Teaching Secondary School Science
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CHAPTER 12

QUESTIONING AND DISCUSSION

THE NATURE OF INQUIRY TEACHING

The essence of inquiry teaching comprises two main elements: arrange the learning environment to facilitate student-centered instruction and give sufficient guidance to ensure direction and success in discovering scientific concepts and principles. One way in which a teacher helps students to obtain a sense of direction and to use their minds is through questioning. The art of being a good conversationalist requires listening and posing insightful questions. Good inquiry-oriented teachers are excellent conversationalists. They listen well and ask appropriate questions, assisting individuals in organizing their thoughts and gaining insights. Inquiry-oriented teachers seldom tell but often question. A properly given question is a hint. If students are studying a pendulum but have not discovered that its frequency is related to its length, the instructor may notice that the students seem to be having difficulty. The instructor can guide the students by asking a series of questions. Listed below on the left are the questions asked. On the right is an analysis of what the instructor is doing.

An Inquiry Discussion

1. What have you found out about the pendulum?	This is a good question because it is divergent. It allows for a number of responses. Students will have found out something, and being able to tell it to the instructor will help clarify any problems.
2. What seems to affect the frequency, i.e., the number of times it swings a second?	This is a more convergent question. It helps students center on frequency. They may not have thought of this before. Students replied that they didn't know.
3. Try some things to find out.	The teacher then leaves and moves on to other students requiring some assistance. Later, the teacher returns.
4. What have you done to find out about the frequency?	Here again the instructor is asking a relatively divergent question since the students may have done many things. The students reply that they have used different weights.
5. How did the use of different weights affect the frequency?	The instructor is asking students to interpret data. Students, however, still have not discovered that the length of the string affects the frequency.
6. What do you think the length of the string would have to do with the frequency?	This question is fairly directive-convergent. The instructor is helping students to center on a particular variable.
7. How would you determine this?	This question asks students to devise an experimental procedure.

Notice that the instructor aided students, through artful questions, to make their own discoveries and to use their minds. The teacher did not steal the thrill of discovery from the students but did facilitate it. Proper questioning is a sophisticated teaching art. To practice it, teachers must know where the students' thoughts are. To do so, instructors must switch from the classical concept of teaching-telling to listening and questioning and being open to the students' ideas. Consequently, the emphasis changes from teacher teaching to student learning. After perceiving students' difficulties, instructors must formulate a question that will be a challenge yet give guidance. To do so, instructors must know what they are trying to teach in a conceptual way and adapt the question so that it is appropriate to the students. Moving about the class, teachers must constantly adapt this procedure from student to student. This process requires unusual awareness and ability. No wonder so many teachers fall back into the classical mode of teaching. To move about a classroom in this manner is to truly individualize instruction, teach for the person and, if done consistently in a positive setting, humanize instruction. Good questioning practices are involved in all areas of science instruction, as indicated in the following list:

Where Is Questioning Involved in Science?

1. Discussion
2. Laboratory exercises
3. Demonstrations
4. Student worksheets
5. Audiovisual aids
6. Evaluations
7. Field trips
8. Projects
9. Games
10. Lectures
11. Simulations
12. Computing

TYPES OF QUESTIONS

Questions may be planned before class or may arise spontaneously because of student interaction. It is always wise to prepare a series of questions before entering an inquiry-oriented class. The mere fact that you have done so contributes to your questioning ability. Having thought about the questions gives you direction and a sense of security, thus enhancing your ability to carry on a discussion.

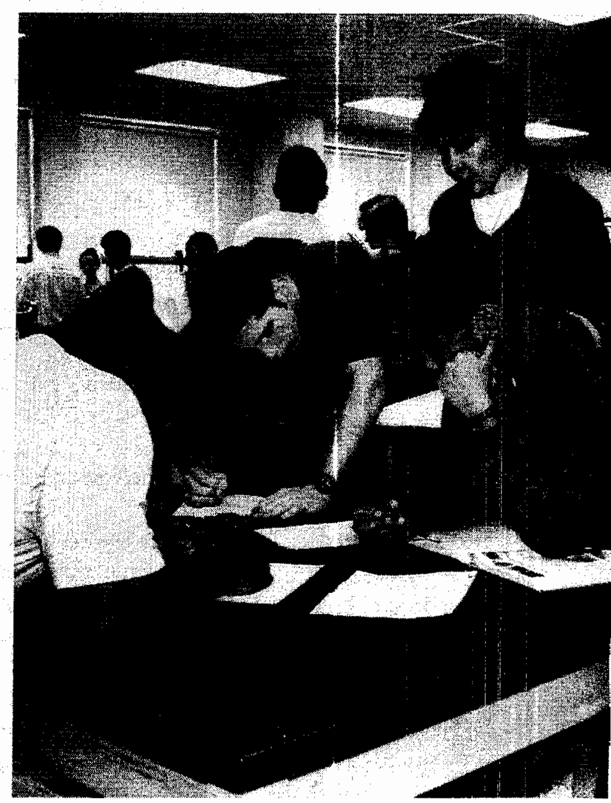
Inquiry-oriented teachers must remain constantly flexible. Even though they have planned a series of questions, they must be willing to deviate from them and formulate new ones as they interact with students. These unplanned, spontaneous questions may be difficult to create at first, but through developing good questioning techniques, instructors become more sophisticated and more likely to interact appropriatel with students.

Before you devise your questions you should de cide the following:

1. What talents are you going to try to develop?
2. What critical-thinking processes will you try to nurture?
3. What subject-matter objectives do you want to develop?
4. What types of answers will you accept?
5. What skills do you wish to develop?
6. What attitudes and values do you wish to emphasize?

Educational Objectives and Questions

Just as objectives can be classified by this taxonomy, s can questions. Refer back to the preceding question and classify them, on the left, according to the taxon omy. Then list five of the best questions and decide wh you believe they are good. Bloom's abbreviated taxon omy is repeated to help you (see chapter 6). An exam ple of how you might use it is shown as a guide.



By moving about the class, the teacher can question and listen to students individually.

BLOOM'S TAXONOMY

Cognitive Domain	*Affective Domain*
Evaluation	Generalized Set
Synthesis	Organization
Analysis	Valuing
Application	Responding
Comprehension	Receiving
Knowledge	

Questions requiring responses from the higher levels of the hierarchy are more desirable because answering them involves more critical and creative thinking and indicates a better understanding of concepts.

USING BLOOM'S TAXONOMY TO CLASSIFY QUESTIONS

Classification	*Sample Question*
Knowledge	1. How many legs has an insect?
Synthesis	2. What hypotheses would you make about this problem?
Application	3. Knowing what you do about heat, how would you get a tightly fitted lid off a jar?
Analysis	4. What things do birds and lizards have in common?
Comprehension	5. Operationally define a magnet.
Evaluation	6. If you were going to repeat the experiment, how would you do it better?
Valuing	7. What is your interest in earth science now compared to when you began the course?
Valuing	8. What do you value about this film?
Receiving	9. Do you watch science shows on television?
Responding	10. Do you talk to your friends about science?

PROCESSES OF SCIENCE AND QUESTIONS

Another way to classify questions is to use science processes. This approach ensures that the basic structure of science and critical thinking is taught. Shown below is a guide to how you might classify questions using science processes.

Science Processes

1. Hypothesizing
2. Inferring
3. Measuring
4. Designing and experimenting
5. Observing
6. Setting up equipment
7. Graphing
8. Reducing experimental error

CLASSIFYING USING SCIENCE PROCESSES

Classification	*Sample Question*
Observing	1. What do you observe about the landscape?
Hypothesizing	2. What do you think will happen to the solution when I heat it?
Designing an Experiment	3. How would you determine the absorption of the different wavelengths of light in water?
Graphing	4. How would you graph these data?
Setting up Equipment	5. Obtain the following equipment and set it up as directed.
Reducing Experimental Error	6. How many measurements should be made to report accurate data?
Inferring	7. What conclusions can you make from the data?

Convergent and Divergent Questions

Another way to classify questions is to determine whether they encourage many answers or just a few. Questions allowing for a limited number of responses and moving toward a conclusion are called convergent. Questions allowing for a number of answers are called divergent; they provide for wider responses plus more creative, critically considered answers. In an inquiry discussion it is generally desirable to start with divergent questions and move toward more convergent ones if students appear to be having difficulties.

Generally speaking, convergent questions, particularly those requiring only a yes or no answer, should be avoided because they allow for fewer responses, thereby giving students little opportunity to think critically. The fundamental purpose in using the inquiry approach is to stimulate and develop critical thinking, creative behavior, and multiple talents. Convergent questions certainly do little to achieve this end. Remember that in an inquiry investigation, it is important that students have a chance to use their minds. Learning to think rationally and creatively does much to increase a person's self-concept. Many teachers are so concerned with getting the right answer that they prevent students from going through a thought process. Even though students may come up with wrong conclusions, they still have had a mental experience in thinking about the problem. Having this experience is probably more important than a right answer. We as teachers would, of course, like for students to think and obtain the correct answer as well. However, recall for a moment a mathematics teacher who only accepts the correct answer to a problem, ignoring the procedures used in obtaining it. Students may have used very good thinking processes to obtain the answer yet misplaced the decimal point. Is the teacher justified in saying that students have not learned because they don't have the right answer? Students will probably never have that problem again but they undoubtedly will have many situations requiring them to use similar logical strategies. It is the thinking that is most important! Teachers who do not reward thinking may stifle students.

Teleological and Anthropomorphic Questions

Teleological (Greek—*teleos*—an end) questions are those that imply that natural phenomena have an end or purpose. The word *anthropomorphic* comes from two Greek words: *anthropos*, meaning man, and *morphos*, meaning form. An anthropomorphic question implies that some natural phenomenon has the characteristics of humanity. For example, such a question might state that some natural phenomenon has a want or wish—rocks fall because they want to.

Why do you think these questions should be avoided? What do they do insofar as developing critical thinking and leading to further investigation? How do they contribute to misconceptions? The answers to these questions should be obvious to you and need no discussion here.

Talent-Oriented Questions

Although the procedures thus far have mainly emphasized the importance of cognitive questions, other types are also important. Teachers should spend a considerable amount of time formulating talent-oriented questions to help them know their students.

We believe that you should not only determine talent but also help to manifest it by rewarding students for all types of talent. Some teachers and administrators may argue that the only function of a science teacher is to develop scientific awareness. It is our view that this awareness will occur to a higher degree if students have opportunities to manifest their best talents, thereby building their self-esteem and developing more positive feelings about science. Some examples of talent-oriented questions are listed below.

Questioning to Discover Talent

Talent	*Question*
Artistic	1. What important ideas should be put on a mural to be hung in our laboratory?
Organizing	2. How should we organize the field trip?
Communicating	3. What should be included in a short article about the science fair for the school paper?
Creative	4. In what ways can we convey to the rest of the school how exciting biology, earth science, chemistry, and physics are?
Social	5. What shall be the social activities for the science picnic?
Planning	6. How shall we plan our investigations of the pond community throughout the year?

Teachers should also ask questions to find out students' interests. What gets them involved? Determining these interests helps the instructor in planning more relevant lessons. Asking students individually about their concerns also conveys to them your interest in them as people and not as sponges to soak up scientific information.

Piaget pointed out that proper questioning gives insights into a student's thought patterns. To do so, the instructor must hypothesize how the student is thinking, then pose questions to see if the hypothesis was correct. The student's response either confirms the hypothesis or indicates further investigation. The instructor may have to formulate a new hypothesis and construct questions to determine its validity. This type of questioning is particularly necessary when the student seems to be having difficulty in discovering or conceptualizing. Excellent teachers in mathematics, physics, chemistry, and other courses often use this approach to diagnose students' thinking-process difficulties and help them resolve problems.

QUESTIONING PROCEDURES

Wait-Time Affects Quality of Responses

Mary Budd Rowe and her coworkers have done an extensive study of the questioning behavior of teachers.[1] In their analysis of taped classroom discussions, they discovered that teachers, on an average, wait less than a second for students to reply to their questions. Further investigations revealed that some instructors waited an average of three seconds for students to answer questions. An analysis of student responses revealed that teachers with longer wait-times (three seconds or more) obtained greater speculation, conversation, and argument than those with shorter wait-times.

Dr. Rowe found further that when teachers were trained to wait five seconds, on the average, before accepting student responses, the following occurred:

1. Students gave longer and more complete answers instead of short phrases.
2. There was an increase in speculative, creative thinking.
3. The number of suggested questions and experiments increased.
4. Slower students increased their participation.
5. Teachers became more flexible in their responses to students.
6. Teachers asked fewer questions, but the ones they asked required more reflection.
7. Students gave a greater number of qualified inferences.
8. Teacher expectations for student performance changed; they were less likely to expect only the brighter students to reply.

Dr. Rowe believes that the expectancy levels of students are more likely to change positively if they are given a longer time to respond. She has also found that the typical pattern of discussion, teacher-student-teacher, can be altered by training instructors to get student-student-teacher responses. This pattern will occur particularly well when students are involved in some controversy, for example, the best design for an experiment or what conclusion can be drawn from data.

For inquiry teaching to occur, most instructors should increase their wait-time tolerance so that students may have more opportunities to think and create.

Good Discussions Are Student-Centered

Most teachers, when they are involved in a class discussion, dominate it to a considerable extent; an inquiry class should be student-centered, which means that the teacher's talking should be at a minimum. Note the two diagrams of discussion interaction in a class in Figure 12–1.

It is not easy to develop techniques so that the second type of interaction operates. How would you as a teacher get the second pattern to operate in your classes?

SOME PRECAUTIONS IN QUESTIONING

It has long been thought that the practice of questioning promotes student thinking and participation, and in most cases it does. However, sometimes certain questioning techniques have the reverse effect, actually shutting off student thinking. Frequently what the teacher

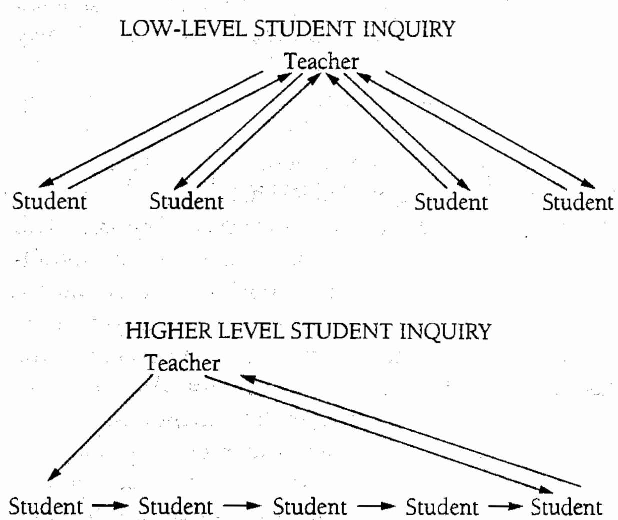


FIGURE 12–1
Discussion Interaction Diagrams

actually does is initiate a question-and-answer practice that does not evolve into true classroom discussion and does not promote expressiveness, active participation, or independent thinking. Instead the process may encourage student passivity and dependency.

A few precautions are given here to alert teachers to practices that may hinder discussion. Sometimes using questions simply results in a back-and-forth interchange between teacher and students in which the teacher is the questioner and the student is the respondent. To avoid this you might hold back from asking questions at the start, thus encouraging students to take some responsibility for carrying on the discussion, rather than simply being targets of teacher questions.

Second, questions are sometimes used to make a point in which a particular piece of information or idea is underscored. This practice can be counterproductive because the same information would be more effective as a declarative statement.

Third, questions are often asked to help students who pause or falter in their responses. We sometimes condition students to speak in short bursts in answer to our direct questions, and they don't expect to have to do anything beyond this. True discussion, however, requires thoughtful, sustained reasoning by the students. It requires more time to express complex thoughts or interpretations. If the teacher pushes in with a question too quickly, the effect is to halt student thought processes and substitute the teacher's thoughts.

Fourth, questions are sometimes used to elicit predetermined answers. In this case the teacher has a particular answer in mind and phrases questions so that the student produces the expected answer. This again shuts off speculative responses from students.

Fifth, teachers occasionally ask questions in reply to a student's question. While sometimes recommended as a way of promoting inquiry, the danger is that it may convey the idea that only the teacher gets to ask the questions and that whenever students ask questions all they get is a redirected question.

Sixth, questions are sometimes used to draw out the nonparticipating students. This assumes that every student is in the frame of mind to respond equally with every other student. The practice may instead intimidate some students and cause others to become wary of future questions. They may thus be preparing answers in advance and failing to listen to the argument or the discussion. Such practices may cause students to withdraw even more rather than to draw them out.

Seventh, to use questions to probe the students' personal feelings and experiences in the classroom is risky. This practice may make the student feel fear and resentment. Such questions ought to be saved for more private contacts in which the teacher and the student can talk together comfortably.

Alternatives to these practices can avoid these pitfalls. For example, the teacher could make a declarative statement rather than asking a question. This tactic can still present the problem or issue to the students and open up avenues for further discussion.

A second alternative to questioning would be to restate the speaker's words. Try to make a statement that interprets what the student has said, thus giving the class an opportunity to reconsider the information.

Third, declare your perplexity when you are confused by what the student has said. Simply state, "I am confused about what you are saying."

Fourth, invite elaboration. Use a statement such as "I'd like to hear more of your views on that."

Fifth, encourage class questions. In a discussion it should be possible for students to ask other students questions or to direct their questions to the person who is speaking, whether teacher or student.

Sixth, let the speaker pause and ask a question. This promotes discussion, indicates the speculative nature of the statements that are being made, and gives the student an opportunity to obtain feedback.

Seventh, simply maintain silence. Use a longer wait-time to indicate to the student that you are conducting a leisurely practice and you want to provide opportunities for reflection, introspection, and thoughtful answers.[2]

USING QUESTIONING IN A COMPETITIVE LEARNING STRATEGY

A useful technique that employs classroom questioning by the teacher has been described by a group of high school teachers in a Colorado school.[3] This approach is in the form of oral quizzing, which normally takes place once a week, usually during a Wednesday class period.

The rules for the oral quizzing are given in Figure 12–2. The numbers on the seating chart represent the average numerical grade the student currently holds. Each student has an equal opportunity to move upward from the C section to the B section to the A section by successfully answering teacher questions on the day of the oral quiz. The strategy has superior motivating potential as well as serving as an excellent mechanism for classroom control.

Advance planning by the teacher is necessary to ensure that questions give proper attention to higher levels of cognition. Teachers who have used this questioning strategy have reported excellent results and recommend its use to others. It is important to recognize that the competitive spirit is emphasized in this strategy, a fact that may cause some teachers to seek alternatives to its use.

WHEN: Any Day

SEATING:

76	83	88	94	100
75	82	87	93	99
74	81	86	92	98
73	80	85	91	97
72	79	84	90	96
71	78	83	89	95

RULES:
1. Students in A or B seats cannot use notes or text during quizzing.
2. Students in C seats can use notes and text.
3. The student to whom the question is being directed must answer quickly. When the instructor calls for the next person this student's turn is over.
4. By design the questioning must start at the top A with the first question.
5. For missed questions, the first student with the correct answer moves to where the question started. All the students in between move back one seat.
6. Tardy students or those who have been absent *for any reason* must move to the last seat in the last row.
7. Inappropriate behavior will also send a student to the last seat.
8. All students must keep track of where their earned seats are. If there is a dispute or someone forgets where to sit, he or she must move to the last seat in the last row.
9. Questions will *only be asked once*. Some questions may be clarified with the student asking, "What do you mean by ___________?"

GRADING:
1. Grades for earned seats will be recorded on Wednesday at the end of the period.
2. Oral quizzing grade will be used to replace the lowest test grade each quarter.

FIGURE 12–2 Oral Quizzing

RESEARCH ON QUESTIONING IN THE CLASSROOM

Questioning remains one of the most influential teaching behaviors in the classroom because of its potential in stimulating thinking and learning. The first major systematic research on questioning was conducted at Columbia University in 1912. Almost all the research conducted from that time until the 1950s focused primarily on describing teacher-questioning behavior. Results uniformly supported the finding that questions stimulating memory and recall were the type being emphasized in classrooms.

Around 1970, a new spurt of activity on teacher questioning began. The emphasis in this research was on identifying specific questioning levels and skills that have an effect on pupil growth.

Questioning is still regarded as an essential and influential instructional behavior. It is the most basic approach teachers use to stimulate thinking and learning in the classroom. Higher level questions produce situations of such complexity that their relative influence has not yet clearly been sorted out.

Fully functioning teachers almost certainly have educational objectives not only at the fact level but also at the concept level and even at the personal meaning and values levels. These objectives necessitate asking higher order questions of students. Teachers then need not determine whether to ask higher level questions but rather how to find an appropriate balance of lower and higher order questions to achieve instructional goals.

Much research has been done on the use of questions as a learning strategy. Questions in textual material have been defended on the basis that they provide advance organizers for the material to be learned. The use of questions at the higher levels of cognition (such as application, analysis, synthesis, and evaluation) has been shown to have a significant positive effect on student learning. Questions placed within the text material appear to produce better understanding and retention than text material without questions. And in a study on presentation style, groups of students reading material with questions at the beginnings of paragraphs scored higher on an immediate posttest than did groups reading without questions.

As a result of the research over the past seventy-five years, we can draw several tentative conclusions concerning questioning in the classroom.

1. Teachers appear to persist in asking questions that require students primarily to recall knowledge and information. It is important to consider stressing higher level questions and to devise a variety of instructional objectives that balance low-level memory questions with preplanned higher convergent and divergent questions.
2. Teachers can be effectively trained to raise the cognitive emphasis of their questions.
3. Cognitive levels of questions asked by teachers and responses from pupils tend to be positively related.
4. The extent of wait-time teachers use after asking questions dramatically influences the quantity and quality of pupil responses. Teacher educators need to provide training opportunities for teachers to practice increasing their wait-time to a minimum of three seconds.
5. At the primary level, the use of lower cognitive level questions tends to be related to pupil achievement. Teachers need to stress the importance of balancing low- and high-cognitive-level questions to stimulate productive thinking at all grade levels.[4]

Questioning in the Content Areas

Students in science classes experience general questioning techniques but also encounter questioning in the content of their science classes. The skills of formulating good questions in science and of seeking solutions to questions posed by their teachers, their textbooks, and their laboratory experiments are practiced and developed in the context of the science discipline being studied.

Research on reading and questioning in content areas is reported by Bonnie Armbruster and others.[5] Results showed that most questions were directly related to textbook material that was to have been read by the students in their assignments, and were largely questions on factual information. Only about 15 percent of the questions required students to analyze, predict, or apply information from the text. These questions came from only a small number of the teachers involved in the study, indicating that the use of higher level questions was somehow related to individual teaching styles. There was also a high percentage of rhetorical questions whose purpose was not clear other than perhaps to form a bridge to foster continuity in class discussions.

Gender Differences

Science educators are becoming increasingly concerned about gender differences with respect to expectations, types of experiences, and participation in science classrooms. Roberta Barba and Loretta Cardinale have investigated student-questioning interactions in secondary school science classrooms.[6]

Results of the study suggest that female students have fewer interactions with science teachers and receive less attention than males. Questions asked of female students were predominantly low-level questions. Males received more teacher interaction, including more questions of higher levels. These interactions seem to give females a signal that they have low ability in the sciences. It is also apparent that such behavior occurs before the secondary school level is reached, causing many females to believe that they are incapable of success in science.

Levels of Questions

Studies of teachers' classroom interactions indicate that 60 to 80 percent of teachers' questions require the lowest level of thinking for satisfactory answers.[7]

A practical questioning technique divides teacher questions into soliciting moves and reacting moves. Soliciting moves are categorized as

- recall questions that draw upon past experience or knowledge;
- data-collecting questions where students react to direct observations;
- data-processing questions, where students hypothesize, analyze, compare, or suggest solutions; and
- verification questions, where students evaluate or judge responses.

Reacting moves by the teacher involve

- accepting, or informing the student that the response is correct;
- rejecting, or informing the student of the incorrectness of the response;
- requesting clarification or further evidence; or
- asking another person.

Employment of the above strategies can raise the level of questions, provide opportunities to practice thinking skills beyond mere factual recall, and foster skills that support inquiry and investigative methods.

Development of effective questioning skills among students is as important as developing better questioning techniques among teachers. As science classes adopt more investigative learning and teaching methods, the ability to ask higher order questions becomes imperative. As with all learning, frequent opportunities to practice the desired skills results in greater improvement.

DISCUSSION AS A MEANS OF INQUIRY

An excellent model for leading a discussion is that of a clever talk show host. What is it that such a person does to stimulate the interesting, even exciting discussions that frequently are held on radio and television programs?

A number of clues can be found in the manner in which the host conducts the show—both in preparation and during the show itself. While each host is different, these are certain common elements. A good talk show host

1. studies the topic before the show,
2. presents an interesting background analysis before eliciting comments from the participants,
3. relaxes the guests,
4. avoids embarrassing anyone,
5. keeps the discussion moving at a good pace,
6. rewords any comments that might be misunderstood,

7. prevents anyone from monopolizing the discussion or going off on a tangent,
8. encourages the participants to speak about their feelings,
9. uses humor to reduce tension, and
10. asks good questions of a divergent variety.[8]

With these guidelines a teacher can conduct a similarly interesting discussion that will stimulate students to open up and participate. There is no dearth of interesting topics in science to bring up for discussion, particularly now that the interrelationships of science to technology and society are fair game in science classes.

Advantages of Discussion

Students become more interested when they are involved, thus discussion is a desirable approach for class procedures. Since an objective of modern science instruction is to teach science as a process, with an emphasis on the individual's cognitive development, students must have time and opportunities to think. A student can't think unless given opportunities to do so. The presentation of problems in a discussion requires students to think before they can formulate answers. A teacher who tells students all about a subject offers only boredom. In addition, the students have been robbed of an opportunity to use their minds. All they have to do is soak up information and memorize it.

Discussion is more likely to develop inquiry behavior. A discussion leader interested in developing inquiring behavior seldom gives answers but asks questions instead. In answering, students learn to evaluate, analyze, and synthesize knowledge. They are often thrilled to discover fundamental ideas for themselves.

Another bonus of discussion is that the teacher receives feedback. An astute discussion leader learns quickly from student comments about how much they understand. The leader then guides the discussion, moving it rapidly when students understand the information and slowing it down when they have difficulty. A lecture-oriented teacher seldom knows what students are comprehending. This teacher may concentrate on a point that the class understands or speed through information that confuses students. One of the greatest mistakes a beginning teacher can make is to assume that the lecture method will work well in a secondary school.

How to Lead a Discussion

Leading a discussion is an art that is not easily learned. There is nothing more exciting than to see a master teacher conducting an interesting and exciting discussion. How can you bring students to this point? Excellent class discussions do not just happen. Inexperienced instructors may think they will walk into a class and talk about a subject off the top of their heads. After all, don't they know more about the subject than the students? While it's true they may know about the material, they are faced with the problem of helping students discover information and develop their talents. This process requires as much preparation as any other class procedure. The first step in preparing for a discussion is to determine what it is you wish to accomplish—ask yourself, what are your objectives? Next, outline questions you think may help students to reach these objectives. Good discussion leaders use the "What do you think?" approach to learning. They ask questions such as those suggested in the section on questioning. For example:

1. Why did you do this experiment?
2. What did the data show?
3. Why did you use this approach?
4. How would you go about finding answers to this problem?
5. How else could you find the answer?
6. What good is this answer for your daily life?
7. What mental steps did you make in solving the problem?
8. How many variables were involved in the experiment?
9. How do you feel about science?

Spend Time Analyzing Thought Processes

Every discussion should stimulate critical and creative thinking. You should spend time analyzing the types of questions you will ask in a discussion to ensure that they require the exercise of these abilities. In this way you will indicate to your students a belief in their becoming more exciting persons. You will also contribute positively to their expectancy level of their critical thinking. Showing students that they are performing relatively sophisticated mental operations—inferring, hypothesizing, evaluating data, and so forth—will encourage them to accept that they can use their minds to derive answers to relatively complex problems. We come to believe that we are good thinkers only by being successful in thinking and by receiving feedback about our thinking abilities from others. Furthermore, teachers build positive student self-concepts when they involve students in tasks requiring thinking and show them how they are developing their minds. An actual inquiry discussion might follow these steps.

Present a problem such as, "What is the lifetime of a burning candle?" Encourage students to formulate hypotheses or give evidence. For example, say an apparatus is set up as follows: a burning candle is placed upright in a pan in which there is some water, and the candle is then covered with a glass container. Show how the experiment is set up by projecting a transparency of it on a screen. Some types of questions to ask are, What will happen to the candle when it is covered? What else will happen to the apparatus as this is done? What would happen if the candle were lengthened, the size of the jar above it were increased, or the amount of water in the container holding the candle were decreased? How would you find out?

After the students have progressed this far, have some student reflect back on what has been said and summarize the good points of the discussion. As a discussion leader, you might at times have to assist a student in doing this by repeating, "What was the problem?" Review the cognitive processes students used in solving the problem. Ask, "What hypotheses were made?" "What was the best hypothesis and why?" "How were the conclusions reached?" "On what are they based?" and "What is required to make better conclusions?"

Questions Must Be Directed at the Students' Level

A neophyte discussion leader often starts a discussion with too difficult a question. If there is no response to a question, the teacher should rephrase it to make it simpler. This procedure may have to be followed several times before there is a response. A question implies an answer. Similarly, if the question is too vague the students may not respond, and rephrasing it may give them some insight. Leading a discussion by questioning without giving answers is a skill that brings great satisfaction, but to be an astute questioner requires practice and a keen awareness of students' comprehension. By questioning correctly, the experienced discussion leader can guide students toward understanding the concepts and principles involved in the lesson or experiment. The questions must be deep enough to require critical thinking rather than a simple yes or no.

Eye contact is an important aspect in leading a discussion. A teacher's eyes should sweep a class, constantly looking for boredom, a student with an answer or a question, or one with a puzzled look. Eye contact gives the instructor feedback and motivates students to think and participate in the discussion. It also shows that you are more interested in the students than in the information being covered.

A Discussion Started in a Novel Way Gains Attention

A motivational technique useful in beginning a discussion is to start it with an interesting demonstration. A vial of blood placed on a demonstration desk can stimulate questions, leading to a discussion of blood or the circulatory system. Burning a candle can lead to a discussion of several scientific concepts and principles. A good rule to follow is to start a discussion with a precept or observation whenever possible. Not all discussions will lend themselves to this procedure, but those that involve the discovery of a concept almost always do.

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