to communicate their ideas. For educators, talk from learners offers a glimpse into what learners think and how they make sense of new experiences in light of what they already know (Scott, 1998).

Research Card #2:

IRE (Initiate, Respond, Evaluate)

In what Mehan (1979b) calls an IRE pattern, the educator ***initiates*** the conversation with a question or comment, the learner ***responds***, the educator ***evaluates*** the response, then repeats the pattern with another question.

IRE example:
Educator: Is this a solid, liquid, or gas? (Initiate)
Learner: It's a liquid. (Respond)
Educator: Yes, it is a liquid. It takes the shape of its container. (Evaluate)
Educator: What about this one, is it a solid, liquid, or gas. (Initiate)
Learner: It's a liquid too. (Respond)
Educator: No, this one is a solid. (Evaluate)

The turn-taking switches back and forth regularly between educator and learner although the educator is directing the conversation because they are asking the questions and determining the correctness of the response. Also, the learner's response may be short answers, while the educator's evaluation may be long, and may elaborate on the learner's response. The educator controls the conversation by the topics they allow to be formulated and the "off-topics" they ignore (Eder, 1982).

A variation to IRE is IRF. In this case, the educator ***initiates*** the conversation with a question or comment, the learner ***responds***, and the educator solicits a ***follow up*** response from the learner for further ideas and clarifications. The turn-taking switches back and forth regularly between educator and learner, although the educator is directing the conversation because they are asking the questions and soliciting follow up responses.

IRF example:
Educator: Is this a solid, liquid, or gas? (Initiate)
Learner: It's a solid (Respond)
Educator: What makes you say that it's a solid? (Follow-up)

Learner: Because it holds its shape. (Respond)
Educator: You're right, it is a solid. (Evaluate)

.

Research Card #3:

Peer-to-Peer Discourse

Peer talk unfolds in pairs or groups of children unhindered by the inherent asymmetry of adult–child interaction. The more equal participant structure of peer groups may be conducive to both cognitive and pragmatic development. Rogoff (1990) highlights Piaget's (1977) argument that children's discussions with adults are less conducive to cognitive development than their discussions with equals—while the superiority of adults might intimidate children from freely expressing their ideas, other children can provide the opportunity for discussion and reciprocal exchanges, thus promoting the types of social interaction conducive to cognitive development. Opportunities to talk are important for learners to share, clarify, and distribute knowledge among peers. Peer discussions exhibit the following characteristics: asking questions, hypothesizing, explaining, and formulating ideas. (Rivard & Straw, 2000)

Research Card #4:

Value of Guidance in Learning Science

Learning science adds increased complexity to the practice of facilitating discourse. Learning science involves acquiring the language and tools of science and the canonical ways of reasoning in science (Anderson, Holland, & Palincsar, 1997; Kuhn, 1962), and is not possible without guidance and assistance (Scott, et al., 2006). "Learning science, therefore, is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the 'ways of seeing' which have been established and found to be fruitful by the scientific community. Such 'ways of seeing' cannot be 'discovered' by the learner—and if a learner happens upon the consensual viewpoint of the scientific community he or she would be unaware of the status of the idea" (Driver, 1989, p. 482). Thus it is necessary for science teachers and informal science educators to engage learners in dialogue about their everyday views of phenomena, **and** introduce the science perspective (science content) (Scott, et al., 2006). A significant part of learning science is learning to talk science. Tools of talk used in science, such as questioning, explaining, predicting, reasoning, and

evaluating, are strategies that may need to be learned and practiced (Dawes, 2004; Lemke, 1990).

Research Card # 5

Reflective Discourse

Educator facilitates a conversation where learners and educators pose questions, respond to one another's comments and questions, and learners seek to understand each other. In a Reflective Discourse pattern, the educator and the learner are talking back and forth, and both are initiating, responding, and following up on each other's comments. The learner is expressing his or her own thoughts, ideas, and questions. If there is more than one learner, they are also talking with each other and trying to understand the thinking of another. The educator and learner engage in an exchange, asking and answering one another's questions, and trying to understand the thinking of the other person (van Zee & Minstrell, 1997). It offers learners the opportunity to voice their everyday views of the world in common language, but requires assistance and guidance from more knowledgeable individuals to make connections between everyday and scientific views (Scott, et al., 2006).

Educator Monologue

Educator explains, describes, clarifies, identifies, and questions. In a Monologue, the educator is doing most of the talking, although whose turn it is to talk may alternate between educator and learner. The educator's turn is usually longer than the learner's, and the educator ends up doing most of the explaining, describing, clarifying, identifying, and questioning. The educator dominates the conversation with scientific views and explanations. It is perceived as an efficient way of communicating scientific knowledge, although it is criticized for expressing only one viewpoint and not allowing learners to articulate their understanding of the ideas.

"Meaningful learning involves making ***connections*** between ways of thinking and talking…between everyday and scientific views" (Scott, et al., 2006). For instance, an educator may begin with Reflective Discourse to give learners a chance to express their everyday views in order to motivate and encourage learners to be engaged, to legitimize learners' ways of thinking, and to probe learners' prior knowledge. The educator may shift to IRF to draw out more of learners' thinking and guide the expressions of their understanding toward the scientific views. The educator may transition into

Monologue to model how to voice and connect learners' everyday ideas in scientific language, and then finish with more Reflective Discourse to give learners the opportunity to practice using scientific language.

Role Play Skits

Educator-Visitor Skit #1

Scene: *A museum educator is displaying a sea otter pelt as two visitors walk by. The visitors approach the educator.*

Visitor #1: What is that?
Educator: It's a sea otter pelt. It's the skin and fur from a sea otter. Want to feel it?
Both visitors caress the pelt.
Educator: *Feeling the pelt too.* It's soft, isn't it?
Visitor #2: *(nods)*
Educator: I love the way it feels. It feels thick too, doesn't it?
Visitor #1: Yeah, it does.
Educator: *Hands magnifiers to both visitors.* Take a close look at the fur.
Visitors look closely at the pelt.
Visitor #1: This fur is thick!
Educator: Look at how many hairs there are in there.
Visitor #2: There are tons of hairs in there.
Visitor #1: Yeah.
Educator: This cardboard square is one square centimeter in size *shows cardboard square*. Someone once estimated that there are more than 155,000 hairs per square centimeter on a sea otter. Sea otters have more hairs in one square centimeter than people have on their whole head.
Educator: Do you know why sea otters would have such thick fur?
Visitor #2: Maybe it's because they come out on land at night and get real cold.
Educator: It does feel cold when you get out of the water, doesn't it? Sea otters used to come out on land a lot, but now they hardly ever do. They spend almost all their time in the water, day and night. They live off the coast of northern California and in Alaska, and the water is very cold in both of those places. I've never heard of sea otters living in places with really warm water. Have you?
Visitor #1: No.
Educator: Thick fur is a structure that sea otters have that is an adaptation to survive in cold water. An adaptation is a structure or behavior that helps an organism survive. Their thick fur traps lots of air next to their skin. The air insulates their skin from the cold water. But that's not the only adaptation they have. Another adaptation they have is a behavior. They eat a lot of food. If you ever get to watch real sea otters-and I hope you do, cause they are so cool-you'll notice that they are constantly diving for food and eating the food they catch. Have you ever seen a real live sea otter?
Visitor #2: No, but I did see one on the nature channel and I want to see the sea otters here in the aquarium too.
Educator: So here's something else I've heard about sea otters. I read that they have to eat about one quarter of their weight every day. That's like if an average 10 year old ate about 40 - 50 sandwiches every day, or if a typical adult ate 90 sandwiches every day. Have you ever known someone who is always eating and eating, but they don't

gain weight? That's what sea otters are like. They're eating all the time but they burn off the calories in the cold water. It's better than aerobics, or any of those weight loss programs you see on TV!
Visitor #2: Dang!
Educator: Do you know why they would have to eat so much?
Visitor #2: I guess they're really hungry? Are they like…really fat?
Educator: Here's a picture of one. *Educator shows photo of sea otter to visitor.* They only grow to be about the size of a large dog, which is small compared to other mammals that live in the ocean.
Visitor#2: Why would they have to eat more living in cold water?
Educator: Why do you think they'd need to eat more?
Visitor#2: When I'm cold I get really hungry. They probably get really hungry being in cold water all the time.
Visitor#1: Yeah, and it probably makes them hungry if they're swimming around all the time.
Educator: Well a whale, which is very big, has a low surface to volume ratio, right? And a shrew, which is tiny, has a high surface to volume ratio. So it has to run around all the time so it can stay warm. And as far as marine mammals go, sea otters are small. And since sea otters are relatively small, they have a higher surface to volume ratio. So that's why they have to eat a lot of food. Got it?
Visitor #1: Yeah, I guess so?
Visitor #2: *(speaking to visitor #1)* Let's go look at the rest of the aquarium.
Educator: Hey, and there are live sea otters in that tank over there. Come back and I'll tell you more about them.
Visitor #1: OK, we'll try.

Educator-Visitor Skit #2
Scene: *Same as before.*

Educator: Do you know what this is?
Visitor #2: Fur from a bear?
Educator: Nope.
Visitor #1: Is it from a walrus?
Educator: No, it's not from a walrus. It's from a ssssss…
Visitor #2: seal?
Educator: No.
Visitor #1: sea lion?
Educator: Good guess, but no. It's a sea otter pelt. Sea otters have 155,000 hairs per square centimeter. That's more hairs in one square centimeter than people have on their whole head. Take a look. *Hands magnifier to visitor #1.*
Visitor #1: OK. That's really thick!
Educator: Yes, sea otters have really thick fur.
Why do you think sea otters would have such thick fur?
Visitor #2: To keep them warm?
Educator: Well it does help to keep them warm in some way, but think about your hair when it gets wet – does that help to keep you warm when you go swimming?
Visitor: No, not really. Maybe the thick fur is for when they come out on land at night and get real cold.
Educator: Nope. Most sea otters don't come onto land. They live in cold water in California and Alaska.
Visitor #2: So, how do they keep warm in the ocean?
Educator: The thick fur helps them stay warm because they put air into their fur and the thick fur traps it and creates an insulation layer that keeps them warm. What else do you think they do to stay warm?
Visitor #1: Do they wrap themselves up in kelp to stay warm?
Educator: Nope, but that's how they keep their babies from floating away. To stay warm sea otters have to eat a lot of… *(waits for visitor to fill in the word)*
Visitor #1: Food.
Educator: That's right. They eat a lot of food to stay warm. Why do you think they would they have to eat more if they live in cold water?
Visitor #2: Is it because they swim around a lot?
Educator: Well, not exactly. As far as marine mammals go, sea otters aren't big, they're...
Visitor #1: Small

Educator: And since sea otters are relatively small, they have a hard time staying warm in cold water even though they have such thick fur. So they have to eat a lot of food to get more energy to stay warm. Got it?
Visitor #1: Uh. Sure.
Educator: In fact, they have to eat about one quarter of their weight every day. That's like if a person weighed 100 pounds, and they ate how much food per day?
Visitor #1: I don't know.
Educator: Let's say a person weighed 100 pounds. How much food would they have to eat if they ate a quarter of that per day?
Visitor #1: 20 pounds.
Educator: No. How much is one quarter of 100 pounds?
Visitor #2: 25 pounds.
Educator: That's right. That's a lot of food to have to eat every day. They live where the water is cold, so that's why they have all these adaptations.
Visitor #1: OK.
Educator: Another thing to know about sea otters is that they almost went extinct. Do you know why?
Visitor #2: Ummm, no.
Educator: It's because their fur is so thick, people hunted them almost to extinction.
Visitor #2: That's nice. *Visitor starts to walk away.*
Educator: Go take a look at the sea otters in the tank over there. If you have more questions about sea otters, come and ask me.
Visitor #1: OK… thanks.

Educator-Visitor Skit #3

Scene: *Same as before.*

Visitor #1: What is that?
Educator: Come over closer and check it out. Go ahead and touch it if you want. Have you ever seen anything like this before?
Both visitors caress the pelt.
Visitor #1: It kind of feels like my cat.
Educator: *(Asks Visitor #2)* What do *you* notice about this?
Visitor #2: It is really soft and thick – way softer than my cat and it has a long tail.
Educator: It does feel really soft and thick to me too. This is the skin and fur of a sea otter – it's called a pelt.
Visitor #1: Oh, yeah. I've heard of sea otters.
Educator: What have you heard about them?
Visitor #1: That they live in the ocean and they use tools.
Visitor #2: I've heard that stuff too. I think they use rocks on their tummy to help them eat. And they live near here, don't they?
Pause
Visitor #1: Yeah I think they do.
Educator: Have you ever seen them in the wild?
Visitor #2: No, but I'd like to.
Educator: There are some that live near here in the ocean, not just in the aquarium. I've seen some out in front of the aquarium – right over there. *(Points to where the visitors could try to see them later.)* Check it out when you go outside later. Did you get a chance to see them here in the aquarium? What did you notice?
Visitor #2: They are really cute, but it seems like they are really, really itchy.
Educator: What makes you think they are itchy?
Visitor #1: They were always scratching and rolling around.
Educator: I know what you mean and scientists have noticed that too. Scientists have figured out a bit about why the sea otters scratch themselves all the time. Hey, would you like to try to figure out the mystery of the itchy sea otters too?
Visitors #1 and #2: *(all together)* Sure
Educator: OK, great. Let's try it. Here's a magnifying glass so you can take a closer look.
Visitor #1: Whoa! There are a lot of hairs packed together
Educator: I know. If you look at it really closely, you can see that it's made up of a bunch of smaller hairs.
Visitor continues to look closely at the pelt.
Visitor #2: Yeah and it looks like there are different kinds of hairs.
Educator: Their fur is thicker than almost any other animal.
Visitor #1: I wonder why?
Visitor #2: To keep them warm, maybe.

Educator: (*looking at visitor 1)* Do you agree?
Visitor #1: Yes. Lots of other animals have thick fur to keep warm too.
Educator: Have you been in the water near here?
Visitor #1: Yes, it's pretty cold.
Visitor #2: And they're out there in the water all the time.
Educator: One thing I can tell you about fur is that it doesn't work very well to keep an animal warm in water. Think about your hair when it gets wet – it loses the ability to keep you warm anymore. Same thing with a sea otter. So, here's the mystery - how do you think their thick fur helps to keep them warm? Remember the things you noticed before about the sea otters.
Visitor #2: When the otter was diving, I saw lots of air bubbles.
Visitor #1: …and remember the way it was always scratching.
Visitor #2: But how can scratching and air bubbles keep the otter warm?
Educator: Let's think about it together. When the otter scratches itself, it creates a layer of air next to its skin and the thick fur helps to keep the air in there. The layer of air keeps its skin nice and dry and warm even in the cold water.
Visitor #2: Hey could those air bubbles we saw coming off the sea otter come from the bubbles that are caught in between the skin and the hair?
Visitor #1: Ooh, I bet yeah. And I bet the sea otters have to scratch all the time because it looks like the air bubbles escape a lot.
Educator: Hm. Pretty good thinking. I think you may be on to something. Let's see what else we can figure out about sea otters. You mentioned earlier that they use rocks on their tummy to help them eat.
Visitor #1: I saw in a book once where an otter was using rocks on a clam or something.
Visitor #2: Yeah they would need to use something to get through that shell.
Educator: Let's take a look at the shells of some of things they eat. Do you think they would need rocks for all of them?
Visitor #2: Not this little mussel.
Visitor #1: Oh, but look at this. *Picks up abalone shell and shows it to #1 and Educator.* This one is really thick. They would definitely need a rock for this one.
Educator: Why don't you go take a look at the otters in the tank and see if you notice any behaviors that could give you some clues, like you did before. There are a few books over here that you could look through too. Be sure to come back and let me know if you find out anything interesting.
Visitor #1: OK.

Types of Questions Defined *(handout)*

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

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

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

A specific "correct" response or set of responses is anticipated when an educator asks a focused question. Focused questions can require the learner to remember information or recognize information that is readily at hand. This is useful to help learners 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 learners synthesize information in a particular way as guided by the educator. Focused questions that ask learners to integrate what they've previously learned are useful if you want them 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, learners may give an explanation in their own words.

Discussion Map

An educator encouraging learners 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 learner response and try to understand their thinking

Roles for Educators

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

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

Questions and the Learning Cycle

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

Invitation Stage: Use questions to help generate interest, and help learners focus on observations. Help learners 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 learners to explore new materials, properties, and events. Guide learners 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 learners synthesize new understandings and make sense of investigations. Help learners classify, categorize, quantify, or order their observations. Have learners use evidence from investigations to make explanations. Help learners 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 learners in authentic problem-solving situations and critical thinking. Help learners generalize their knowledge and test their hypotheses. Encourage learners 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 learners 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…?

Marine Skulls Cart

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 interact with skulls of several marine animals to explore similarities and differences between the animals and how and what they eat.

Audience
This activity is designed for the general public. It can be appropriate and challenging for all ages and audiences. It is best executed for small groups of visitors**.**

Setting
This activity works well as a cart anywhere in an informal science setting.

Activity Goals
Learners will be more aware of and more interested in the structure of marine animals' skulls and/or jaws.
Learners will develop the ability to predict what the animal likely eats by observing the shape of its mouth and teeth.
Learners will gain a greater appreciation for the diversity of marine organisms and their feeding mechanisms.

Concepts
- Different marine animals eat different things in different ways.
- What an animal might have eaten when it was alive can be determined in part by observing its skull and teeth.
- Differences exist between the skulls and teeth of mammals, bony fish, and cartilaginous fish, and similarities exist within each classification.

Ocean Literacy Principles
Some of the following Principles will be more relevant to different audiences, depending on their prior knowledge and the direction of the conversation between the audience and the facilitator.
5. The ocean supports a great diversity of life and ecosystems.
    a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
    c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
    d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
    e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Materials
Animal skulls/jaws:
shark, dolphin, sea lion, moray eel, wolf eel, skate, rockfish, or other bony fish
Plastic animal models corresponding to the animal skulls/jaws on display
Photographs of animals

Prep Section Make sure that all of the materials (skulls, models, etc.) are present in the cart.

Procedure and Set-up
Arrange the skulls and jaws on top of the cart randomly to allow visitors to make their own groupings. Keep models and photographs of animals to the side and ready for use.

Guiding Questions
What do you notice about this skull? These teeth?
How are the skulls similar? How is [this one] like [that one]? How are they different?
How would you group these skulls?
Why would you group these together? What clues (or evidence) did you use to place them together?
What sort of food do you think this animal might eat? Why? What about the skull/teeth leads you to think that?
Which of these animals (models or photos) matches that skull? What was your evidence?

Activity Description
The series of activities described below can be presented in almost any order and can be repeated, or cycled through as new visitors approach. Facilitators should gauge the areas of interest and knowledge level of visitors and help them to select activities that will relate to and be of interest to them. You may start the interaction with the sorting activity and spend five minutes discussing the similarities a visitor sees in the mammal skulls, then move into what animals eat, then into the differences between mammals and all the other animals.

1. Interacting with the Skulls
Invite visitors to look at and touch the animal skulls and jaws that have been set out on the Marine Skulls Cart. Tell visitors that all these objects came from different ocean animals. Once they have had time to look over some of the objects initiate a conversation with them about the objects they are touching. Use the following questions and tasks to get the conversation started if needed. Remember to encourage visitors to ask their own questions as well as invite them to respond to each other's comments and questions.

- Go ahead and pick up anything on the cart you find interesting. What is interesting about it to you?
- As you look at the skulls, think of a question or two about the animal that you would want to know more about.
- Try to come up with some questions about what you see or touch.
- How would you describe what the object looks and feels like?
- What do you notice about it? What do you wonder about?
- Do you have an idea about what that object might be?

- What would you call all these things on the cart?

Note: You will likely need to mention to younger visitors that skulls are the "head bones" of animals and that these are all from kinds of animals that are living in the oceans today (not dinosaurs).

- As visitors offer suggestions about what the objects might be, ask them what evidence they used to make that decision.

Potential key ideas to discuss during the initial interactions:
Skulls help to protect the brain of animals.
Skulls and jaws from different animals look very different, but they have some things in common.
Teeth from different animals look very different.

2. Free Sort
Invite visitors to sort the skulls using any common characteristics they notice. As the visitors sort, ask them to share with everyone:

- As you look at the skulls and jaws, think of a question or two about the animals that you want to know more about.
- Try to come up with some questions about what you see or touch.
- Why did you place these items together?
- What characteristics did you use to sort?
- What do you notice about any one of these skulls?
- Do you see any other skull that is similar?
- Can you find two skulls that are similar? Why did you choose those two?
- Can any item be placed in more than one category?
- What do you have questions about? Can we figure this out together? What other information would we need to answer that question?

Potential key ideas to discuss during the free sort depending on how the visitor sorted the skulls:
• Some of the skulls are from bony fish (moray eels, wolf eel and rockfish)
• Some of the skulls are from cartilaginous fish (skates and shark)
• Some of the skulls are from mammals (dolphin and sea lion)
• Differences exist between the skulls and teeth of mammals, bony fish, and cartilaginous fish, and similarities exist within each classification.

3. Guided Sorts: comparing similar types of organisms
Sample questions for each type of animal:

Eels: Ask visitors to observe the eel skulls.

- As you look at the skulls, think of a question or two about the animal that you would want to know more about.
- Try to come up with some questions about what you see or touch.
- What do you notice about the eel skulls?
- How are they the same?
- How are they different?

Call attention to the teeth and jaws.

- Where are the teeth?
- Do you think we can tell what they eat by looking at the teeth and jaws?

- How does looking at the teeth and jaws help us figure it out?

Potential key ideas

• The wolf eel is called an eel, but it isn't a true eel. It has a large pectoral fin and a separate tail fin. True eels like the moray eel have their dorsal and anal fins combined with their tail fin. Sometimes as with the moral eel, true eels don't have any pectoral or pelvic fins.
• Wolf eels have strong jaws, canines and crushing molars to eat hard shelled prey like clams. Their jaws are massive which allows them to have more muscle attachments and the strength to crunch hard-shelled prey.
• Moray eels have very sharp teeth for catching fish. They have an extra set of jaws in their mouth that helps them to swallow food. Their jaws are slender which allow them to enter narrow crevices to hide and chase fish.

Cartilaginous Fish:

- What differences do you see in the shark and skate jaws?
- How are the teeth of the two jaws similar?
- How are they different?
- What can we tell about what they eat by looking at the teeth and jaws?

Potential key ideas

• The skate has rounded teeth and the shark has very sharp, serrated teeth.
• The skate uses its flat, crushing teeth to eat hard-shelled prey, like snails
• Sharks use their sharp teeth to eat fish or marine mammals.
• Both sharks and skates teeth are actually the skin with scales growing into the mouth.
• We can find shark and skate teeth because they routinely shed or lose them and they become fossilized.
• The jaws of sharks and skates are not connected to their skulls, so they are not found together.

Mammals:

- As you look at the skulls, think of a question or two about the animal that you would want to know more about.
- Try to come up with some questions about what you see or touch.
- Compare the dolphin and sea lion skulls.
- How are the dolphin and sea lion skulls the same?
- How are they different?
- Can you find where the nose of the sea lion was?
- What about the nose of the dolphin?
- Where is your nose?
- How might the placement of the nose help the organism survive in the ocean?
- What do you notice about the teeth?
- How are the teeth different?
- Looking at the teeth, what do you think this animal ate? Why?

Potential key ideas:
• Both marine mammals have a very strong skull with large eye sockets.
• The dolphin has its nostrils on the top of its head, while the sea lion has it on the front of its face.
• Dolphins can come to the surface and quickly take a breath without even slowing down their swimming. They just skim the surface with the top of their head.
• The dolphin is adapted to a totally aquatic way of life, and the sea lion has adaptations for both the water and the land.
• Dolphin teeth are all identical - conical and sharp for catching and eating fish whole.
• Sea lions have sharp canine teeth for fighting each other and for catching fish. Some seals eat other seals and even penguins.

3. Guided Sorts: compare and contrast different groups of organisms

Mammals and fish:

- How are the mammal skulls similar to each other?
- How are they different from the fish skulls?
- How are the fish skulls similar to each other?

Potential key ideas:
• Generally, mammals have more different kinds of teeth than fish do. Dolphins are an exception since they have evolved more to the marine environment than seals and sea lions have and in turn have more fishlike adaptations.

Boney and Cartilaginous Fish:
Have visitors compare the shark and skate jaws to the eel skulls.

- What do you notice?
- How are they different?

Potential key ideas:
• These two jaws represent two classes of fish, e.g. those with a boney skeleton vs. a cartilaginous skeleton.
• Bony fish have the skull connected to the upper jaw and both the skull and jaws are present.
• Cartilaginous fish do not have the skull and upper jaw connected.
• Cartilaginous fish have a very small, cartilaginous skull that is not usually collected or fossilized.
• Often, even the jaws of cartilaginous fish are not fossilized, instead scientists collect fossilized teeth and then make a jaw for the teeth to fit into.

4. Skull identification
Introduce the animal models and photographs and encourage visitors to match the animal models to the skulls to determine which skull belongs to which animal. This works especially well with younger visitors (5 and under). *Note: If you start with this activity, visitors will often leave after each animal has been identified.*

Related Activities/Extensions/Modifications
Use animal models and pictures to:
• Make inferences about and discuss locomotion - how different animals get around in (and out of) the water.
• What information can we get about locomotion by looking at the body shape or skull?
• Discuss habitat and counter-shading. What information can we get about where an animal lives by looking at its color?

Additional Resources
Books and field guides with additional information about the animals represented on the cart are interesting and helpful for the visitors to find additional information that they can share with each other and the facilitator. Posters and videos playing in the back ground are also engaging and provide the opportunity for continued conversations about the organisms in their habitat.

Background

Sea lions
Male sea lions have a sagittal crest on their skull where the large jaw muscles attach. This is an adaptation for male-to-male competition for defending their harems in the water. Sea lions are one of only a few seals and sea lions that have an aquatic territory. Their territories are found from the Channel Islands south into Mexico.

Sea lions have sharp teeth for catching and hanging onto slippery fish. Their canines are also used in male-to-male competition. Sea lion males always have larger canines for competition and defense than the sea lion females.

Sea lions (Otariidae) are different from seals (Phocidae). Sea lions belong to the 'eared seal' group; they have external ear flaps, whereas seals belong to the 'true seal' group and they only have an opening through which they hear. Also, sea lions can rotate their front and rear flippers allowing them to "walk" and climb on rocks, and are the ones often seen in circuses. Seals cannot 'walk' on their flippers–they 'inchworm' along the land. Seals, sea lions and walruses are grouped together and known as Pinnipeds. They are all carnivorous mammals. There are different views about the evolution of the seals and sea lions as follows: 1) they all evolved from a common bear-like ancestor and diverged from one another about 25 million years ago or 2) they all evolved separately about 20 million years ago with the seals evolving from otter-like ancestors and the sea lions from a bear-like ancestor. Sea lions and bear skulls are remarkably similar.

California sea lions tend to feed alone or in small groups unless there is a large quantity of food. Foods eaten include: cephalopods, anchovies, herring, Pacific whiting, rockfish, hake, salmon, squid and octopuses (Riedman, 1990). California sea lions feed on fish and squid near the ocean surface down to 80 feet but can dive to depths greater than 500 feet.

Dolphins
Dolphin skulls are very streamlined. Their elongated snout and jaws (called the rostrum), with lots and lots of cone-shaped teeth allow them to capture and eat fish, octopus, and squid whole. Unlike seals and sea lions that have their noses on the front of their face like a dog, the nasal pathways of dolphins (and other whales) open to the top of the skull. The placement of their nostrils on the top of their head allows them to take in breaths very quickly, with only the top of their head breaking the water. This is an adaptation to a completely aquatic life style.

Although it may appear that whales and dolphins have their eyes almost on the sides of their head, it is thought that they are actually able to see forward with both eyes. They are able to do this because the positions of their eyes are so far out and their rostrum is so narrow.

Wolf eel
Wolf eels are not true eels but belong to a group called the wolf fishes. (True eels have no pelvic and sometimes no pectoral fins, and their dorsal and anal fins are fused with the tail fin forming one continuous fin.) These fish are equipped with massively powerful jaws, large crushing teeth, and very tough skin around the mouth. These features allow them to eat hard-shelled or spiny prey such as clams, snails, crabs, and sea urchins. Most species have strong canines and molars for digging out and crushing clams and other hard-shelled prey. They feed on sedentary prey, including very slow moving fish and don't chase fish into crevices.

Sometimes divers can hear wolf eels crunching snails and sea urchins underwater. Divers have even been known to make lasting friendships with wolf eels by providing them with choice food items to eat.

Moray Eel
Moray eels are true eels and have their dorsal and anal fins fused with their tail fin. They are known to chase fish into tight crevices. Their jaws grab and lock tight and then they tie themselves into a knot and pull their head with the fish through the knot. This allows them to tear off pieces of flesh with their very sharp teeth. It has also been discovered recently that moray eels have a second set of toothed jaws located in their throat. These jaws project forward into the mouth and help to drag prey into their throats so they can swallow it. Many fish are known to have grinding plates or jaws on the roof of their mouth, but the moray can actually drag prey from the mouth into the throat with them. This discovery reminded the researchers of the *Alien* movies. Morays have a very slender skull, which allow them to enter tight crevices as they chase fish.

Shark
The jaws and teeth of sharks are not connected to the skull (as other vertebrates skulls and jaws are). The cartilaginous jaws do not fossilize as easily as does bone and the shark skull is also very small in comparison to similarly sized mammals. Loose teeth are found much more often than whole jaws because they are made of denticles (scales) and they become fossilized. The teeth of sharks are actually the scales on the skin, which grow into the mouth. Stingray stingers and the "saws" on saw sharks are actually denticles, too. Sharks have large teeth for holding and

cutting prey or snagging fish. The jaws of the shark project forward and they are actually able to create a vacuum to suck food in as they are grabbing and slashing prey. Pushing water quickly out of their gills creates the vacuum in their mouth as it does with most boney fish.

Skate
Skates are cartilaginous fish with flat bodies and both eyes on top of their head. Their pectoral fins are shaped like large wings and their gills and mouth are located on the underside of their body. Skates use their small rounded teeth for grinding food between the two plates. They eat hermit and other crabs, clams, shrimp and small fish. Skates, like other shark relatives can locate prey with a sense organ that detects weak electrical signals from the prey, even if it is hiding under the sand. They trap their prey under their "wings" and can also create suction on the sandy bottom with their gills to help capture prey.

Skates and rays (stingrays) look very similar, but are in different orders of cartilaginous fish. One of the differences between skates and rays is that skates have a thicker tail with no spine (stinger) and rays often have a thin tail with a spine at the base or midway down the tail. There are torpedo rays in most oceans that have no stinger but are electric.

Vocabulary
Predator—any organism that exists by killing and eating other organisms
Prey —an animal hunted or seized for food
Classify/Classification —To arrange or organize according to class or category. The systematic grouping of organisms into categories on the basis of evolutionary or structural relationships between them; taxonomy
Cartilaginous—having a skeleton composed either entirely or mainly of cartilage, as vertebrates of the class Chondrichthyes, which includes the sharks, skates and rays
Cartilage—a firm, elastic, flexible type of connective tissue of a translucent whitish or yellowish color
Osteichthyes—a class of fish having a skeleton composed of bone in addition to cartilage
Chondrichthyes—cartilaginous fishes; a class comprising cartilaginous fishes with well-developed jaws and including the sharks, skates and rays
Adaptation—any alteration in the structure or function of an organism or any of its parts that results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment.

