Chapter 9 DEMONSTRATIONS, LECTURES, DISCUSSIONS, AND FIELD TRIPS

Hands-on, minds-on laboratory activities lie at the heart of classroom inquiry. Nevertheless, if properly designed, demonstrations, mini lectures, discussions, and field trips can be used to enrich and expand student inquiry. The purpose of this chapter is to help you design and carry out these activities effectively. We will start with demonstrations.

During field trips several puzzling observations can be made, and several hypotheses can be generated.

DEMONSTRATIONS

Some Options

Consider some demonstration options that you might use to begin a unit on air pressure. For each option you first place two thick books on a table about 5 inches apart. You then lay an 8.5- by 11-inch

APPLICABLE NSES STANDARDS

Standard B Science teachers guide and facilitate learning. In doing so, they

- Orchestrate discourse among students about scientific ideas.
- Challenge students to accept and share responsibility for their own learning.
- Recognize and respond to student diversity and encourage all students to participate fully in learning.

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Standard D Science teachers design and manage learning environments that provide students with the time, space, and resources needed for learning. In doing so, they

- Identify and use resources outside of the school.

piece of paper on the books so that it spans the space between them. Please rank the following four options in terms of their effectiveness in engaging the students in the topic. Also provide reasons for your ranking:

(a) Rapidly blow air under the paper and note that the paper bends down between the two books. Then ask students for some alternative explanations for why the paper bent down.

(b) Tell students that you are going to rapidly blow air under the paper and ask them to predict what they think will happen. Once students have made some predictions, ask them why they made those predictions. Then blow under the paper and observe what happens. Next have students discuss the results in terms of their predictions and reasons.

(c) Tell students that you are going to rapidly blow air under the paper and ask them to predict what they think will happen. Once students have made some predictions, you then blow under the paper and observe what happens. Then explain that the paper bent down because blowing reduced the lower air pressure so the greater upper air pressure pushed down.

(d) Rapidly blow air under the paper and note that the paper bends down between the two books. Then explain that the paper bent down because blowing reduced the lower air pressure so the greater upper air pressure pushed down.

Crouch, Fagen, Callen, and Mazur (2004) conducted a study that compared the effectiveness of similar options in a physics course. Demonstrations included colliding a rubber ball and a putty ball with a bowling pin to see which ball knocked the pin over, comparing tension on a string when fixed to a wall at one end versus when attached to weights at both ends, and comparing the time of travel for balls on two tracks that have the same starting and end points but only one of which has a dip in the middle. Interestingly, they found that option (b) was the most effective. Option (d) was the worst. In fact, students who experienced option (d) did no better in terms of understanding than control students who saw none of the demonstrations. How would you rank options (a) and (c)? Why?

Selecting Demonstrations

Demonstrations can contribute to student inquiry if used at the right time in the right way. For example, as suggested above, they can be used during the engagement phase of learning cycles to raise questions and spark student interest, particularly if they present unexpected results. Demonstrations can also be used during term introduction to help explicate new concepts. And they can be used during concept application to extend student understanding to new contexts. Demonstrations can even be used to help assess student understanding.

Experienced teachers have developed and published several excellent demonstrations. Unfortunately, many of these published demonstrations merely describe without explaining the concepts behind them or suggesting effective ways of presentation. Consequently many do little more than entertain. To help make demonstrations more effective Simanek (2003) suggests asking the following six questions prior to selecting a demonstration: (1) Does the demonstration fit into your course story line? (2) Is the demonstration important enough to justify building a story line around it? (3) Does the demonstration clearly illustrate a phenomenon or help explicate new concepts? (If too many interacting concepts affect the outcome you should select a "cleaner" demonstration.) (4) Can the demonstrated concepts be understood at the level of the course? (If not, don't use them.) (5) Do you fully understand the demonstration? (If not, don't use it.) And (6) Is the demonstration being conducted for entertainment or because the concepts behind it need demonstrating? Also keep in mind that demonstrations should not take the place of student explorations. Obviously conducting a demonstration requires only one "setup" while explorations require enough materials for each group of students. Nevertheless, in most cases the added cost of getting materials into students' hands is well worth the price in terms of increased motivation and learning.

Practicing the Demonstration

Simanek (2003) also suggests practicing the demonstration until you have it perfected. You can even present it to a critical observer who can tell you what points are not clear and what details of explanation you have omitted. Also make sure that you know what the demonstration demonstrates—not what you intend it to demonstrate. Next prepare your students. Show them the apparatus, describe what you intend to do before you do it, and indicate what they should watch for. Ask students to predict in advance what will happen. And don't proceed until at least some students have provided explanations (i.e., hypotheses) for their predictions. Only when you have made the situation clear and have the students' attention should you conduct the demonstration. Then analyze the results. Discuss which student predictions and hypotheses were supported and which were contradicted. Repeat the demonstration again during the discussion and be prepared to test additional student hypotheses by varying the demonstration or by making some additional measurements.

Showmanship Tips

Lastly, Simanek (2003) offers several showmanship tips that will help you effectively pull off the demonstration. These include using an apparatus large enough for students to see clearly. When something can be seen only in a narrow range of angles, stand to one side so the audience subtends a smaller angle from your position or show it from different angles if necessary so no one is cheated. If necessary, stand back in the classroom to judge the effect. And don't ask students to trust a measurement that they can't see. For electrical experiments you might consider projection analog scales or projection digital meters. Avoid using electronic balances. Instead use visible mechanical ones. Often a visual indication of which direction something moves is all that is needed.

The use of colors and plenty of light can enhance visibility and help distinguish one thing from another. Use paper sheets that come in many bright colors as do ping-pong balls and golf balls. Use a selection of unpatterned tablecloths in attractive colors. Equipment stands out much better against them. White or black string can be replaced with colored kite string, mason's cord (a hardware store item), or rug maker's cord. You may want to add food coloring to water to make it more visible. Make sure, however, to tell students that you have added food coloring so they won't think it is something other than water. Lastly, conduct the demonstration in a well-lighted classroom and use sensory clues. For example, to indicate that something is rigid, tap it on the table so students can hear it or yank a string to show it doesn't stretch.

LECTURES

Although lectures are a frequent means of college instruction, evidence indicates that they are a poor way to teach. For example, when students are interviewed a day or two after a lecture, they often recall only insignificant details. Interviewing students periodically during lectures suggests why this is so. Interviews reveal that after an initial settling-in period of about 5 minutes, students pay attention well for only the next 5 minutes or so. Then confusion and boredom set in, and attention falls off rapidly, only to pick up again near the end of the lecture when students are somewhat revived by the thought that the lecture will soon be over. Even lectures in medical schools have a poor reputation. For example, Edlich (1993) concluded that medical lectures are outdated and ineffective. Similarly, McIntosh (1996) noted that most are frequently a one-way process unaccompanied by discussion, questioning, or immediate practice.

Why then are lectures so commonly used in higher education? The answer is simple. They are relatively inexpensive because one professor can "teach" as many as 350 tuition-paying students all at once. Fortunately, economics do not compel secondary school teachers to do the same. Nevertheless, some secondary teachers, perhaps thinking that they should do unto their students what their professors did unto them, lecture longer and far more often than they should.

This is not to say that lectures, at least relatively brief interactive ones, can never be useful. In fact, if redefined as "brief occasions in which you address the entire class at the appropriate time using interactive techniques," then lectures can become an effective component of inquiry instruction. More specifically, brief interactive lectures can help arouse interest in a topic, or they can provide needed background information during the engagement phase. They can introduce new concepts during concept introduction. And they can extend introduced concepts to new contexts during concept application.

Characteristics of Effective Lectures

Effective lectures are characterized by teacher and student questions, a shared responsibility for sense making, small-group problem-solving activities, a variety of supporting media, and limited note taking. In contrast, ineffective lectures are typically characterized by little or no interaction and few, if any, teacher or student questions. Instead, students depend on teachers for all information, and typically there are no student activities, no supporting media, and extensive note taking. In short, during ineffective lectures teachers stand behind a lectern and talk.

Sullivan and McIntosh (1996) suggest several techniques to make lectures more interactive and effective. These include beginning with an introduction that captures students' interest and attention, communicating on a personal level, and maintaining eye contact to provide you with feedback on how well students understand. You should also communicate a caring attitude and exhibit enthusiasm by smiling, by moving around the room, and by gesturing with your hands and arms. And try to display a sense of humor, using humorous transparencies or slides and/or topic-related stories. Also make sure to avoid the use of slang or repetitive words, phrases, or gestures that become distracting. Avoid the use of fillers (e.g., "and um," "you know").

As mentioned, you should use a variety of audiovisuals and ask a number of well-thought-out questions targeting a divergent question to specific students. Use students' names when asking and answering questions, if possible, as name recognition is a powerful motivator. And don't forget to encourage student questions by providing positive feedback when students ask questions, answer questions, or make comments. Praise creates a positive climate and encourages student participation. Repeat students' questions and answers to ensure that all students hear the discussion. You can answer student questions directly, ask students a different related question, or offer the question to another student. But make sure to avoid a questioning pattern. Always asking and answering questions in the same way undermines effectiveness. Lastly, make smooth transitions between parts of the lecture (e.g., a brief overview of the next topic, a review of the agenda between topics, a change of media, a summary before a new topic, or an activity).

Planning Interactive Lectures

Now that you have some idea what is involved in delivering good interactive lectures, let's briefly consider how they should be planned. You will need to consider a number of factors including lecture notes, lecture length, room configuration, media use, and small-group discussions and activities.

Prepare careful lecture notes in outline form. You can prepare your outline on sheets of paper, note cards, overhead transparencies, flipchart pages, slides, or computer-based projections (e.g., PowerPoint). Using text rather than an outline encourages you to read the text, which quickly results in student disinterest, boredom, and even disruptiveness. The outline will help you stay on topic, introduce the main points, glance at a specific point, and quickly return attention to the students. Most important, relax and focus on delivery instead of worrying about what point to make next.

How long should you lecture? By analyzing videotaped medical school lectures, Arredondo, Busch, Douglas, and Petrelli (1994) set the recommended lecture time at no more than 45 minutes, including approximately 15 minutes devoted to audience interaction—and they are talking about medical students! After analyzing medical lectures, P. Renner (1993) recommended that lectures last no longer than 30 minutes. Consequently, when working with secondary school students you should limit your lecture time even more. For example, your remarks during the engagement phase of learning cycles should last no longer than 5 minutes. Remarks during term introduction can last up to about 20 minutes, but they should include considerable questioning and student interaction.

With regard to room configuration, a room with tables arranged in a U shape and chairs for 20–24 students is ideal as it allows you to interact extensively with students and use a variety of small-group methods and media. If you ever have to lecture to a considerably larger group, a room with 100 seats arranged theater-style with an aisle down the middle allows you to move up and down the aisle and interact with students. You can also ask students to turn their chairs around to form small discussion groups. A lecture room with a sloped floor and 200 anchored seats makes it difficult to divide students into small groups. You can still, however, ask students to turn to their neighbor to discuss a question, generate some hypotheses, or solve a problem. Most large lecture rooms are equipped for the use of slides, overhead transparencies, video, and computer-based projections. To develop an effective lecture, you will need to learn to use these media effectively.

What to Do During Each Part of the Lecture

A key to delivering an effective lecture is to divide it into parts and use a variety of techniques in each part. The three main parts of a lecture are the introduction, the body, and the summary. The introduction should capture student attention and interest. Sullivan and Wircenski (1996) suggest a number of ways of spicing up your introduction, including asking for a show of hands in response to a general question, using an interesting or a famous quote, relating the topic to previously introduced content or to a real-life experience, using a case study or problem-solving activity, using videotape or other media, showing an appropriate cartoon, making a provocative statement to encourage discussion, conducting a demonstration, using a game or role play, or sharing a personal experience.

Once you have the students' attention and interest, make a smooth transition to the lecture body, which contains the core of the lecture information. Here the use of brainstorming, discussions, problem-solving activities, case studies, and games can be effective. Make sure to ask and encourage lots of questions. Finally move on to the lecture summary. The summary should briefly address only the main points. You may ask students for questions, which gives them a chance to clarify their understanding. Or you can ask them questions, which gives you a check on their understanding. You may also use a transparency, slide, or flipchart to briefly review the main points.

Table 9.1 contains a checklist to help plan, evaluate, and improve your lectures. The checklist can also be used to evaluate up to five of your own videotaped lectures or for a colleague to observe and evaluate your lectures.

TABLE 9.1 Lecture Skills Checklist

Lecture Skills	*Lecture Number*				
	1	*2*	*3*	*4*	*5*
Preparation Skills					
Selected lecture methods in advance.					
Prepared lecture notes in advance.					
Prepared audiovisuals in advance.					
Planned effective techniques to introduce the lecture.					
Arranged room appropriately.					
Verbal Presentation Skills					
Projected voice (changed pitch, tone and volume).					
Avoided fillers ("and um," "you know," etc.).					
Used many examples.					
Provided praise and reinforcement.					
Accepted student ideas and suggestions.					
Used appropriate humor.					
Nonverbal Presentation Skills					
Maintained eye contact.					
Maintained positive facial expressions.					
Gestured with hands and arms.					
Maintained good posture.					
Moved around the room with energy.					
Followed lecture notes.					

For each skill, use the following rating scale to indicate the level of performance:

NO: Skill not observed in this lecture.

NA: Skill not applicable to this lecture.

1: Cannot perform this skill and requires extensive practice.

2: Can perform this skill but requires additional practice.

3: Competent at this skill and requires no additional practice.

(Continued)

Table 9.1 (Continued)

Lecture Skills	*Lecture Number*				
	1	*2*	*3*	*4*	*5*
Questioning Skills					
Asked questions at varying levels of difficulty.					
Asked questions to group.					
Asked questions to individual students.					
Involved all students (if possible).					
Repeated student responses and questions.					
Provided positive reinforcement.					
Audiovisual Skills					
Used presentation media correctly.					
Summarizing Skills					
Asked for questions.					
Asked questions.					
Used media to review main points.					

For each skill, use the following rating scale to indicate the level of performance:

NO: Skill not observed in this lecture.

NA: Skill not applicable to this lecture.

1: Cannot perform this skill and requires extensive practice.

2: Can perform this skill but requires additional practice.

3: Competent at this skill and requires no additional practice.

Discussions

Virtues of Good Discussions

When I first started teaching I had an intuitive sense that discussions were worthwhile. In fact Cavanaugh (2001) cites several virtues of good classroom discussions. These include sharing observations and ideas, gaining insights from diverse points of view, increasing student communication and argumentative skills, increasing topic connection and student ownership, increasing awareness of and tolerance for ambiguity and complexity, increasing awareness of hidden and sometimes incorrect assumptions, encouraging attentive respectful listening, encouraging respect for diverse opinions, developing the capacity for clear communication of ideas and meanings, developing habits of collaborative learning, developing skills of synthesis and evaluation, and affirming students' role as cocreators of knowledge.

Keys to Good Discussions

In spite of these considerable virtues, as a new teacher I had difficulty getting students to pay much attention to me—not to mention to discuss anything worthwhile. No matter how hard or what I tried, nothing seemed to work. Fortunately at that time I had the habit of leaving my classroom door open, and so did the experienced teacher across the hall. So periodically I would look into his classroom to see what was going on. Amazingly, whenever he was holding a discussion, his students all seemed engaged and paying attention to what he or to what each other were saying. How in the world did he get his students so involved? Surely his students were no different from mine, yet somehow his students were sharing ideas, listening to each other, and participating while mine were simply giving me blank stares and silence. What was his secret?

After reading about inquiry instruction in the previous chapters you may already have figured out the answer. It turned out that his secret was that he never asked his students to discuss a topic or listen to him until *after* they had participated in a hands-on exploration of the topic to be discussed. It turns out that once students have explored a topic and have shared an experience, they are more than willing to share their thoughts and listen to those of others about what has been discovered and what it might mean. So his secret was this: *Explore first; discuss second!*

In addition to holding discussions only *after* student explorations, discussions can be improved by making certain that students know at the outset that they are expected to be full participants. For example, Cavanaugh (2001) introduces the following discussion guidelines given to each student on the first day of class:

> You are expected to contribute to the quality of classroom discussions. Among other things, participation will allow you to test and improve your ability to convince peers that you have approached questions and problems thoughtfully and that your approach will help achieve the desired result. Criteria used to measure effective class participation include:
>
> 1. Is your comment clear and relevant?
> 2. Do you support your comment with evidence and a well-reasoned argument?
> 3. Do you explore the implications and importance of your comment and those of others?
> 4. Is your comment insightful? Does it broaden the discussion and/or clarify an issue?
> 5. Is your comment complete and concise?
>
> An average comment satisfies 1 and some of 2. A good comment satisfies 1–3. An excellent comment satisfies 1–5. Class participation represents a significant component of your grade (30%). When asked a question, you are not allowed to say "I don't know." You are not required to know, but you are expected to think. So if asked a question and you don't know the answer, you are responsible to think of a possibility, to guess, to speculate, and to wonder aloud.

Thus, it helps to make sure that the students know in advance that they all need to be involved. And to keep them all involved you should resist responding to student comments yourself. Instead, randomly ask students, by name, to respond. And keep in mind that a good discussion is based on thoughtful, deliberative, and well-reasoned responses, rather than on intuitive, instantaneous, and gut-level reactions. So become comfortable with silences and be willing to pause for several seconds while students formulate thoughtful responses. In other words, make sure to use wait-time I and wait-time II. Also remember to express interest in their comments by encouraging them to elaborate on their comments, by asking students to respond to each other's comments, by explaining a link between the comments of two students, by making a contribution that builds on a student's comment, by paraphrasing a student's comment, and lastly by summarizing several comments.

Establishing eye contact is also important as it opens a communication channel and selects a specific student for a turn to speak. Breaking eye contact during a student's turn and scanning the class helps distribute the student's comments throughout the class. Your scanning eyes also signal students that they should be paying attention to the speaker. Regular scanning keeps students engaged and can provide you with important feedback. In short, scanning is a surveillance tool. If you are making eye contact with *all* the students, they are more likely to stay involved—and if they are not involved, you will know it immediately.

Lastly, you might want to try assigning the following conversational roles to specific students to improve discussions:

1. *Problem, dilemma, or theme poser:* Introduces the topic of conversation
2. *Reflective analyst:* Records the conversation's flow, offering a periodic summary
3. *Scrounger:* Listens for suggestions and needs, records them, and reviews them at the end of the discussion so the group may decide on an action plan
4. *Devil's advocate:* Expresses a contrary view to group consensus
5. *Detective:* Listens for unexplored biases and brings attention to them
6. *Theme spotter:* Identifies themes needing time at the next session
7. *Umpire:* Listens for personal judgments in order to enforce ground rules (see below)

Classroom arrangement is also important when planning discussions. For example, arranging desks in a circle or horseshoe prevents students from hiding in corners or behind others. These arrangements also improve communication by allowing students to see each other's faces and hear each other's responses. They also allow you easier access to students. Decreasing the distance between you and your students is important as it establishes and narrows a communication channel. Moving toward the speaker is a clear signal that you are interested in what a student is saying and that others should be listening too. Moving away from a speaker widens the communication channel. As you back up, the audience grows as more students can move into the speaker's gaze. Also working from among or even behind students can lessen the threat from the teacher. And sitting in a student desk as part of the circle signals that you want to be *a part of* the discussion rather than *apart from* it.

Discussion Formats

Cavanaugh (2001) and Johnson and Johnson (2003) list several formats that are available for discussions and small-group work. Those listed by Johnson and Johnson are called **cooperative learning** formats as they explicitly include an element of peer teaching and both personal and group accountability. Cooperative learning formats include

Think-Pair-Share. The teacher poses questions and/or problems. Students are then given a set time period to individually think of a response. They then pair up to discuss their thoughts and perhaps reach consensus. Lastly, the teacher asks student pairs to share their thoughts with the entire class.

Brainstorming. Student groups are given time to generate alternative hypotheses to a posed causal question. Students then offer hypotheses one at a time, and the teacher (or another leader) records all hypotheses on a chalkboard or poster. No criticism or elaboration is allowed until the brainstorming period ends.

Circle of Voices. Students form groups of five. Students then have 3 minutes of silent time to consider the topic. Next each student has 3 minutes to discuss the topic with others in the group. Group members may react to the comments expressed.

Posted Dialogues. Groups summarize their conversations on large sheets of newsprint, transparencies, or whiteboards. Students then walk about the room reading all the responses and adding comments.

Rotating Stations. Each group starts at a station where students have 10 minutes to discuss a provocative issue and record their ideas on newsprint or a whiteboard. When time is up, the groups move to new stations where they continue their discussion based on ideas recorded by the previous group. Rotations continue every 10 minutes until each group has visited each station.

Snowballing. Students individually respond to a question or an issue. They then create progressively larger conversational groups by doubling the group every few minutes until everyone reconvenes in one large group.

Three-Step Interviews. The class is divided into four-member groups, each with an A-B pair and a C-D pair. During step 1, A interviews B, and C interviews D. During step 2, B interviews A, and D interviews C. During step 3, each student shares information with others in the group of four.

Numbered Heads Together. Each student in a four-person group is numbered from 1 to 4. The teacher poses a question, an issue, or a problem. Students discuss within the group and prepare a response. The teacher then calls on students by number to represent their group.

Roundtable. The teacher poses a divergent question or gives each group a worksheet. The group has only one piece of paper or worksheet and perhaps only one pen. A student writes down one response, says it aloud, and then passes the paper or worksheet to the person on the left. The process continues in this way.

Generating Truth Statements. Groups of four students create three endings to open-ended statements (e.g., "It is true of energy that . . ."). They then choose one or more to share with the class.

Workshops. Workshops are typically used to introduce and discuss new skills. Time is allotted for students to work on and/or prepare for a specific task. You can answer questions or work with students during that time.

Critical Debate. Identify a contentious issue and frame the issue as a debate motion. Ask students to select a group to draft either supporting or opposing arguments. Once students have selected the group they wish to join, announce that those who have selected the supporting group will draft arguments to oppose the motion, and vice versa. After argument preparation, both groups choose a student to present their case. After these initial presentations, both groups reconvene to draft rebuttal arguments and again choose a student to present them. Following the debate, the teacher holds a discussion focusing on the quality of student arguments and how it felt to argue against positions students were committed to. If you like, students can be asked to write a follow-up paper reflecting on the debate.

Jigsaw. Generate a short list of topics. Each student then becomes an "expert" on one topic, first by him- or herself and then in discussion with other experts. Next, each expert helps non-experts become experts. For example, a class of 25 students works on five topics. Each student selects one topic and develops the required expertise before and/or during class time. Students who have selected the same topic gather in groups of five to discuss and compare what they have learned. When these discussions are over, new groups of five are formed including an expert for each of the five topics. The experts then lead a discussion of their topic. These discussions end when all group members think they understand all of the topics. The jigsaw may end there, or it may end following a whole-class summary.

Concluding and Evaluating Discussions

Regardless of the discussion format, at the end of a discussion you should ask for final comments, summarize progress, and/or ask for ideas about how students could continue the inquiry. Summary questions might include the following: Have students debated and refuted a particular statement or position? Have they effectively tackled and exposed "what's wrong" speeches, articles, or stories that include incorrect science content and/or faulty arguments? Have they taken the role of teacher in which they present their ideas and arguments on a whiteboard, on the class board, on an overhead, or perhaps using a PowerPoint presentation? These sorts of activities build accountability and foster a student-centered class.

You might also have students write reflections or exit journal notes to process their experience. And don't forget to evaluate the discussion by asking whether or not (a) the discussion was effectively initiated, (b) the educational objectives were achieved, (c) there was equitable student participation, and (d) there were high-quality student responses. The bottom line is that regardless of the particular format used, you want discussions to foster higher-order thinking and reflectivity.

Field Trips

In addition to demonstrations, brief interactive lectures, and discussions, field trips can foster inquiry. Student motivation and excitement are usually high during field trips. Therefore students are apt to learn and retain more than they will in the classroom. Likewise many phenomena can be explored in the field that simply can't be brought into the classroom. In terms of learning cycles, fieldwork can serve as the exploration phase with term introduction and application taking place back in the classroom. In some instances the first two phases, or perhaps even the initial applications, can take place in the field.

Some Alternative Approaches to Fieldwork

To obtain a better sense of how fieldwork can promote student inquiry, here are four alternative approaches to initiating fieldwork. Start by ranking them in terms of how you perceive their effectiveness at provoking student thinking and self-regulation. Use 1 for most effective and 4 for least effective. My comments will follow.

(a) Provide students with rulers. Have them run a transect from the upper to the lower zone in the intertidal area and measure and record shell sizes of *Tegula funebralis* snails (a common West Coast snail) found along the transect. Ask them to plot size-versus-frequency graphs for all the snails measured.

(b) Provide students with rulers, quadrats, and a map of the intertidal area. Ask them to measure and record *Tegula* shell sizes and determine the density of the snails from three locations in the intertidal area—the lower, middle, and upper zones. Then ask them to search for quantitative relationships among the variables and to explain these relationships in light of other observations and ecological concepts.

(c) Explain to students that interspecific competition affects population characteristics of many species. For example, the snail *Tegula funebralis* is common in the intertidal area. The older snails (larger ones) are found in the lower zone while the younger snails (smaller ones) live in the upper zone. Tell students this is because their food source (algae) is more abundant in the lower zone. However, the starfish *Pisaster* that preys upon them lives in the lower zone. Because the smaller snails are too slow to escape the starfish, they must remain in the upper zone. Now have your students go to the intertidal area and collect data to verify that what you have explained is correct.

(d) Provide students with rulers, thermometers, identification keys, quadrats, and a map of the intertidal area. Ask them to select an abundant population in the area, identify interesting variables with respect to individual organisms and the population's distribution, and search for quantitative relationships among these variables.

Because of their openness procedures (b) and (d) are the most likely ways to initiate student thinking and self-regulation. Procedure (d) may be more effective than (b) for the more advanced students in that it is more open and allows students an opportunity to examine interesting phenomena that you may not have anticipated. However, this procedure affords little guidance and may not be as effective as the somewhat more structured approach in

(b) for concrete operational students. The choice of openness or structure depends on the reasoning skills of your students and their past experiences with inquiry-based instruction.

Procedure (a) provides firsthand experience. However, as presented, it is not likely to initiate student reasoning and self-regulation due to its directive and "cookbook" nature. Self-regulation could, however, be initiated if the plotted data raised some questions relative to previous partial understandings. Procedure (c) unfortunately is very much like the kind of labs and fieldwork many teachers conduct. Because students already know what the data are supposed to show, no reasoning, no self-regulation, and no intellectual development is likely to occur. Further, procedure (c) encourages reliance on authority rather than on evidence and self-initiative; thus it is contradictory to the nature of science.

A Field Trip Checklist and Some Precautions

As mentioned, field trips can serve a vital purpose in the curriculum in terms of both motivation and lasting learning. Just think back on your own experiences. Do you remember the field trips you took? Most likely you do. Do you remember the lectures you sat through? Most likely you do not. Nevertheless, to make the most of fieldwork, you will not only need a well-thought-out field trip plan, but you will also need to take care of some vital administrative details. To help make sure that nothing is overlooked, read through and check off each item listed in Table 9.2 before each and every trip. Also Table 9.3 lists some important field trip precautions that should not be overlooked.

TABLE 9.2 A Checklist of Important Items Prior to Taking a Field Trip

———	Permission granted by school administration
———	Arrangements made with field site personnel
———	Field site fees determined and method of payment determined
———	Departure and return dates/times and locations set
———	Transportation arranged
———	Parent/guardian consent forms prepared and signed
———	Qualified chaperones obtained
———	List of participating students made (one left with principal)
———	Emergency medical forms for students who require them obtained
———	Cellular/emergency phone obtained
———	Lunch and/or snacks prepared
———	Special clothing obtained (e.g., hats, shoes)
———	Special equipment obtained (e.g., pencils/pens, binoculars, thermometers, paper, clipboards)
———	Location of lavatory facilities determined

Source: Chiappetta & Koballa, 2002.

Table 9.3 Field Trip Precautions

- Inform students of any hazardous areas they should avoid or near which they should exhibit extra caution.
- Inform students of appropriate water and clothing to bring and to wear—including footwear and hats.
- Caution students about any possible poisonous or hazardous plants (e.g., cacti) and instruct them in plant identification.
- Warn students not to stick hands into crevasses or to pick up reptiles and/or dead organisms.
- Warn students about eating plants or plant parts unless identified as edible by an expert.

Source: From *Science & Safety: Making the Connection*, by the Council of State Science Supervisors (n.d.), available at http://www.csss-science.org/downloads/scisafe.pdf.

Summary

- Demonstrations can contribute to student inquiry and learning if used during the engagement phase of learning cycles. They can also be used during term introduction to help explicate new concepts. And they can be used during concept application to extend student understanding. Several techniques exist to help you plan and carry out effective demonstrations.
- Standard lectures are a poor way to teach. Nevertheless, relatively brief interactive "lectures" can become an effective component of inquiry instruction to help arouse interest in a topic or provide needed background information, to introduce new concepts, or to extend introduced concepts to new contexts.
- Several techniques exist to help you plan and carry out brief lectures in a more interactive and effective way.
- Classroom discussions have many virtues. The secret to good discussions is explore first; discuss second.
- Several formats exist for holding effective discussions. Regardless of the format used, you should evaluate discussions by asking for final comments or for student-written reflections.
- Field trips can also foster inquiry where student motivation is usually high and students are apt to learn and retain more than in the classroom. Good field trips, like good classroom inquiries, should allow for a variety of paths of inquiry.

Key Term

cooperative learning

Application Questions/Activities

1. Consult a recent publication such as *Journal of Chemical Education*, *The Physics Teacher*, *The American Biology Teacher*, or *Journal of Geoscience Education* for an article describing a classroom demonstration. Briefly describe the demonstration and answer the following questions:
   (a) What puzzling observation(s) will be demonstrated?
   (b) What causal question(s) will be raised?
   (c) What predictions and hypotheses are students likely to generate?
   (d) How can student hypotheses be tested?
   (e) What concept(s) is demonstrated, and how/when will you introduce the related scientific term(s)?
2. Select an inquiry-based lesson and then select a discussion format that can be used during the term introduction or application phase. What format did you select, and how will it be used? Why did you select that particular format? How will you try to ensure all students will be involved in the discussion?
3. Select an inquiry-based lesson and plan a brief interactive "lecture" that you can use during the term introduction phase. What specific divergent and/or convergent questions will you raise, and in what order will you raise them? What student answers do you expect? How will you respond to each student answer? What new terms will you introduce? Explain how the term or terms introduced relate to the preceding exploration activity.
4. Suppose you are taking students on a field trip to explore an out-of-doors location. Tell us where you will go. Describe the location and how you will use it to provoke student inquiry. What exploration activity will students engage in? What term introduction and application activities will follow (in the field or later in the classroom)? What modifications will you make for students in wheelchairs, for students with visual impairments, for students with hearing impairments, and for gifted students? What specific rules and procedures will you propose to help ensure student safety while on the field trip? How and when will you inform students of those rules/procedures? What, if any, other precautions will you take in case of an accident?