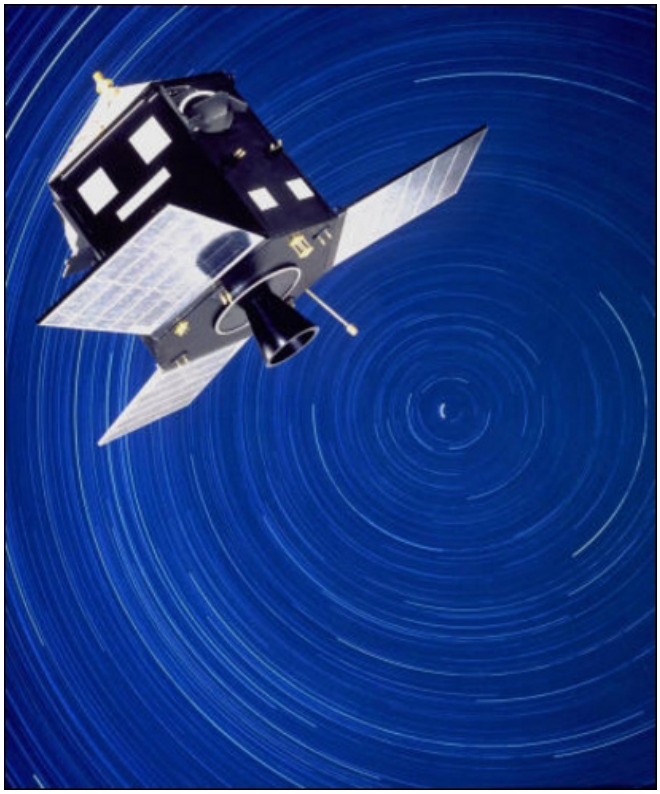
Planetarium Activities for Student Success

Planetarium Educator's Workshop Guide

by Alan J. Friedman,
Lawrence F. Lowery, Steven Pulos,
Dennis Schatz, and Cary I. Sneider

iNTERACT! PASS Classic

Cover photograph of the Whirlpool Galaxy in Canes Venatici (M51) courtesy Richard Bennion, Ewell Observatory, Belmont, CA. http://www.ewellobservatory.com.



The Hipparcos spacecraft was designed to find pinpoint positions more than one million stars and with exceptionally high precision for more than one hundred thousand stars. It's data, with parallax computations determined distances to those stars with unprecedented accuracy

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Planetarium Educator's Workshop Guide

Contents

Many planetarium educators from all over North America attended the trials of these workshop materials. These educators, and the host planetarium staffs, have given us invaluable suggestions and comments, and have designed activities which are included in this book. We hope that planetarium educators everywhere will consult those who participated in these first workshops so that the benefits of this program can be widely shared. Names and addresses of the initial workshop participants are listed the Appendix.

Acknowledgments

1980 Edition

In 1977, Project Director Alan Friedman of the Lawrence Hall of Science obtained support from the National Science Foundation to develop and implement workshops to share audience participation techniques with the planetarium community. The authors prepared a first draft of this workshop guide and presented five workshops during the summer of 1978, at Berkeley, California; Staten Island, New York; Cleveland, Ohio; Herndon, Virginia; and Dallas, Texas. Over 100 workshop participants suggested improvements that were included in subsequent drafts of this guide. The final version was published by the International Planetarium Society as *Special Report No. 10*, in 1980.

Many of the modules in this workbook are based on materials first developed by Lawrence Lowery for the University of California Teacher Preparation Project. Alan Friedman, Cary Sneider, and Steven Pulos of the Lawrence Hall of Science, and Dennis Schatz of the Pacific Science Center, Seattle Washington, adapted those materials and developed new modules expressly for planetarium educators.

The following staff members of the Lawrence Hall of Science Astronomy and Physics Education Project tested the first version of this workshop: Michael Askins, Bryan Bashin, Cynthia Carilli, Cathy Dawson, Gaylord Fischer, Stephen Gee, Mark Gingrich, Alan Gould, Cheryl Jaworowski, Tom Mathis, Bob Sanders, and Budd Wentz. Jill Kangas typed and typeset all of the printed materials, and with Larry Throgmorton, edited the final version. Illustrations and graphics are by Budd Wentz, with the assistance of Michael Askins. The NSF grant supporting this work was administered by Lawrence Hall of Science Associate Director Robert Karplus, Principal Investigator for this project. Alan Friedman was Project Director. Special thanks are extended to Alexander Barton and Linda Kahan of the National Science Foundation for their continuing encouragement and support.

The authors would also like to thank the following planetarium educators who contributed ideas and feedback to this workshop guide: Jeanne Bishop, Westlake Schools Planetarium, Westlake, Ohio; Jane Geoghegan, Thomas Jefferson Planetarium, Richmond, Virginia; Gerald Mallon, Methacton School District Planetarium, Norristown, Pennsylvania; George Reed, West Chester State College Planetarium, West Chester, Pennsylvania; and Sheldon Schafer, Lakeview Museum of Arts and Sciences Planetarium, Peoria, Illinois.

Hosts for the trial workshops were: Robert Risch and Jim Vickery, Jefferson County (Jeffco) School District Planetarium, Lakewood, Colorado; Tom Hamilton, Wagner College Planetarium, Staten Island, New York; Robert Andress, Warrensville Heights High School Planetarium, Warrensville Heights, Ohio; Rolfe Chandler, Herndon High School Area III Planetarium, Herndon, Virginia; Eloise Koonce, Richardson Independent School District Planetarium, Richardson, Texas; and James Rusk, Mesquite Independent School District Planetarium, Mesquite, Texas.

1990, 1993 Editions

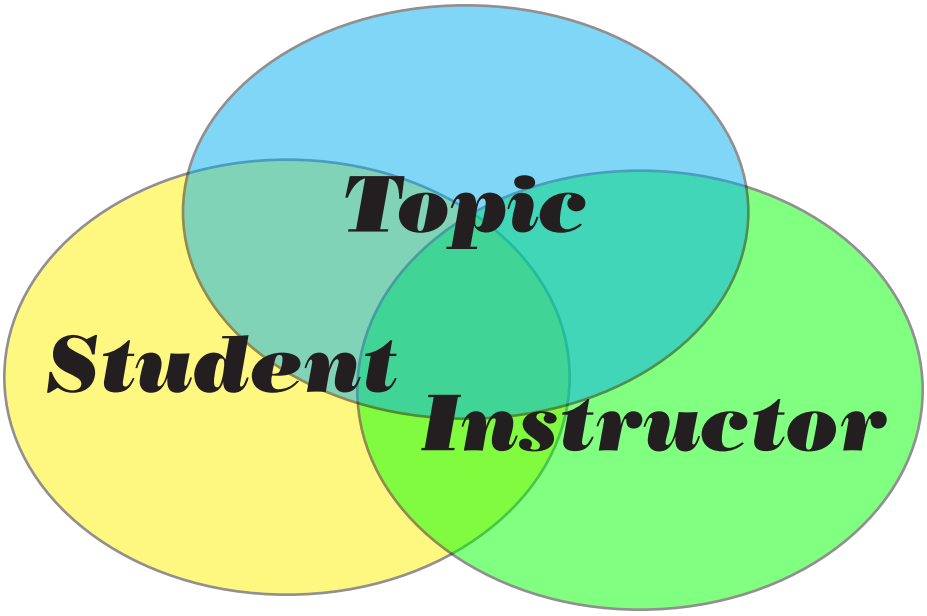
Grants from the National Science Foundation and Learning Technologies, Inc. enabled us to extend this work to the nation's schools, and to publish the *Planetarium Activities for Student Success* series. Project Co-Directors were Cary Sneider, Director of Astronomy & Physics Education at the Lawrence Hall of Science in Berkeley, CA, and Alan Friedman, Director of the New York Hall of Science, in Corona, New York. Staff members of the Lawrence Hall of Science who contributed to the series included: Lisa Dettloff, John Erickson, Alan Gould, John-Michael Seltzer, and Michelle Wolfson. Staff members of the New York Hall of Science who contributed to the series included: Terry Boykie and Steven Tomecek. Special thanks are due to our Program Officers at the National Science Foundation, Florence Fasanelli and Wayne Sukow.

We wish to acknowledge the assistance provided by our Advisory Board, who helped to plan this series, and who commented on early drafts: Gerald Mallon, Methacton School District Planetarium, Norristown, PA; Edna DeVore, Independence Planetarium, East Side Union High School Dist., San Jose, CA; Philip Sadler, Project STAR, Harvard Smithsonian Astrophysical Observatory, Cambridge, MA; Sheldon Schafer, Lakeview Museum of Arts and Sciences Planetarium, Peoria, IL; Robert Riddle, Project Starwalk, Lakeview Museum of Arts and Sciences Planetarium, Peoria, IL; David Cudaback, Astronomy Department, University of California, Berkeley, CA; and Joseph L. Snider, Department of Physics, Oberlin College, Oberlin, OH.

Perhaps most important are the approximately 150 individuals from around the nation who attended three-week institutes in astronomy and space science at Lawrence Hall of Science during the summers of 1989, 1990 and 1992. These educational leaders provided valuable feedback for their final revision. Their names and addresses are listed in the Appendix.

In addition, we would like to thank the staff of the 1989, 1990, 1992, and 1993 Astronomy and Space Science Summer Institutes: Joseph Snider, Terry Boykie, John Radzilowicz, John Hammer, Robert Jesberg, Jacqueline Hall, Dayle Brown, Alan Gould, Cary Sneider, Michelle Wolfson, John-Michael Seltzer, John Erickson, Lisa Dettloff, Kevin Cuff, Debra Sutter, Chris Harper, Kevin Charles Yum, John Hewitt, Edna DeVore, and David Cudaback.

Illustrations for Planetarium Educators Workshop Guide


Topic
Student
Instructor

Introduction

Perhaps our most powerful tool in capturing our students' imaginations is the planetarium. For at least a small part of their school day, our students can journey to the countryside and pick out familiar constellations against an inky black sky, or travel to Mars or a planet circling a red sun.

But the very power of the planetarium to whisk students through space and time poses a dilemma: How do we balance education with entertainment? Debate about where the balance point should be has been going on since the first planetarium program. Some school shows have been criticized as being too dull (all education) while others have been accused of flashy programs with no substance (light shows that are all entertainment).

This workshop has been developed by the authors and their many collaborators as a tool for enhancing planetarium education ***and*** entertainment for any audience and any occasion. Over the past several years we have found strategies for making science content more entertaining and simultaneously more meaningful. These strategies include techniques for selecting and arranging content and for actively involving the students in the planetarium program.

The Planetarium Educator's Workshop Guide is intended to be used by any group of educators who want to get together to experiment with new techniques for presenting astronomy and space science to students. This group of educators may be the staff of a school district that has a permanent or portable planetarium, or attendees at a teachers' conference or science institute. While an individual teacher may find the ***Guide*** useful, it is designed to be most effective (and most enjoyable) for a group of people who are willing to spend a few hours sharing ideas and challenging each other's assumptions. Tips for presenting a workshop are in Module 9, pages 81-88.

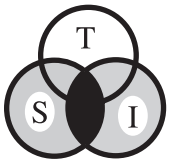
The goals of the workshop program are to enable you to:

- Select realistic goals and effective teaching techniques for particular groups of students.
- Involve your students in active investigations during planetarium programs, including public shows.
- Assess programs to find out which elements are working best in helping students learn from their planetarium visit.
- Help other teachers present classroom activities that complement and extend students' experiences in the planetarium.

While the authors of this workshop guide are enthusiastic about active ("participatory") learning in the planetarium, our purpose is not to prescribe any one technique for developing planetarium programs, nor to criticize poor techniques. Rather, the workshop modules present a variety of perspectives for viewing what occurs in a planetarium, and a number of specific, useful strategies for creating programs.

We welcome your comments on these guides and your suggestions for improvements.

Teachers who have the opportunity to use a planetarium have one of the happiest of professions. Almost all of us really enjoy what we do and believe that our work in communicating the excitement of astronomy and other sciences is important. We are chronically underbudgeted and overworked, but we have the opportunity to be scientist, teacher, actor, magician, and general ham to hundreds if not thousands of students a year.



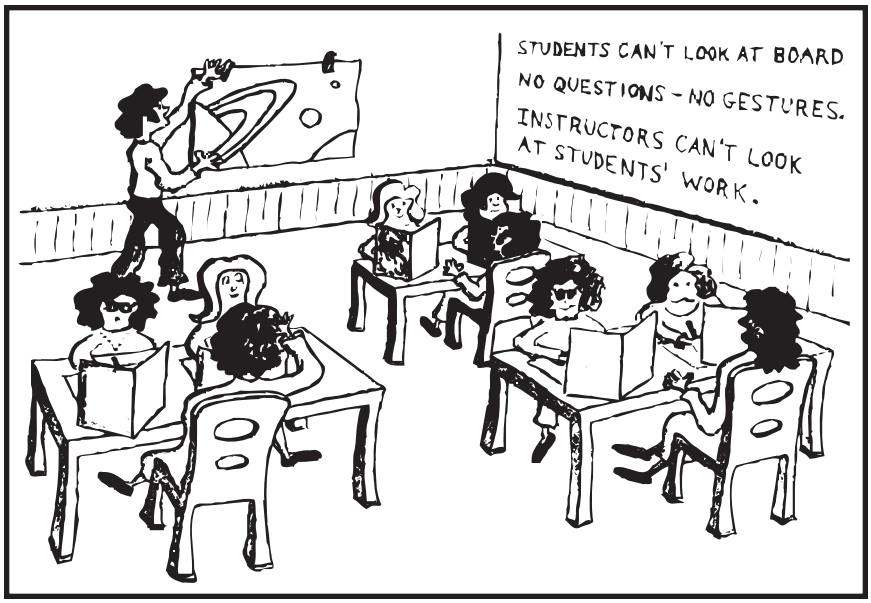
The goal of this activity is to provide an opportunity for you to switch roles with a student and experience three different teaching techniques, involving three different levels of interaction with an instructor.

Module 1: Communication

Here is a simple exercise that quickly leads to fundamental issues in planetarium education. Begin by separating workshop participants into groups of three. Each group selects one member to be an "instructor." The other two are "students," who sit facing the instructor. The workshop leader places a drawing so that only the instructors can see it. Each instructor's task is to describe the drawing so that the students, using paper and ink markers or crayons, can reproduce it as accurately as possible in three minutes. The instructors are asked to limit themselves to certain teaching techniques for each round of the game as described on the following page.

At the end of three minutes, instruction ends and the students can compare their work with the original drawing. Instructors and students discuss the difficulties they encountered in this task, and identify the teaching strategies that seemed to work best. For each round of the game a new drawing is placed on the wall, and the rules are changed slightly to permit different levels of interaction between the students and the instructor. You can also switch roles each round so that each person has the opportunity to play "instructor" and "student."

After each round of the activity, stop to discuss with the rest of the group the effect of changing the rules to permit more interaction between the students and the instructor. How does your ability to understand what is being communicated change? What instructional strategies become possible as more interaction is permitted? Jot down the insights which you feel are most important.



Insights:

Rules for round #1:

a) Use no gestures.

b) The students may not ask questions.

c) The instructor cannot see what the students are doing (a barrier is placed between their papers and the instructor).

Insights:

Rules for round #2:

a) Use no gestures.

b) The students may not ask questions.

c) The barriers are taken away so the instructor can see what the students are doing.

Insights:

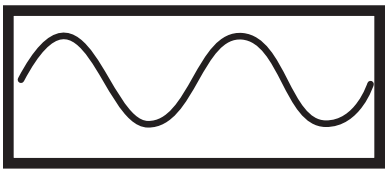
Rules for round #3:

a) Use no gestures.

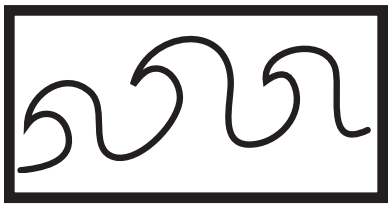
b) The students are permitted to ask questions during the activity.

c) The instructor can see what the students are doing.

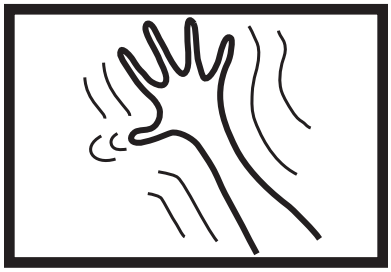
Instructor says: "A Wave."



Student 1 imagines: "A Wave."



Student 2 imagines: "A Wave."



Learning often takes place best when students have opportunities to express ideas and get feedback from their peers. But for feedback to be most helpful to learners, it must consist of more than the provision of correct answers. Feedback ought to be analytical, to be suggestive, and to come at a time when students are interested in it. And then there must be time for students to reflect on the feedback they receive, to make adjustments and to try again.

—*Science for All Americans*, American Association for the Advancement of Science, 1989, page 146.

This activity has proven to be a remarkably efficient (and fun) way to bring out most of the strategies good communicators use to get information across. For example, you'll probably notice that analogies are a frequent tool. Rather than trying to describe every detail of the drawing below, an instructor will often say "It's shaped like a wave." This strategy works well as long as the analogy is sufficiently close, and the learner has the same picture of "a wave" that the instructor has. That second condition is usually assumed by the instructor, but may be inappropriate. Students may imagine "a wave" to be quite different from what the instructor meant.

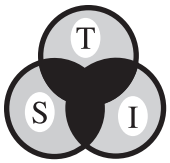
Interaction between the student and instructor like that allowed in Rounds #2 and #3 is essential to check such assumptions and may suggest the use of other analogies, or an entirely different strategy for communicating ideas.

This exercise itself is analogous to the problem of communicating an idea in your mind to your student's mind. Our exercise limits the idea to a simple line drawing which could be communicated in a planetarium by just showing a slide. But even pictures can be interpreted differently by instructors and students (see Module 4). Communicating more subtle scientific concepts, such as moon phases, the reason for day and night, gravity, or the nature of a black hole, requires the instructor to continuously check his or her assumptions about how the students are receiving the message.

The insights you can gain from doing this activity introduce the remainder of this workbook. In the modules that follow, we examine specific techniques planetarium educators can use to create accurate, enjoyable programs that allow you to communicate effectively with students.

Incorporating more interaction with students will be a constant theme. Every technique we discuss will have advantages and disadvantages, and we have no "surefire" guarantees to offer. Techniques that incorporate more student-instructor interaction are more effective communication tools than techniques that do not, but interaction does take time. The quality and quantity of communication must be balanced. We hope you will weigh the advantages and disadvantages of each technique presented in this workbook.

Module 2: A Framework for Examining Planetarium Programs

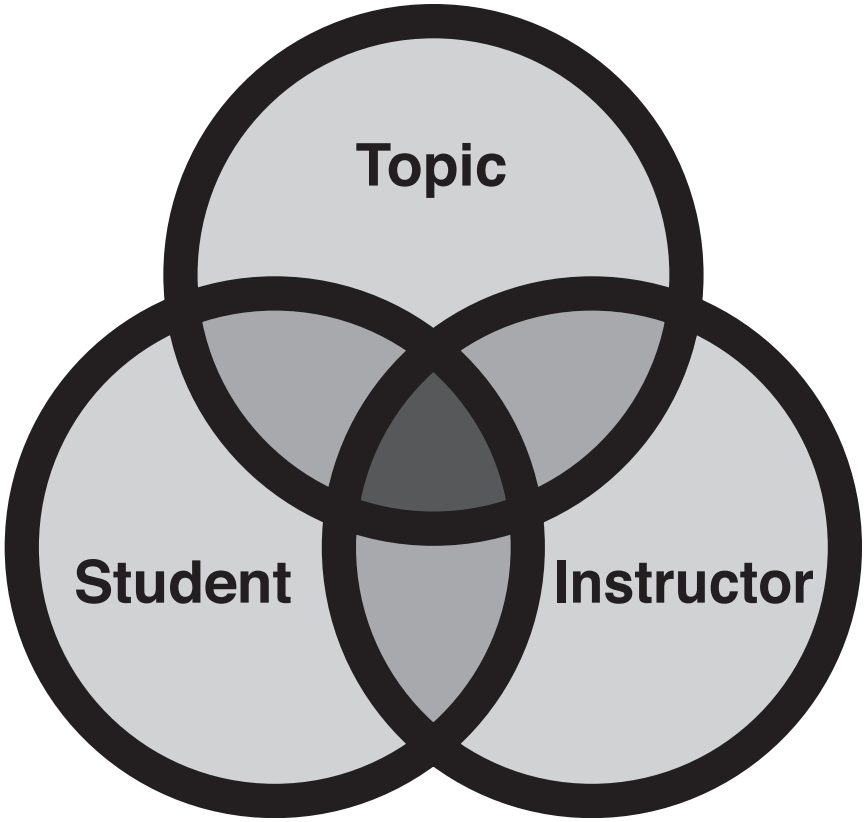


The goal of this module is for you to become familiar with one framework for examining planetarium programs. You'll try out this framework while discussing with other planetarium educators the kind of programs you'd like to present.

Every planetarium program experience can be thought of as a combination of three interrelated factors: The topic of the program, the student, and the planetarium instructor. These can be represented by three interwoven circles.

1. *The Topic*—The images, sounds, facts, concepts, skills, and attitudes that you wish to communicate to the student.
2. *The Student*—His or her background experiences, perspectives, interests and learning abilities.
3. *The Instructor*—All the strategies you use to communicate the topic of the program to the student. (The actual instructor can be a person or a machine.)

The framework of three interwoven circles suggests that effective education occurs at the intersection of all three circles. Considering all three aspects can help you create the most meaningful and enjoyable learning experience.



T The Topic

If you had to select only three topics to present in this year's schedule of planetarium programs for your school district, what would they be and why do you believe they are important?

Topic	Importance

S The Students

What are the most important things you should know about your students when planning a program for them? Why is this information important?

Info About Students	Importance

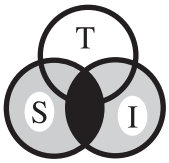
I The Instructor

Techniques	Importance

What are three of the most effective instructional techniques you have used? Why do you believe these are important in helping students learn?

In our trial workshops, we found great variety in the responses various planetarium educators gave to each of these questions, because the particular topics, students, and instruction techniques are different for each of us. Even with these differences, the following modules will help you match your own choices of topics and instruction techniques with your students for the best result.

Intersecting circle symbols next to the title of each module provide a helpful guide to the module's focus. Module 1, for example, stressed the interaction between the instructor and the students, so to the right of the title, intersecting student's and instructor's circles are shaded. The area of intersection is blackened to show that the interaction between these two factors is the focal point.



The goal of this module is for you to become aware of many different ways in which you can organize the planetarium experience for the students.

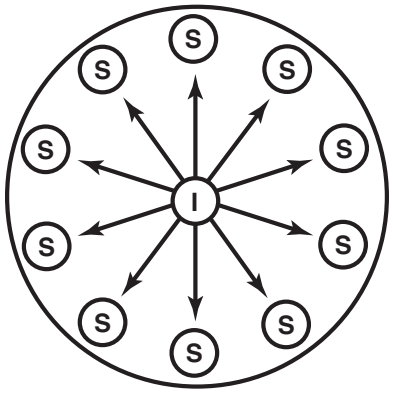
Module 3: Organizational Patterns

This section outlines a number of ways you can interact with your students in the planetarium. As you read about each pattern of organization, turn back to this page and list the advantages and disadvantages you see in each.

Each organizational scheme will be illustrated by using a section of an actual single-visit planetarium program.

Organization	Advantages	Disadvantages
Didactic		
Small Group Task		
Individual Task		
Informal Discussion		
Group Meeting		
Socratic		

Didactic Organization



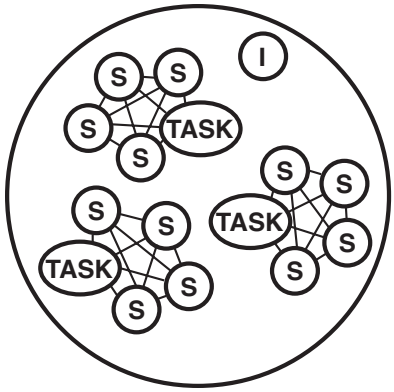
In this type of arrangement, you present material verbally and/or visually to the learners, without expecting any response from them. As the diagram illustrates, information flow in the didactic mode is entirely in one direction—from the instructor to the students.

Most completely taped shows are examples of didactic organization, as are live lecture-style shows in big planetariums.

A typical didactic presentation on constellations would feature the instructor telling constellation mythology, or describing to students how to find the Big Dipper.

Didactic organization is almost always a part of any planetarium program, even one which will feature audience participation, and student interaction with the instructor. What advantages and disadvantages do you see with this pattern? Record your views on page 8.

Small Group Task Organization



The whole audience is divided into small groups by row or seating section to initiate this organization. Each group is assigned a task to accomplish.

The small group task organization allows each student to interact with other students while working on a common task. Each individual has sufficient time to make his or her own contribution to the task solution.

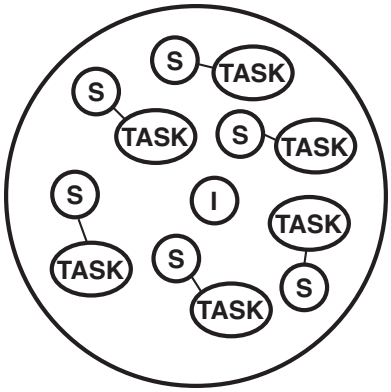
An example of the small group task organization may be found in the Holt Planetarium program "Constellations Tonight" (Volume 5 of the PASS series) in which small groups of students cooperate to find constellations in the planetarium sky. The students learn how to use a star map through a didactic approach, then work in groups of four or five to cooperate in finding an assigned constellation in the planetarium sky.

This organization has the advantage that students can easily help each other, providing mutual encouragement. The following suggestions may contribute to the success of small group organization patterns:

1. Be sure the task is clearly defined and understood.
2. Provide the necessary materials in advance.
3. Check on the progress of each group.
4. Hold to a realistic time schedule.
5. If possible, keep each group small, not more than five members.
6. Provide reports to the larger group when tasks are completed.

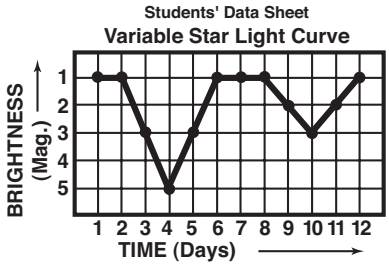
Turn back to page 8 and list the advantages and disadvantages of the small group organization.

Individual Task Organization



This pattern of organization enables each student to make his or her own observation, perform a unique role, or solve a problem. Each student becomes physically and intellectually involved in the subject you are presenting. Each individual can be engaged in a different task or each can be assigned the same task. With a small audience, this pattern allows you to move from person to person to provide information and assistance.

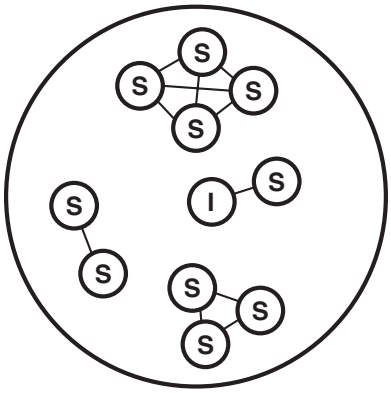
For example, the topic of variable stars can be presented at the middle school or high school level as an observing and recording task for the students to perform individually during the planetarium program. After a short didactic presentation of what variable stars are, and how amateurs provide useful scientific data on them, each student receives a clipboard, pencil, and sheet of graph paper. A "variable star" is projected onto the dome. Surrounding stars of constant brightness are labeled with numbers (via another slide projector) to show their magnitudes.



Each student estimates the brightness of the variable star and marks a dot on his or her graph to show that estimate. Each "night" a new point is plotted until the students have recorded the entire light curve of the variable star. Discussions follow this activity to interpret what the light curve might mean. (See Volume 2, Activity #9, of the PASS series for more details on this activity.)

Record your thoughts about the advantages and disadvantages of this organization scheme on page 8.

Informal Discussion Organization



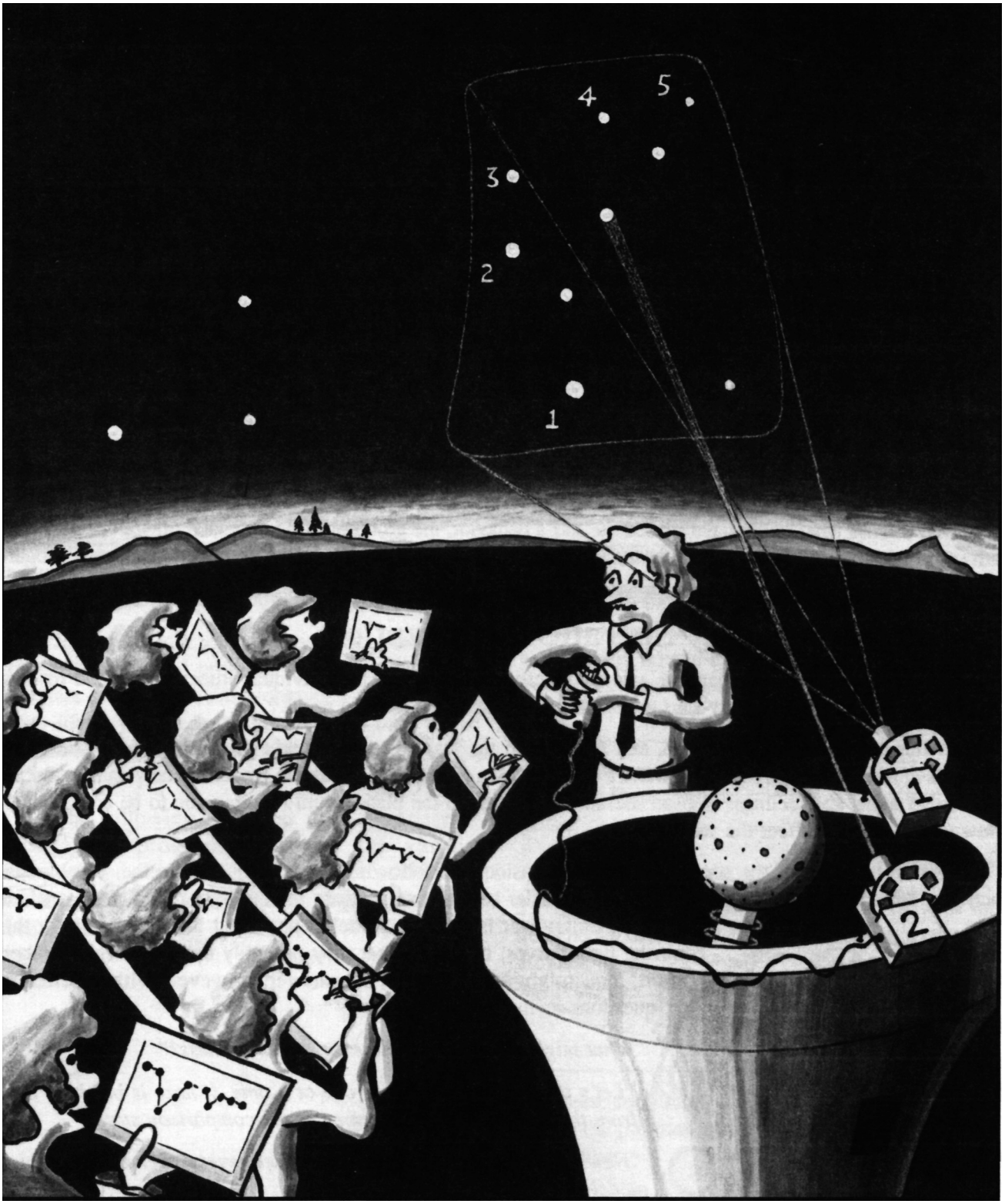
This pattern of organization allows free, uninhibited discussion by the students among themselves.

As instructor, your role is to listen to the students' opinions, and be ready to answer questions if asked. Since the students naturally break into informal discussions among themselves after any planetarium program, this behavior is often not considered an "organization" at all. However, conscious planning for student discussion during the program can make a very valid contribution to learning.

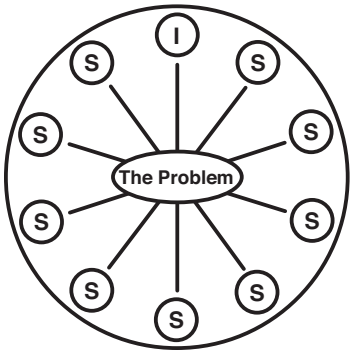
For example, this pattern is especially useful after an activity like the variable star task described above. Students are curious to see if they made the same estimates as their neighbors. The instructor can make this easier by explicitly suggesting that they take a few minutes to compare.

Informal discussion is particularly important if you are going to call on students to describe an observation to a large audience. Students are often shy and uncertain that they have observed correctly. Informal discussion permits them to confirm their observations with peers.

What are the advantages and disadvantages of this approach? Record your thoughts about this organizational scheme on page 8.



Recording the light curve of a variable star: an individual task activity



Group Meeting Organization

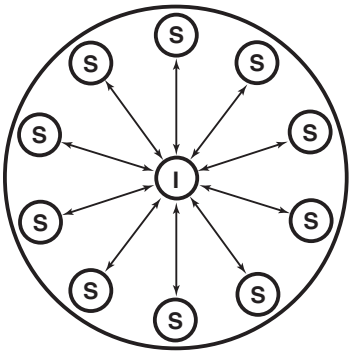
In contrast to the didactic organization which is instructor-centered, or the informal discussion organization which is student-centered, the group meeting is problem-centered.

This type of discussion generally works best when there is a problem to be resolved. The problem may be initiated by you or by the students. Your role is to facilitate the discussion and not to direct it. You may listen, call on individuals to speak, make suggestions, or appoint a member of the audience to lead the discussion. In any case, you must be prepared to go along with the group's decision.

For example, after the variable star activity described on page 10, this kind of discussion is a very good way of drawing together the students' observations of the variable star. The instructor might ask one of the students to lead a discussion for a while to decide: (1) How many dips in the brightness occurred? (2) When? (3) What was the minimum brightness? Individuals will have different answers, so the group task will be to reach a consensus about the best description of the variable star light curve. The instructor must work with each group's opinions.

What are the advantages and disadvantages of this approach? Record your thoughts on page 8.

To discuss what might have caused the star's behavior, the group meeting approach may work well with advanced students, but for most classes the instructor could try a Socratic method described in the next section.



Socratic Organization

In this pattern of organization, you frequently ask questions of individual students, respond to their answers, and lead them step-by-step to the particular ideas you have in mind. After posing the first question, and listening to the responses, you might probe further by asking the students to justify or clarify their answers. You might also refocus the discussion by adding new data, or asking for further ideas and feelings. A good socratic interaction in the planetarium requires you to be conscious of how your questions affect the students.

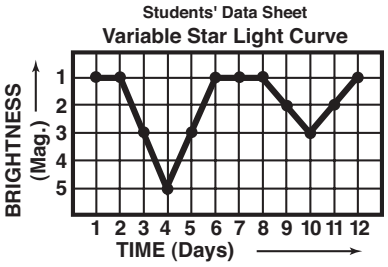
As an example of the socratic approach, consider the following way of concluding the variable star activity. Suppose you would like visitors to consider several explanations for the light curve, and conclude that an eclipsing binary star is the best model. You would like them to infer this from the light curves, but know that they probably cannot do this on their own. You might lead them to the answer, however, with a series of questions including the following:

> ***"What might have caused these dips in brightness?"***
>
> ***"Let's take those possibilities one at a time. If haze is blocking light from the star, what would happen to the comparison stars?"***
>
> ***"Now suppose I tell you both dips repeat every twelve days. Which model works best now?"***

A similar approach can be used for the students to consider the relative sizes of the two stars from the data they have recorded.

Record the advantages and disadvantages of this pattern of organization on page 8.

A Review of Organizational Patterns



As you look back over these six organizational patterns, notice how your role as planetarium instructor differs. In the didactic and Socratic patterns you decide which ideas are discussed. In the group meeting structure, you still control the flow of ideas, but the visitors have greater freedom to select the content. When the students are organized in small groups to discuss ideas or work on a task, you are free to wander from group to group and offer suggestions and assistance where needed. When each individual is working on a task, you can assist individuals as a personal tutor.

Examples of each of these strategies in the context of an actual program may be found in the complete scripts in PASS Volumes 5-8. You might enjoy identifying each of the strategies used in the scripts, or speculating on alternative strategies for each segment.

The following segments from a variety of planetarium programs illustrate the various organizational patterns. Please fill in the pattern that you think the instructor is attempting to initiate in each example.

1. "Overhead, you see a photo of the moon taken by the Apollo astronauts. What do you notice about these circular features? What shapes like these have you seen on earth?"

   _____ Organization

2. "Now I will show you some spectacular photographs of the moon, and explain what they tell us about how old the moon is, and how it was probably formed."

   _____ Organization

3. "This lamp will represent the sun. I want each of you to stand up and turn around, so the sun appears to rise and set for you."

   _____ Organization

4. "Work together in groups of three. Pick out a group of stars, and make up a story about some animal or person represented by those stars."

   _____ Organization

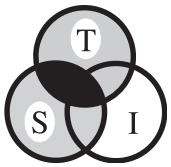
5. "Since many of you seem concerned with the tremendous cost of the Viking mission, let's take five minutes to discuss whether or not the mission was worth the cost. Who would like to express an opinion first?"

   _____ Organization

6. "Please feel free to come up to the console at the end of the program and ask whatever questions you would like."

   _____ Organization

Module 4: How the Students See It



This module offers a number of suggestions for 1) assessing your students' knowledge and reasoning abilities; 2) selecting concepts at the appropriate level for your students to learn; and 3) applying instructional techniques that are most likely to result in lasting conceptual change.

Most of us have noticed that some students have difficulty understanding certain concepts, no matter how careful we are in providing the correct explanations and no matter how many charts, diagrams, and slides we use.

Over the past decade, many educational researchers have studied such persistent misconceptions. For example, one study of 9th through 12th grade students from nine high schools in the Boston area showed the following results on a basic test of astronomy concepts.[1]

1. **Why does the moon have phases?** 62% of the students believed it had something to do with shadows of the Earth or Sun. Only 36% of the students correctly understood that phases result because the Moon moves around the Earth.
2. **Why do we experience summer and winter?** 43% of the high school students knew that seasons had something to do with the tilt of the earth. Interviews showed that the most common misconception was that "Summers are warmer than winters because the earth is closer to the sun in summer than it is in winter."
3. **How long does it take the Earth to go around the sun?** Only 52% gave the correct answer of one year. 30% of the students knew that it takes about a month for the Moon to go around the Earth, and only 10% of the students were aware that the moon turns on its axis once a month.

Many researchers believe that one reason why people have such difficulties learning basic astronomy concepts is that people construct their own meanings based on a combination of new learning experiences and what they already believe when they enter the classroom or planetarium. Since in this view a student's knowledge prior to a lesson is so important, it is very helpful to give students an opportunity to discuss what they believe **before** studying the subject further. That helps the teacher understand the students' starting points, and alerts the students that theirs is not the only point of view.

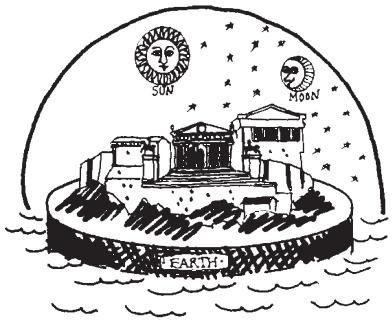
Other researchers emphasize that common learning difficulties occur because people's reasoning abilities develop at different rates.[2,3] Since in this view a person's developmental level is thought to be very important, it is helpful to select different objectives and different kinds of learning experiences for young students than for older (or more intellectually advanced) students.

Both of these factors—prior learning and development of reasoning abilities—are valid and useful in many situations. In this module you will use both viewpoints as you learn about ways to assess students' readiness for learning new concepts, to select realistic educational objectives for planetarium and classroom lessons, and to plan instructional strategies that are likely to be successful.

1. Sadler, Philip M., "Misconceptions in Astronomy," Harvard Smithsonian Center for Astrophysics, in *Proceedings of the Second International Seminar on Misconceptions in Math and Science* (J. Novak, Ed.), Cornell University, 1987.
2. Schatz and Lawsen, "Effective Astronomy Teaching: Intellectual Development and It's Implications," *Mercury*, July, 1976.
3. Schatz, Dennis, et. al., Effective Astronomy Teaching and Student Reasoning Ability: A Self-Paced Workbook, Lawrence Hall of Science, 1978. (Out of print.)

A. Do Students Have Theories?

If you ask your students about the shape of the earth, most would say it is "round." But several researchers have found that many students have a very different meaning of "round earth" than is intended by their teachers.[4, 5, 6, 7, 8]



Thales' idea of the world in 500 B.C. "The earth is like a cork bobbing in the sea."

Interviews of elementary and middle school students showed that some students thought of the earth as a "circular island people can sail around," or that the round earth is a "planet in the sky, where astronauts go." Many of those who understood that the earth is shaped like a ball were puzzled about why people did not fall off the bottom of the ball. To resolve this problem, some thought that people lived just on top of the ball, or on the flat part in the middle. Some of these ideas were similar to models of the earth suggested by natural philosophers, thousands of years ago.

Some educational researchers have argued that children's ideas—like their concepts of the earth's shape and gravity described above—are consistent and systematic, and deserve to be called "theories." Others have argued that children's ideas are fragmented, and lack the systematic and consistent qualities that we usually think of when we think of scientific theories. Some interesting studies were conducted by Vosniadou and Brewer [9, 10, 11, 12, 13, 14] to settle this debate.

On vacation in Antarctica, Mr. & Mrs. Smith experience odd gravitational effects.

The method used by Vosniadou and Brewer was to interview students individually concerning their ideas about the Earth's shape, gravity, day and night, as well as the movements of the sun, moon, and stars. They interviewed 20 first graders, 20 third graders, and 20 fifth graders. Building on the earlier research studies, the researchers confirmed that students held a variety of ideas, or "mental models" about the Earth's shape.

Most common among the first graders were what they called "initial" models of the Earth as a flat disk or rectangle, just as it appears to be. Older children developed more elaborate "synthetic" models when they tried to synthesize their

4. Nussbaum, J., and Novak, J., "Children's Conceptions of the Earth as a Cosmic Body: a Cross-Age Study," Science Education, vol. 63, no. 1, 83-93, 1979.
5. Sneider, C. and Pulos, S., "Children's Cosmographies: Understanding the Earth's Shape and Gravity," *Science Education*, vol. 67, no. 2, 205-221, 1983.
6. Sneider, C., Pulos, S., Freenor, E., Porter, J., and Templeton, B., "Understanding the Earth's Shape and Gravity," *Learning 86*, vol. 14, no. 6, February, 1986.
7. Lightman, Alan and Sadler, Philip, "How could the Earth be Round?," Harvard-Smithsonian Center for Astrophysics, submitted to *Science & Children*, October, 1987.
8. Sneider et. al., *Learning 86*, op. cit., p. 17.
9. Vosniadou, Stella, and Brewer, William F., "Theories of Knowledge Restructuring in Development," *Review of Educational Research*, Spring 1987, Vol. 57, No. 1, pp. 51-67.
10. Vosniadou, Stella, "Knowledge Acquisition and Conceptual Change," *Applied Psychology: An International Review*, 1992, Vol. 41, No. 4, pp. 347-357.
11. Vosniadou, Stella, and Brewer, William F., "Mental Models of the Earth: A Study of Conceptual Change in Childhood," *Cognitive Psychology*, Vol. 24, pp. 535-585.
12. Vosniadou, Stella, "Universal and Culture-Specific Properties of Children's Mental Models of the Earth," in *Domain Specificity in Cognition and Culture*, Edited by Hirschfeld and Gelman, Cambridge University Press, in press.
13. Vosniadou, Stella, and Brewer, William F., "Mental Models of the Day/Night Cycle," *Cognitive Science*, in press.
14. Vosniadou, Stella, and Brewer, William F., "Constraints on Knowledge Acquisition: Evidence from Children's Models of the Earth and the Day/Night Cycle," unpublished manuscript.

initial ideas with what they were told in school about the globe. For example, a synthetic model would be the idea that there are dual Earths—the flat one we live on, and the ball-shaped planet called Earth in the sky. About half of the fifth graders expressed more "scientific" mental models, that the Earth is shaped like a ball, with people living all around it.

Analyzing the remaining questions, Vosniadou and Brewer found that no matter what mental model of the earth children held, 80% to 85% of them applied their model consistently when answering questions about the movements of the sun, moon, and stars, or why we experience day and night. They conclude from this that it is not enough for teachers to just tell their students about the globe, and explain phenomena the "correct" way, but rather to help them change the fundamental ideas on which their theories are based, so that they can develop new, more adequate theories.

Students' Theories About Gravity

Many teachers are familiar with the idea, expressed by many students, that there is no gravity in space "because there is no air there." These students see astronauts floating around in the space shuttle cabin and conclude that there must be no gravity there because it is above the atmosphere. It's also common for students to say that there is no gravity on the moon, and that astronauts can walk slowly on the moon because their space suits are so heavy.

A recent study by Bar, Sneider, and Martimbeau[15] has shown that these misconceptions are common among 6th graders, but that most students at this age can learn that gravity acts through space, beyond Earth's atmosphere. During the 50-minute class, the students made predictions about the path that a ball would follow when it rolls off a table, then did the experiment to see the actual trajectory. They discussed how the ball tends to keep going straight, but that gravity curves its path and pulls it downwards. They then saw a series of transparencies of the whole Earth, with a huge mountain. A cannon on top of the mountain fired a cannonball, and the students predicted how it will move with low force, medium force, and very high force. They saw the cannonball eventually go into orbit. They discussed its path, observing that the cannon ball would tend to go straight, but that gravity pulls it into a circle. They then viewed transparencies of a space shuttle and the moon in orbit around Earth. When asked why these bodies don't just go straight, they realized that the same force must be at work here too—gravity must be acting across space, to curve their paths into an orbit.

The students' written answers to the question, "Does gravity act in space where there is no air?" before and after this class indicate that many (though not all) students have changed their minds, and that more students come to understanding the scientific view of gravity. The data from this study is shown in the following chart.

15. Bar, Varda, Sneider, Cary, and Martimbeau, Nathalie, "Does Gravity Need Air?" unpublished manuscript, Lawrence Hall of Science, University of California, Berkeley, CA 94720, March, 1993.

"Does gravity act in space where there is no air?" (N=48)

Sixth Grade Student Responses	Pre-test	Post-test
Yes.	13	23
No.	31	10
Not much.	0	3
Only near planets.	0	4
No answer, or I don't know.	4	8

The Earth, Moon, and Stars—One Approach to Teaching

Earth, Moon, and Stars is a 65-page Teacher's Guide in the series Great Explorations in Math and Science (GEMS), developed at the Lawrence Hall of Science. Designed for middle school students in grades 5-8, the activities require about a month of science activities, and are aimed at helping students to improve their mental models of the earth and its place in space.

The first activity asks the students to imagine that they lived thousands of years ago when people believed that the earth was flat; and to imagine how they might have explained how the sun returns to the eastern part of the sky every morning, after setting in the west the previous night. By asking the students to construct models, like those constructed by many ancient cultures, the teacher is inviting the students to consider a wide range of possible models for the Earth. The emphasis is on using models for creative problem solving, rather than finding any "correct" model of the earth.

In the second activity, the students answer a questionnaire much like those asked by researchers who were investigating students' actual ideas about the earth's shape and gravity. "If the earth looks flat, why do people say it is round?" "If you could look straight through the Earth, which way would you point to see people in far-off countries like China or India?" and so on. After answering the questionnaire individually, the students share their ideas while the teacher acts as a facilitator, taking care not to label any particular idea as correct. The students act as a community of scientists, identifying their points of agreement and disagreement, and considering the logical consequences of alternative theories. The teacher eventually explains the viewpoints of Aristotle and Newton, but not before the students have had a chance to clarify their own theories, and encouraged to decide for themselves what makes most sense.

The next two activities in the *Earth, Moon, and Stars* unit are about the moon. The students observe the moon's phases for about two weeks, taking care to note its relation to the sun on each occasion. They then model the Earth-sun-moon system using their heads as the Earth and a lamp for the sun. Each student receives a white ball for the moon. They see how to model night and day, and the moon's phases and eclipses from the geocentric point of view. This is not a *demonstration* by the teacher, but a *simulation* conducted by the students, to refine their own mental models of the Earth, and to use those models to explain phenomena that they have observed in the sky.

What Are Your Students' Ideas?

In the last two activities the students make star clocks, identify constellations, and observe how they change their places in the sky during the early evening. By again simulating the earth's spin, they see how the motion of the stars can be explained by the motion of the ball-shaped earth turning on its axis.

To find out your students' ideas about the earth's shape and gravity, hand out copies of the questionnaire on the next page, from the second activity of *Earth, Moon, and Stars*. Collect their questionnaires and classify their responses according to the instructions on page 22, entitled "Levels of Understanding About the Earth's Shape and Gravity." Give each student a separate score for the concept "Earth's Shape" and for the concept of "Gravity." Then, use the bar graph at the bottom of that page to create a "profile" of your students' ideas.

If many of your students have not developed scientific concepts of the earth's shape and gravity, you may want to teach the entire *Earth, Moon, and Stars* unit, or some other activities to communicate these basic concepts. After the unit you can find out how much they learned by giving them the same questionnaire again, a month or so after they have completed the unit. Make another copy of the scoring instructions to create a profile of their ideas *after* the unit. Compare the two profiles to see how your students have changed their ideas.

Do not be disappointed if your students do not all advance to higher levels of understanding right away. Learning that the earth beneath our feet is really a huge ball in space is not an easy concept; and many people learn this gradually after many experiences like those in the *Earth, Moon, and Stars* unit. Our understanding continues to deepen over time. You can feel very proud if the class profile has shown some movement from lower to higher levels of thinking on one or both of these important concepts.

As a way of getting started, you and some of your colleagues may wish to make copies of the questionnaire and answer the questions yourselves, before looking at the "astronomer's answers" on the following pages. The last question is challenging for many adults, so discussing your alternative answers to this question could be a lot of fun, and would give you a very good idea of how your students will feel when they start to clarify and modify their own mental models of the earth as they discuss their answers to these questions.

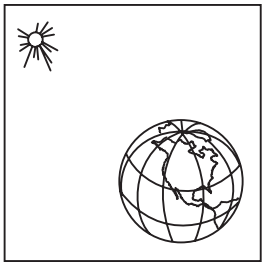
Name _____ Date _____

What Are Your Ideas About the Earth?

QUESTION 1: Why is the Earth flat in picture A and round in picture B?

(Circle the letter in front of the best answer.)

A



B

A. They are different Earths.

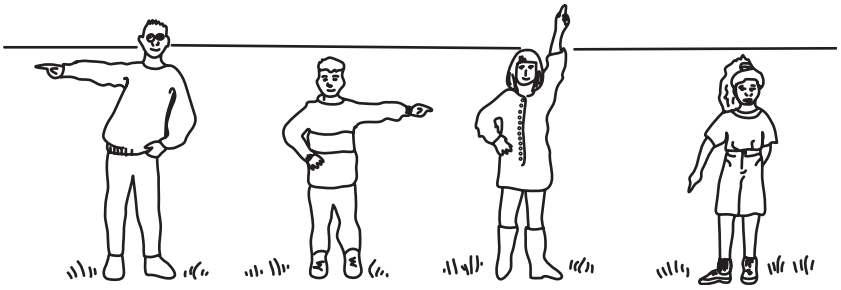
B. The Earth is round like a ball, but people live on the flat part in the middle.

C. The Earth is round like a ball, but it has flat spots on it.

D. The Earth is round like a ball, but looks flat because we only see a small part of the ball.

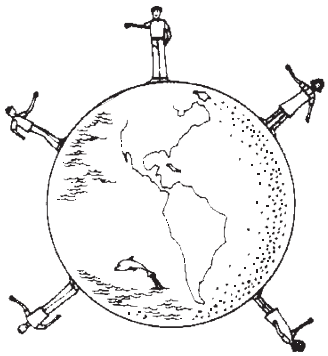
E. The Earth is round like a plate or record, so it seems round when you're over it and flat when you're on it.

QUESTION 2: Pretend that the Earth is glass and you can look through it. ***Which way would you look, in a straight line, to see people in far-off countries like China or India?***

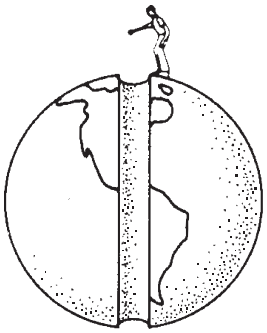


A. Westward? B. Eastward? C. Upward? D. Downward?

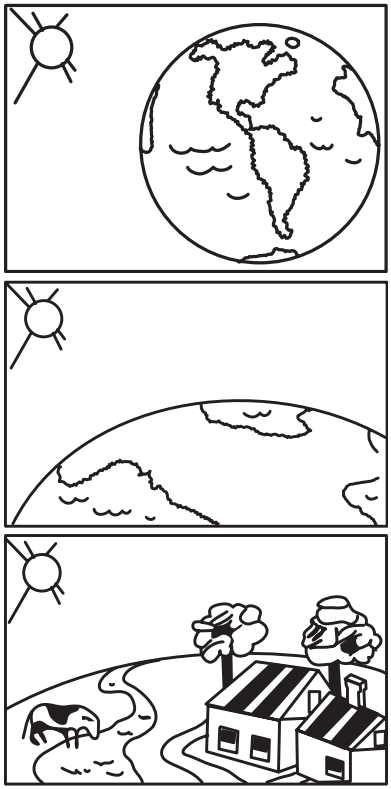
QUESTION 3: This drawing shows some enlarged people dropping rocks at various places around the Earth. ***Show what happens to each rock by drawing a line that demonstrates the complete path of the rock, from the person's hand to where it finally stops.***



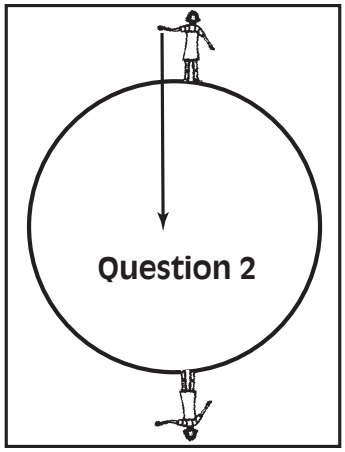
QUESTION 4: Pretend that a tunnel was dug all the way through the Earth, from pole to pole. Imagine that a person holds a rock above the opening at the North Pole. ***Draw a line from the person's hand showing the entire path of the rock.***



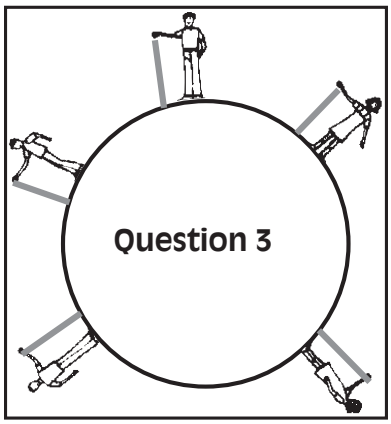
Modified and adapted from the February issue of *Learning 86*, copyright 1986, Springhouse Corporation.



Question 1



Question 2



Question 3

The Astronomer's Answers

Following are answers to the questionnaire that might be given by an astronomer. Also included are suggestions for leading a discussion. Whether the discussion is among teachers or students, it is best to wait until they have discussed all of the questions before providing them with "the astronomer's answers."

Question 1. The astronomer's answer would be "D." The Earth is round like a ball, but looks flat because we only see a small part of the ball." You can expect some variation in elementary students' ideas on this question since it requires a correct understanding of the part-to-whole relationship between the "flat ground" of our everyday experience, and the "ball-shaped Earth" that we learn about in school. This reasoning skill typically develops during the early elementary years, but understanding such a relationship is much easier if illustrated with a physical object, such as a large weather balloon.

Question 2. The astronomer's answer would be: "D." Downward." When first confronted with this question, most people try to imagine which direction they would fly in a plane to get to China or India, and will answer "eastward" or "westward." Ask your students to imagine that the Earth is made of glass and that they can look straight through it. You might also use a globe and ruler to show what happens if you look due east or west: the ruler (representing the way you would look) points off into space.

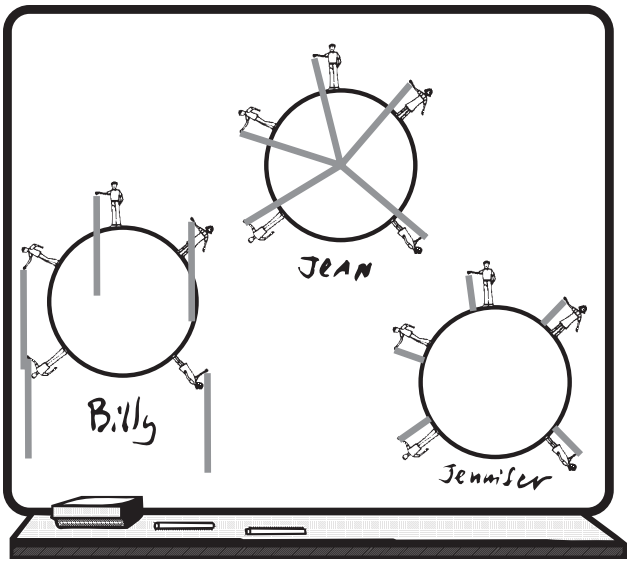
Question 3. To help the students discuss their answers to this question, draw three or four large circles on the board, each with figures holding rocks as shown on the questionnaire. Invite students to come up to the board to draw their answers. The pictures of three or four alternative views will help you focus the discussion on which answer is best.

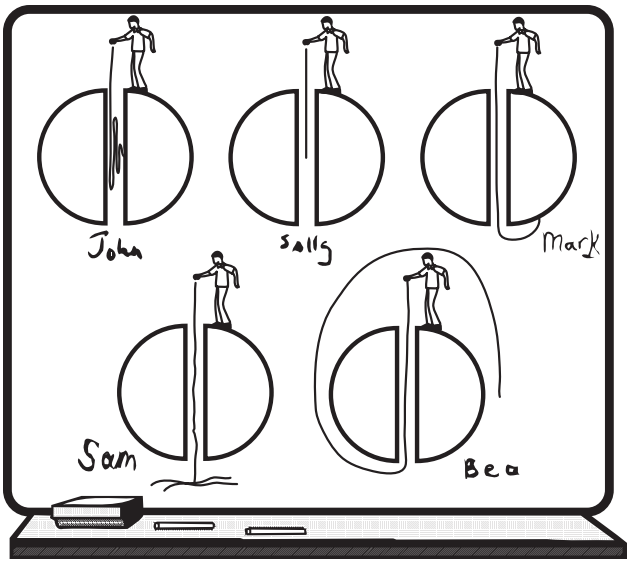
The astronomer's answer would show each rock falling straight down, towards the center of the Earth, landing next to the person's feet. It is common for students to show the rocks falling off the Earth, to an absolute down direction in space, or to compromise the two views by showing the rocks falling at an angle. Some students show the rocks falling all the way to the center of the earth, which would be true if the Earth were made of Jello!

At some point in the discussion, you may need to explain why "down" is always toward the center of the Earth. Ask your students to think about the people who live all around the ball-shaped Earth. The only way to explain why these people do not fall off is to imagine that "down" is toward the center of the Earth. To demonstrate this idea, turn an Earth globe so that the South Pole is "up" and ask the students to imagine being there. People on the South Pole must think that people in the Northern Hemisphere live upside-down!

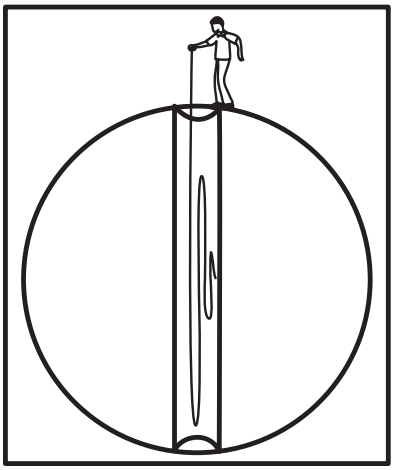
Question 4. This one stumps many adults! Again, it is helpful to draw several circles on the board, showing the figure and tunnel. Invite students to come up and draw their answers until several different ideas are represented. Then lead a discussion about them. Take a final vote on each of the ideas represented on the board, before presenting the astronomer's viewpoint.

The best way to explain how an astronomer would answer it is to explain the history of the concept of gravity. When the ancient Greeks came up with the idea of a ball-shaped Earth, they had to explain why people who lived on the



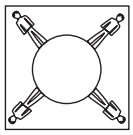
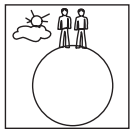


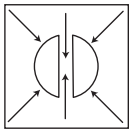
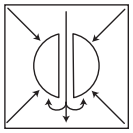
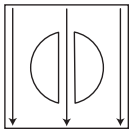
other side of the world didn't fall off. Aristotle, who lived about 2,300 years ago, thought that everything went to its "natural resting place" in the center of the universe, which he believed to be at the center of the Earth. If Aristotle had filled out the questionnaire, he would have drawn a line to the center and stopped there.



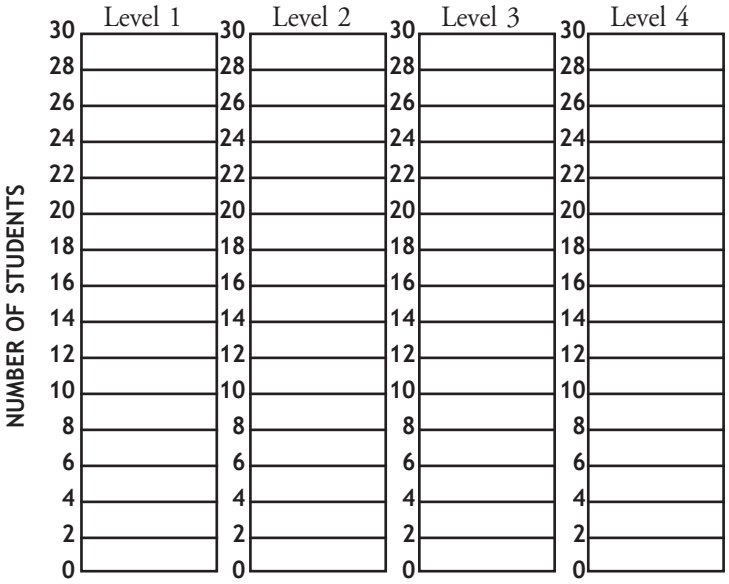
That idea was revised "only" about 300 years ago by Isaac Newton, who believed that the rock falls because of a pulling force which acts between all particles in the universe. Every particle within the Earth pulls on every particle within the rock. He named that force **gravity**. From the rock's point of view, "down" is always toward the greater mass of the Earth. Before it reaches the center, the rock keeps going faster and faster because it is still falling "down." It only starts slowing after it passes the center, because then the greater mass of the Earth is behind it. If Isaac Newton were to fill out the questionnaire, he would draw the rock falling back and forth between the two poles of the Earth until air resistance finally slowed it down. Eventually, it would settle in the exact center of the Earth, suspended in the middle of the tunnel.

Levels of Understanding About the Earth's Shape and Gravity

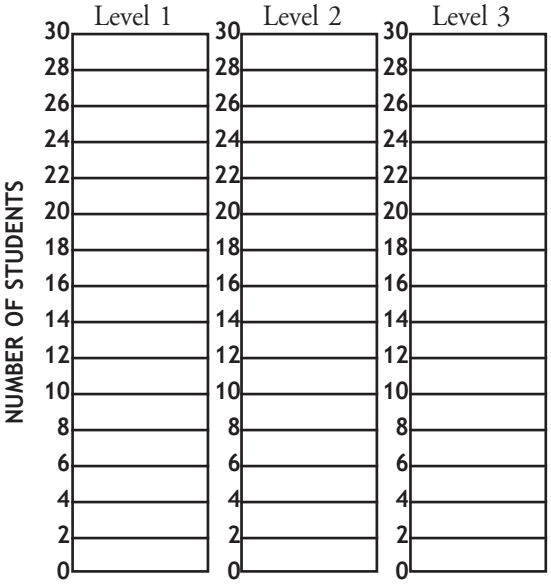
Earth's Shape	Definition of Each Level	How to Classify Answers	Number of Students
 SHAPE LEVEL 4	The Earth is shaped like a ball, and people live all around the ball.	QUESTION 1: Answer D and QUESTION 2: Answer D.	
 SHAPE LEVEL 3	The Earth is shaped like a ball, but people live just on top of the ball.	QUESTION 1: Answer D and QUESTION 2: Answers A, B, or C.	
 SHAPE LEVEL 2	The Earth is shaped like a ball, but people live on the flat parts of it (or inside the ball).	QUESTION 1: Either Answer B or C.	
 SHAPE LEVEL 1	The Earth is flat.	QUESTION 1: Either answer A or E, or no answer at all.	

Gravity	Definition of Each Level	How to Classify Answers	Number of Students
 GRAVITY LEVEL 3	Objects fall toward the center of the Earth.	QUESTION 3: Rocks are shown falling straight down to the surface of the Earth, near each figure's feet, and QUESTION 4: The rock is shown falling toward the Earth's center, where it either falls through and bobs up and down, or stops in the center.	
 GRAVITY LEVEL 2	Objects fall toward the surface of the Earth.	QUESTION 3: Rocks are shown falling straight down to the surface of the Earth, near each figure's feet, and QUESTION 4: The rocks do not end up in the Earth's center. (They may be shown passing all the way through the earth, sticking to the Earth's surface, or taking some other path.)	
 GRAVITY LEVEL 1	Objects fall down in space.	QUESTION 3: Rocks are shown falling straight down to the surface of the Earth. (They may be falling down to the bottom of the page or shooting at some other angle around the planet).	

Class Profile—Earth's Shape



Gravity



B. Frames of Reference

As discussed in the introduction to this module, some researchers have emphasized the development of students' ideas or theories. The authors of the *Planetarium Educator's Workshop Guide* agree that this point of view is very useful in designing good programs for students because it helps us to remember that students always come to our programs with their own ideas about the universe. A very important part of our jobs is understanding what our students already believe, so we can help them construct new, scientific theories about the earth, planets, stars, and galaxies, and the other topics of our planetarium programs.

We also believe that the other factor—reasoning abilities that develop as a child matures—are equally important. For example, in order to understand that the earth looks flat because it is just a small part of a very large sphere, the students need to be able to change their frame of reference, from the viewpoint of a person on the surface, to the viewpoint of an astronaut, looking at the earth from space. Development of this skill takes time. The *Earth, Moon, and Stars* unit is written for 5th-8th graders because we can be reasonably certain that students in this age range have developed this reasoning skill.

In the remainder of Module 4 we'll consider several reasoning abilities that are critical for students to develop in order to understand many important topics in astronomy. We'll begin with a reasoning ability to consider a situation from multiple frames of reference.

We often project pictures of models and diagrams onto the dome: the earth as seen from space, the earth, sun, and moon as seen from above the plane of the ecliptic, and so on. To learn some of the ways students may interpret such diagrams, begin by solving the problem on the next page.

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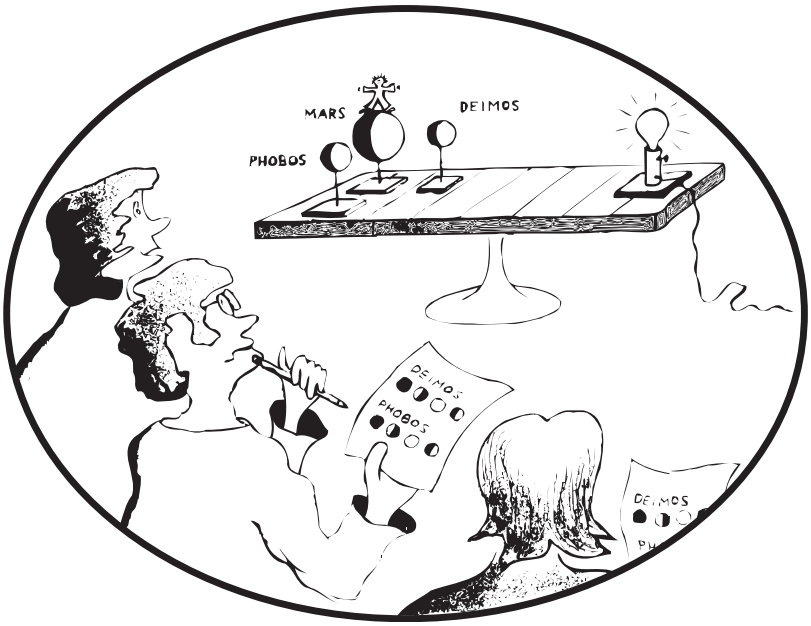
The Martian Moon Problem

"Deimos and Phobos, the two moons of Mars, have phases just as our moon has. Please look at the model and determine what phase each moon is in for the person who is observing from the surface of Mars. Circle your response."



Deimos

A B C D

Explain how you figured out your answer.

_____

_____

_____

_____

Phobos

A B C D

Explain how you figured out your answer.

_____

_____

_____

_____

Examine the following answers to the Martian Problem given by college students. Then, answer the two questions at the bottom of the page and compare your results with other individuals in the workshop.

Phobos Problem

Student #1 Answer:

"B" Explanation: "I imagined myself on the surface."

Student #2 Answer:

"B" Explanation: "My point of view—I just reversed what I saw."

Student #3 Answer:

"B" Explanation: "Put myself on Mars in my imagination."

Student #4 Answer:

"D" Explanation: "Observing shadows on models."

Student #5 Answer:

"D" Explanation: "Moon is moving towards sun."

Student #6 Answer:

"D" Explanation: "Because Phobos is in the direct sunlight and not in front of Mars."

1) **Identify the differences in thinking between the first three students and the last three students.**

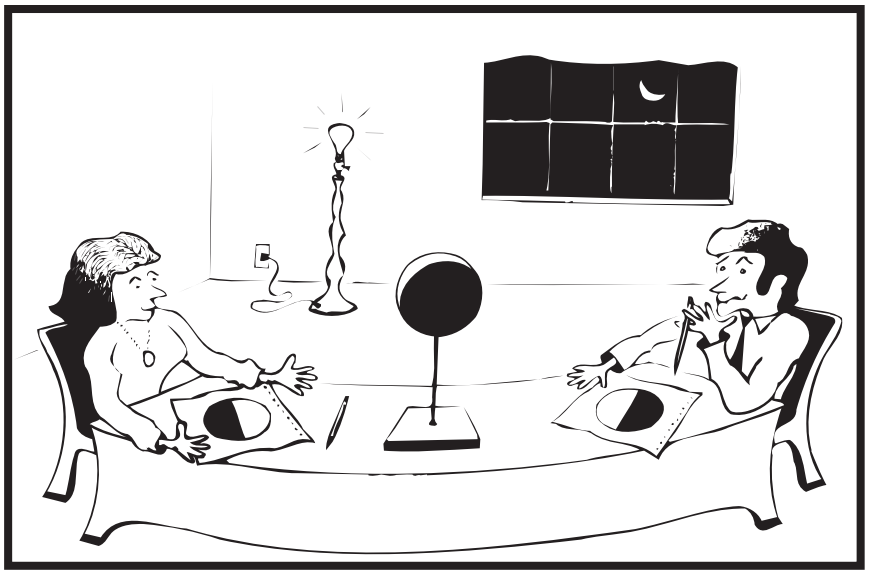
2) **Suggest several concepts that are traditionally introduced in the planetarium that may be difficult for the last three students.**

One of the most useful perspectives for appreciating how students understand the planetarium program has emerged from a half-century of research pioneered by Swiss psychologist and epistemologist Jean Piaget and his colleagues.[15] These investigators have studied how people solve problems like the Martian Moon Problem.

Piaget noted distinct differences in people's abilities to perceive a situation from a point of view different from their own. In our example, the three individuals who gave correct answers and explanations to the Martian Moon Problem could perceive this unfamiliar setting by imagining themselves in a different frame of reference. In contrast, the other three individuals' thinking was dominated by what they saw directly from their own frame of reference, or by information not relevant to the problem.

Piaget discovered that some students who were not able to figure out problems like the Martian Moon Problem simply by thinking about them were able to find solutions through concrete experiments. For example, two students who were confused by the Martian Moon Problem could be seated facing a ball representing the moon, which is illuminated by a "sun" (light bulb). They would then be asked to draw the "moon" exactly as they see it. When they compare drawings, they will see that their views of the moon are reversed. They may also change seats to see if their partner really observed what he or she drew. Now, some individuals will be able to apply this concrete experience to successfully solve the Martian Moon Problem. Others will again give only what they see from their own point of view for an answer.

According to the approach taken by Piaget and his colleagues, these differences in ability to perceive a situation from a different point of view indicate three levels of intellectual development. An individual who cannot perceive that



15. Many books are available by and about Jean Piaget. Readers may wish to consult: The Child's Conception of the World, Piaget, J., Paterson, N.J.: Littlefield, Adams, 1960; The Child's Conception of Space, Piaget, J., and Inhelder, B., New York: Norton, 1967; Understanding Intellectual Development, Rohwer, W., Ammon, P. and Cramer, P., Hinsdale, IL: The Dryden Press; and The Origins of Intellect: Piaget's Theory, Phillips, J., San Francisco: W.H. Freeman & Co., 1969.

there is a different point of view from his own is operating at the **egocentric level** (also known as the intuitive level). "Egocentric" here should not imply selfishness, merely that a person at this stage assumes that everyone sees the same thing he or she does. If direct experience with concrete objects and events, such as a model, helps a person to accept a different viewpoint from his own, then he or she is operating at the **concrete level.** Finally, if the person can imagine a different point of view just from looking at a diagram or hearing a description, she is operating at the **formal level.**

In general, young children operate entirely at the egocentric level. Beginning about age 8 or 9, many children can perceive a different point of view through concrete experiences. The potential for formal level thinking does not appear until sometime during high school. (See Frames of Reference table.) Piaget also developed categories to describe the behavior of younger children, but we will not describe these categories in this workshop.

Although a person's general reasoning ability may be sufficiently advanced to permit understanding a point of view different from his own, he will not always achieve that understanding. Whenever the situation is too complex, or the subject matter is unfamiliar, even adults begin at the egocentric level. This pattern is evident in some of the college students' responses to the Martian Moon Problem.

It is usually necessary to ask the students questions during a program to find out how they are understanding the content of the program. If you find that the students are operating at the egocentric level, you may decide to present the topic from the students' point of view. It may even be necessary to abandon the attempt to communicate a particular concept altogether in favor of other concepts that can be readily communicated egocentrically or concretely in the time available.

Frames of Reference
Egocentric Level (starts about age 4) — Can imagine only one's own point of view.
Concrete Level (starts about age 8 or 9) — Can imagine another viewpoint, but only after a concrete experience.
Formal Level (starts about high school age) — Can imagine a situation from different points of view.

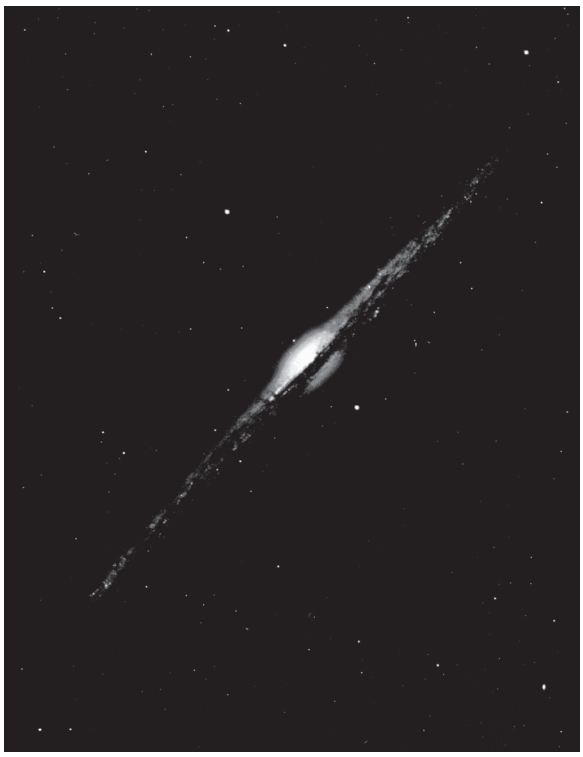
1) Turn back to the cartoon on page 23. At what level is the Wizard reasoning in the second frame?

   At what level is he thinking in the last frame?

2) Based on the reasoning levels summarized in the "Frames of Reference" table (page 27), examine the astronomical concept illustrated below, and suggest a strategy for communicating this concept to a concrete level planetarium visitor.

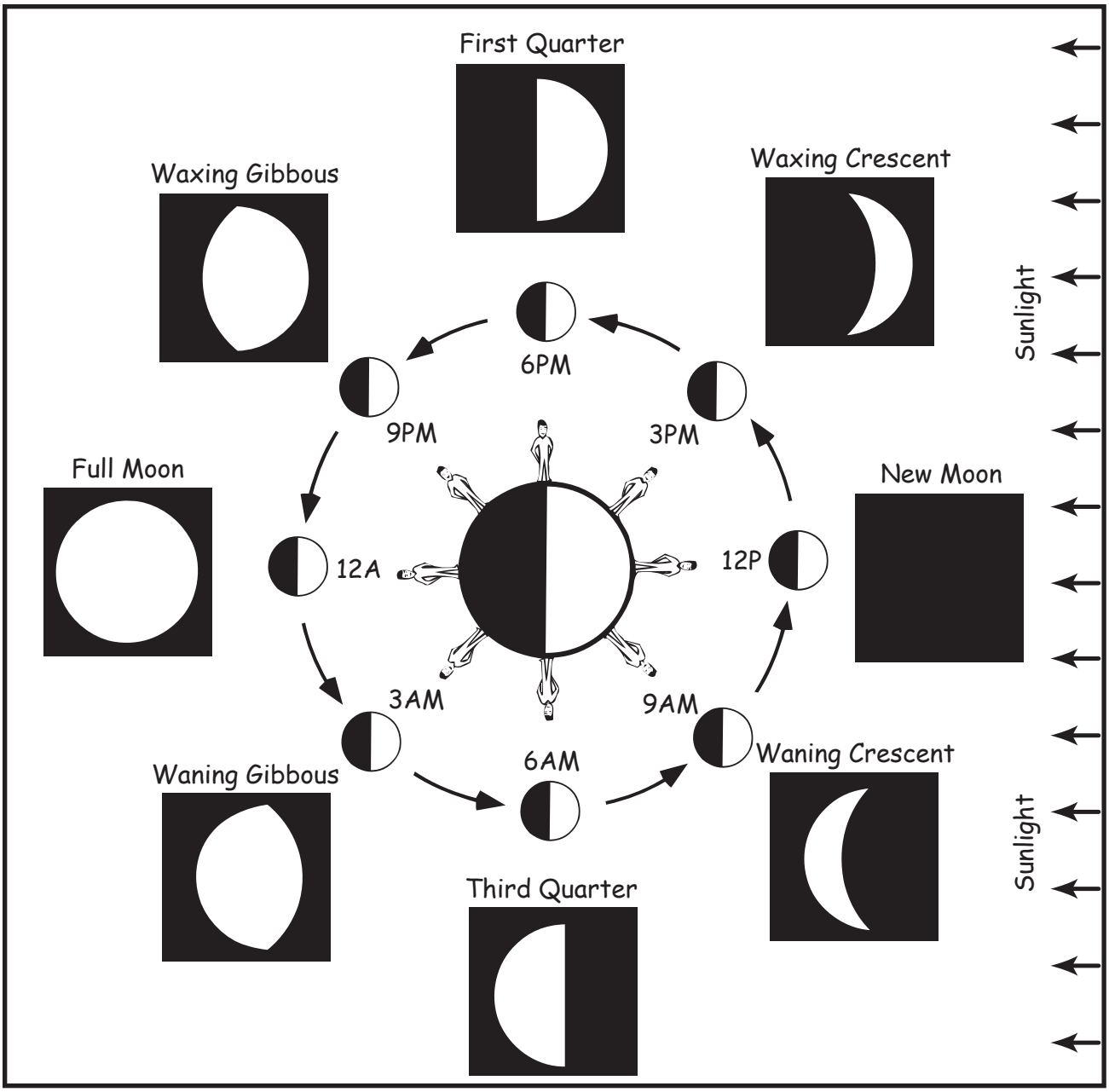
   CONCEPT: The two galaxies in these photographs actually have the same spiral shape. However, the galaxy shown at left is viewed from the side, and the galaxy on the right is viewed from above (or below).

   Recommended Strategy:



(Photographs courtesy of Lick Observatories.)

In many astronomy textbooks, diagrams like the one below are used to explain the phases of the moon.



What level of reasoning is required to understand this diagram?

Explain your answer.

Scientific Explanation Skills

Egocentric Level (starts about age 4)—Commonly attributes motives and purposes to inanimate objects, or assumes all phenomena are produced by human actions for human purposes, e.g. "The sun comes up so we'll feel warm."

Concrete Level (starts about age 8 or 9)—More complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations, e.g. "The sun does not always rise in the east and set in the west because I have a compass and found it set in the southwest."

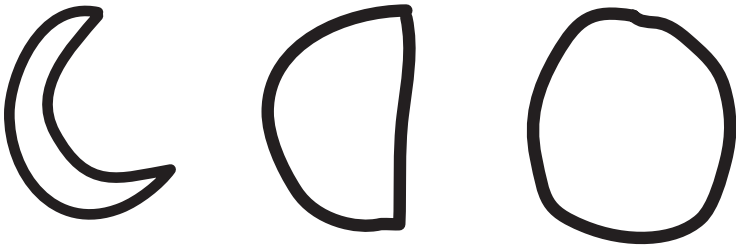
Formal Level (starts about high school age)—Can extend explanations to predict new observations and objectively compare one's own explanations with alternatives, e.g. "If the earth is really closer to the sun in the winter, the difference must not be very great, or it would be hotter in the winter than in the summer.

C. Scientific Explanation

Planetarium instructors frequently provide explanations of physical phenomena: why there is day and night; why the moon goes through phases; why the stars shine; and so on. Again, we can divide ability to solve problems requiring scientific explanations into egocentric, concrete and formal level responses. A summary is given below.

The distinction between the levels given in the "Scientific Explanation Skills" table (left) is illustrated by children's answers to the following problem. Begin by writing your own answers.

A teacher asked her students to draw what the moon looked like. Some students drew it as shown on the left, others drew it as shown in the middle, and still others drew the moon like the picture on the right.



Are these pictures all of the moon? If yes, then explain why the moon has different shapes at different times.

Now consider the following responses to the same question by some school children. How do their notions of a "scientific explanation" differ from your own?

Joe, 8 years old.

Interviewer: How can you explain these different shapes, Joe?

Joe: It divides itself in different shapes....

Interviewer: Does it ever put itself back together again?

Joe: In the daytime. In the nighttime it divides itself again.

Interviewer: Why is it that you can only see this part (pointing to crescent) or that part (pointing to half disk) at a time?

Joe: Cause it's been divided up.

At what level of reasoning is Joe's answer? _____

Explain. _____

Tina, 10 years old.

Tina: Something like its our planet or another planet covering half of it or the sun or something covering parts of it... Yeah, our planet.

Interviewer: How does our planet get up there in the sky?

Tina: Well, like I'm looking at it cause the shadow of the earth is on that part of it.

Interviewer: In this picture (pointing to half disk) where do you think the shadow of the earth is?

Tina: There is no moon like that.

Interviewer: You've never seen a moon like this?

Tina: There's no such thing as that kind. It can only be curved, because the planet's round and the moon's round so the planet can't be straight on one side to do that.

What level of reasoning is Tina's answer? _____

Explain. _____

Herbert, 13 years old.

Herbert: Because at different days, like a quarter moon, full moon, half moon, just changes its position.

Interviewer: How does changing its position change its shape?

Herbert: Cause, all right, if it spins around a kind of fog or mist can get on this part, and it will sort of look like a quarter moon....

Interviewer: How does one side get light and the other side get dark?

Herbert: Maybe cause reflections can't see the dark side, the sun, but reflections can see the light side.

Interviewer: On here (pointing to the full moon) where is the dark side?

Herbert: In back.

Interviewer: In this picture (pointing to crescent) where do you think the sun is?

Herbert: Over in this direction. Like the sun is right here and it's showing that part (indicating correct position of sun).

What level of reasoning is Herbert's answer? _____

Explain. _____

Derek, 9 years old.

Derek: Because every month the moon, the clouds come over half of it. And then when the moon is full there's no clouds around it. In a year then it goes back to normal.

Interviewer: Do the clouds stay that way all night? Or do they move around so you see it all different ways in one month?

Derek: No, it stays that way for a month.

What level of reasoning is Derek's answer? _____

Explain. _____

Young people can learn most readily about things that are tangible and directly accessible to their senses—visual, auditory, tactile, and kinesthetic. With experience, they grow in their ability to understand abstract concepts, manipulate symbols, reason logically, and generalize.... The difficulties many students have in grasping abstractions are often masked by their ability to remember and recite technical terms that they do not understand. As a result, teachers—from kindergarten through college—sometimes overestimate the ability of their students to handle abstractions, and they take the students' use of the right words as evidence of understanding.

—*Science for All Americans*, American Association for the Advancement of Science, 1989, page 146.

The students' responses are typical of a large number of interviews recorded at the Lawrence Hall of Science. They are also quite similar to the views expressed by children in the same age groups that were reported by Piaget fifty years ago. Since many of those interviewed in our study reported learning about the moon in school and at museums and planetariums, and could list dozens of facts about space explorations, their failures to provide adequate explanations for the phases of the moon cannot be attributed to lack of exposure to the correct concepts.

Joe's explanation illustrates a mode of reasoning common to the egocentric level child. Egocentric explanations attribute motives and purposes to inanimate objects or assume all phenomena are produced by human actions for human purposes. Because the child has intention and purpose, he assumes everything else has these attributes as well. This mode of thinking is called "animism."

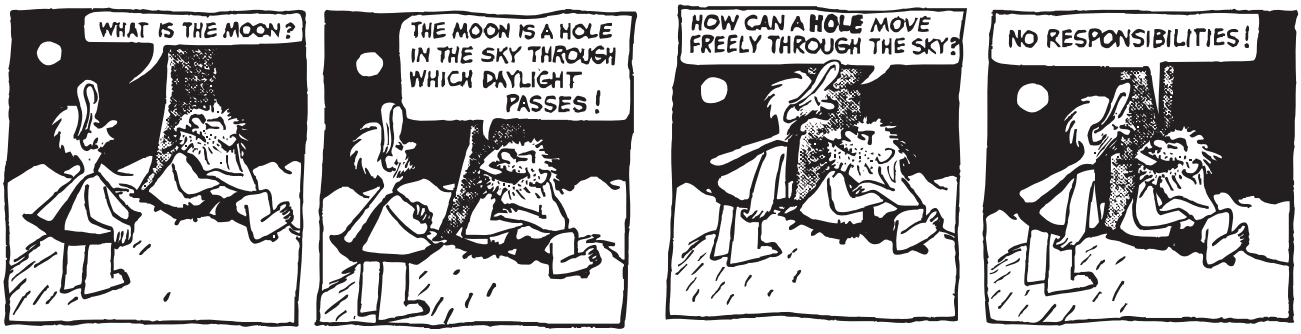
Tina begins with the idea that something is covering up the moon and quickly proceeds to an explanation which involves the Earth's shadow. It is possible that she recalls learning about lunar eclipses and is confusing that explanation for phases of the moon. When Tina realizes that her explanation doesn't fit the straight shadow on one of the moon pictures, she rejects the picture as a fabrication! Thus, her prior understanding of moon phases affects her ability to observe as well as explain what she sees.

Herbert seems to have the right idea from the very beginning when he claims that the moon "just changes its position." However, when asked to explain his ideas more fully he at first slips back to an explanation like that given by Derek, in which fog or mist covers the moon to cause the phases. Then he switches back to the more advanced explanation involving reflected light coming from the sun. Furthermore, Herbert demonstrates that he can visualize the relationships by correctly explaining where the sun must be in order to produce the lunar phase that we see. These more complex relationships are concrete level explanations.

Derek's explanation is more advanced than Joe's since it involves only natural phenomena. However, like Joe, he accepts a simple association as an adequate explanation. Since many children have noticed clouds covering things like the sun and moon, it is not surprising that this explanation is common among children of this age. Like Joe, Derek extends this idea to invent an explanation, but has little concern for the need to reconcile new observations. What is important for Joe and Derek is that their explanations make sense from their own points of view, indicative of egocentric reasoning.

In summary, students' abilities to observe and explain what they see depends on their level of development **and** on their prior understanding of the phenomenon.

Please examine the following cartoons and determine at what level the explainer is operating.



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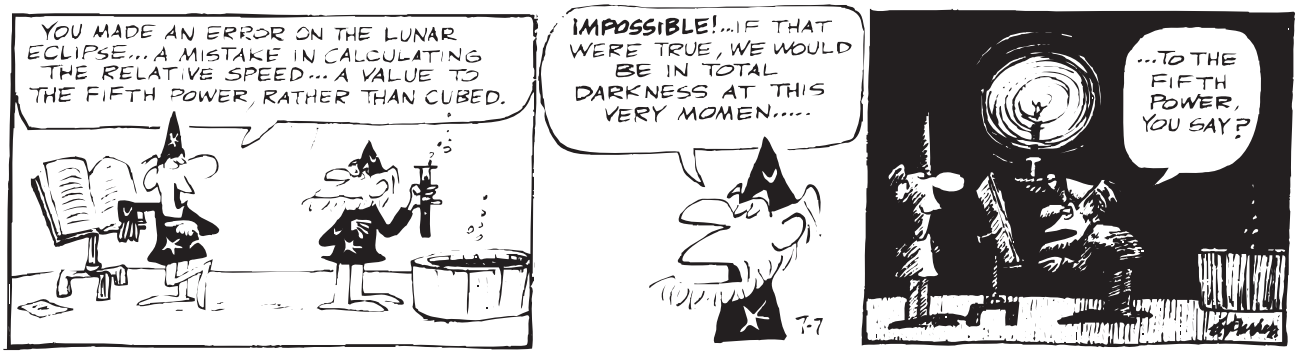
Level (egocentric, concrete, or formal) Please explain your answer.



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At what level is the Wizard on the right operating in the last frame? Please explain your answer.

D. Classification Skills

Classification Skills
Egocentric Level (starts about age 4) – Can notice similarities and differences, and can only classify after much trial and error.
Concrete Level (starts about age 8 or 9)–Beginning with classification by a single trait, can later recognize that objects may belong to more than one class, and can arrange objects along a continuum.
Formal Level (starts about high school age)–Can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy.

A great deal of the information that we present in the planetarium requires the students to understand how certain information is arranged and how it relates to other information; for example, classifications of stars and planets; and differences between nebulae, star clusters, galaxies, and subclasses of these objects. How do students perceive our descriptions of the way these objects are classified?

Children at the egocentric level can attend to only one aspect of a situation at a time, so they cannot systematically classify a large number of objects. They can, however, notice if two objects are similar or different.

When encountering a new set of objects, a person who is capable of operating at the concrete level begins by perceiving similarities and differences. Then he or she may be able to separate these objects into several groups according to shape, color, or some other single trait.

A number of additional classification skills develop throughout the concrete stage. These skills include the ability to sort according to a single trait, to arrange objects along a continuum (from big to small, hot to cold, etc.) and to recognize that an object may belong to more than one class (e.g. realizing that our Sun is also a star, or that Earth is in the solar system and in the galaxy at the same time).

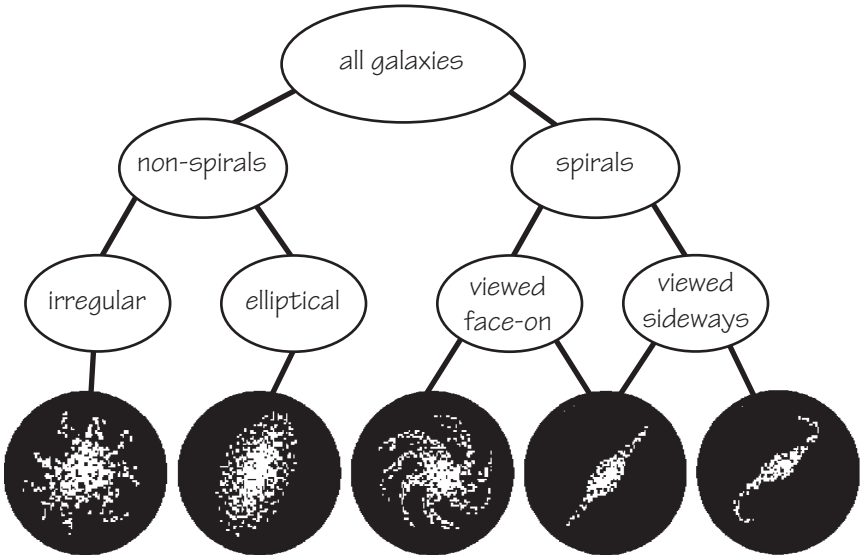
Constructing hierarchies of classes and then rearranging the objects into different hierarchies is a formal level classification skill that does not fully develop until high school age. With sufficient preparation, a high school senior might well be able to understand how astronomers classify galaxies, nebulae, and clusters, and then subclassify these into various types (e.g. open or globular clusters); but most elementary school students would find this hierarchy of definitions too complex, no matter how clearly the lesson is presented.

Presenting classification schemes that your students are able to use is essential if they are to understand the concepts your program is designed to teach. The different levels of classification reasoning are demonstrated in the solutions to the following problem.

Students of various ages were given six pictures of galaxies and asked to classify them any way they wished. Below each response, please indicate the reasoning level that the student is using in order to give that response.

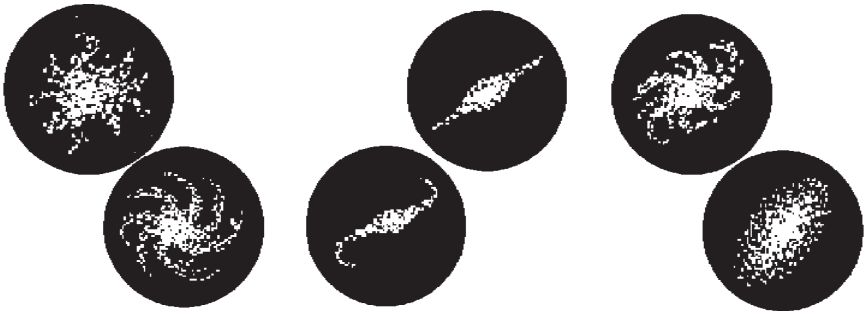
What is the level of thinking? Please explain your answer.

1. "Basically, there are two kinds of galaxies; spirals and non-spirals. The spirals might be seen face-on or sideways, and the non-spirals might be either elliptical or irregular in shape."



What is the level of thinking? Please explain your answer.

2. "The pictures in the bottom row are all spirals and the pictures in the top row are not spirals. Also, the ones here (on left) are skinny, the middle ones are egg shaped, and the ones here (on right) are rounded."



3. "In order from nicely shaped galaxies towards more squiggly galaxies."

What is the level of thinking? Please explain your answer.

_____

_____

_____

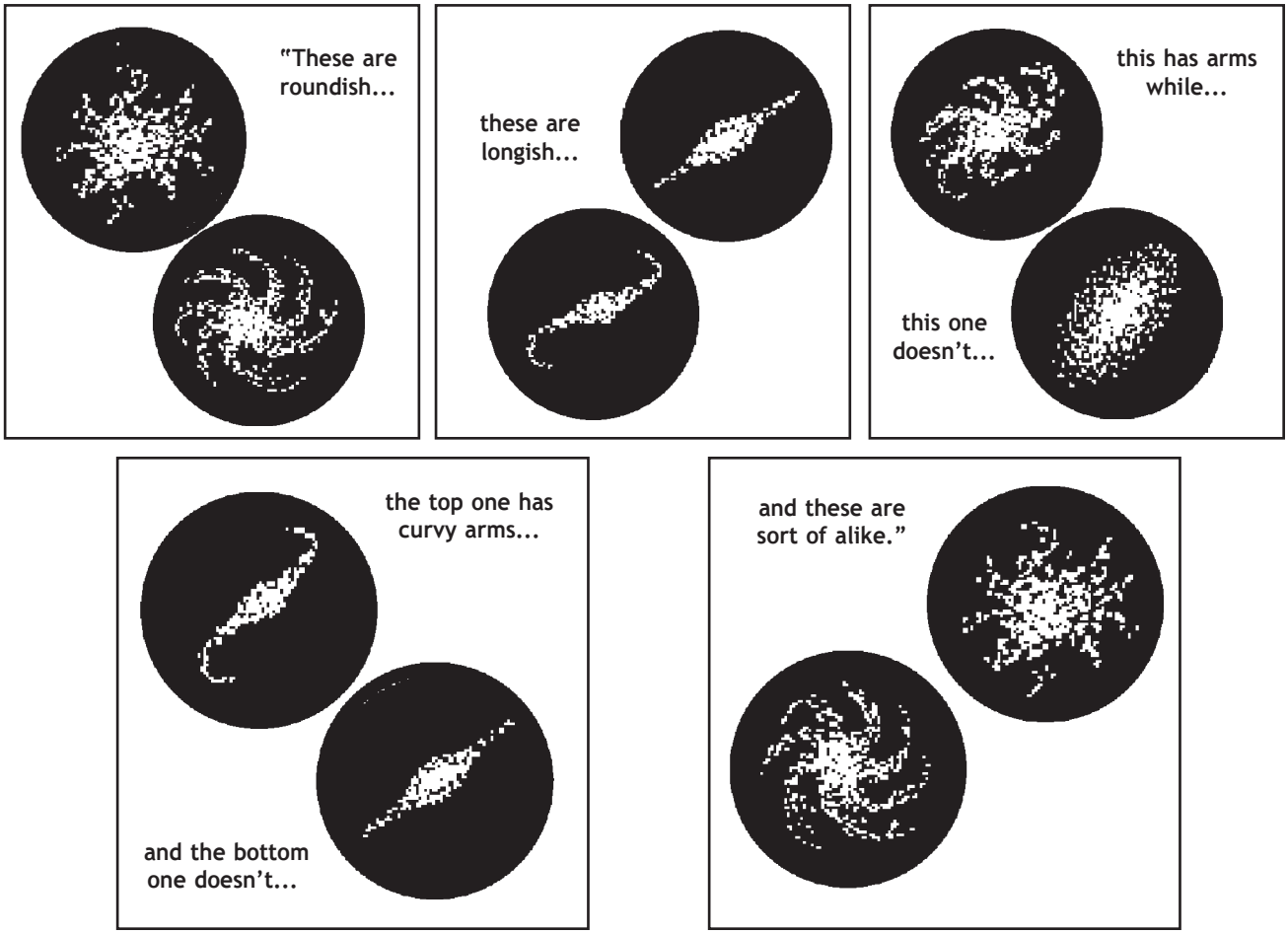
4. Regarding the galaxy groupings below:

What is the level of thinking? Please explain your answer.

_____

_____

_____



	Summary of Piagetian Levels of Development		
	Egocentric Level starts about age 4	*Concrete Level* starts about age 8 or 9	*Formal Level* starts about high school age
Frames of Reference	Can imagine only one's own point of view.	Can imagine another viewpoint, but only after a concrete experience.	Can imagine a situation from different points of view.
Scientific Explanation Skills	Attributes motives and purposes to inanimate objects, or assumes all phenomena are produced by human actions for human purposes, e.g. "The sun comes up so we'll feel warm."	More complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations.	Can extend explanations to predict new observations and objectively compare one's own explanations with alternatives.
Classification Skills	Can notice similarities and differences, and can classify only after much trial and error.	Can classify by a single trait, recognize that objects may belong to more than one class, and arrange objects along a continuum.	Can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy.

E. Teaching Approaches

In this module we have considered the role of students' knowledge and reasoning skills in learning. Following are some suggestions for teaching approaches that take these factors into account.

Instruction and Knowledge

Recognizing that students come to our classrooms and planetariums filled with a great many observations and ideas about the natural world implies that we should encourage our students to discuss their ideas about a subject before we attempt to teach it. This will help us better understand the misconceptions that need to be overcome, select more appropriate educational objectives, and allow us to exploit the students' diverse ideas to help them construct new, more adequate concepts.

One way to initiate a productive discussion is to illustrate a concrete situation and ask a question about it. Examples from this module include questions about the appearance of moons from the surface of Mars, about the path of a rock dropped through a hole in the earth, and why the moon appears to be different shapes at different times.

As you facilitate your students' discussions, help them to identify a few alternative viewpoints. Encourage discussion about which point of view best explains the observations, or is consistent with other information that they believe to be true.

Such discussions need not take a long time, nor do they need to result in agreement on the scientists' viewpoint. It is most important that you become aware of your students' current understanding, and for the students to begin to question their own points of view.

Moving the students from their own viewpoints to more powerful concepts is not easy, and it is unrealistic to expect them to give up explanations which satisfy them without a struggle. As you become more aware of common misconceptions, you can plan activities in which the students make observations which conflict with these misconceptions, so that they become open to new ways of thinking. Several activities which are designed to do this are included in Volume 2 of the PASS Series, *Activities for the School Planetarium*.

Let's take a minute to consider one activity designed to challenge the idea that moon phases are caused by the earth's shadow. Darken a room as completely as possible and turn on a single light bulb in the middle to represent the "sun." Give each student a ball to hold which represents the "moon." Their heads are the "earth." As the students move the moon ball around their heads, they see the moon go through its various phases. They also see a lunar eclipse as the full moon passes into the earth's shadow, thus allowing them to disentangle these two concepts. (This activity is fully described in Volume 7 of the PASS Series, *Moons of the Solar System*.)

The moon phases activity also illustrates the interplay between knowledge and reasoning skills, since it works much better if each student has a moon ball than if the teacher demonstrates the activity to the class. When each student has his own "moon" to look at, he can see it go through its phases from his own point of view. Whereas if the teacher demonstrates the concept, the students must imagine the view through the teacher's eyes, which is a difficult challenge for

most children, and even for many adults who are unfamiliar with the subject matter.

Another approach to helping students change their current concepts is to contrast a difficult problem (referred to as the "target problem"), with a simpler problem of the same type (referred to as the "anchor"). In the Martian Moon Problem, for example, most people select the right phase for Deimos, but have a difficult time selecting the right phase for Phobos. Asking the students to consider how these two problems are similar or different may help them solve the "target" problem of Phobos, by thinking about how they solved the "anchor" problem of Deimos.[10]

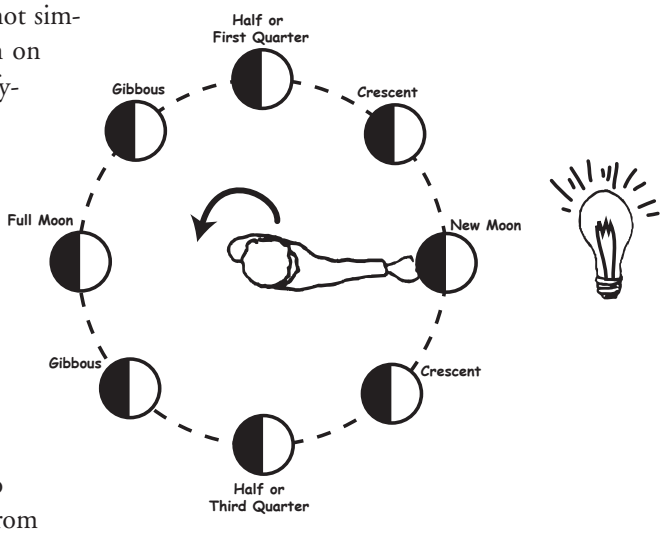
Persistent student misconceptions can be disheartening, since it makes the teacher's job seem so difficult. Teaching is a challenging profession, but it does not have to be disheartening if we adopt realistic expectations. One of the most useful lessons that we can learn from educational researchers who study common misconceptions is that people change their concepts gradually. Thus, it is more realistic to expect our students' ideas to be a little closer to the scientist's viewpoint after a lesson than to expect them to understand a new concept completely.

Additionally, it is more realistic to expect conceptual change after several activities that address the same concept. Classroom activities which complement planetarium programs by presenting the same concept in a different way are therefore likely to be an effective approach to conceptual change.

Piaget refers to the process by which a person's reasoning skills advance to higher levels as "self-regulation." According to his theory, self-regulation begins when an individual first uses his present reasoning to attempt to solve a problem. When the person's reasoning skills clearly fail to produce a satisfactory result, the individual has the opportunity to modify his or her reasoning.

Instruction and Reasoning Skills

An important aspect of this process is that teachers cannot simply "teach" reasoning skills. Students must construct them on their own, just as they must construct concepts by modifying or replacing their current ideas with new ones. Thus, telling students how to solve problems is not as helpful in developing new reasoning skills as giving them hints once they begin to seek new reasoning patterns on their own.



One useful approach in helping students develop more adequate reasoning skills is to give them problems at the appropriate level. Start with something familiar and interesting to the students, so they are willing to get involved. Then, introduce a more difficult problem for which their present reasoning strategy doesn't work, so they will be especially susceptible to helpful suggestions from you or other students.

10. Schultz, K., Murray, T., Clement, J., and Brown, D., "Overcoming Misconceptions with a Computer-Based Tutor," in *Proceedings of the Second International Seminar on Misconceptions in Math and Science* (J. Novak, Ed.), Cornell University, 1987.

Note: Many of the activities and illustrations in this module are drawn from *Earth, Moon, and Stars*, a Teacher's Guide in the series *Great Explorations in Math and Science* (GEMS). This guide can be purchased from: GEMS, Lawrence Hall of Science, University of California, 94720. The GEMS phone number is 510-642-7771. You may wish to write for a brochure of the latest GEMS guides.

For example, students who can solve the Deimos problem in The Martian Moon Problem, will be interested in trying to solve the Phobos problem, even if they find it difficult. Listening to other students explain how they try to "imagine the view from Mars," or "reverse what I saw" may help those who do not yet have these reasoning skills to develop them.

If, on the other hand, the level of difficulty is too great, frustration may occur, and the students may avoid the situation in the future. When the level of difficulty is just right, the students will be able to construct for themselves new reasoning strategies that they will continue to use in the future.

To apply this theory to planetarium programming, you may wish to keep in mind the following general points:

1) Many of your students will approach astronomy problems with concrete or egocentric reasoning. They will not become involved in the program unless they can start at their own level.

2) Some topics can be understood using concrete or egocentric approaches, while others require formal reasoning in order to be understood. Consequently, by carefully selecting topics you can design programs which begin at the level of your students.

3) If students can become involved in a topic at a level which is comfortable for them, and then are challenged by slightly more complex or unexpected information, they may experience intellectual growth. In other words, experiences like these not only help the students understand particular concepts in astronomy, but may also improve their abilities in such general areas as using different frames of reference, classifying objects and events, and formulating explanations.

For easy reference when planning planetarium programs, page 37 contains a summary of the Piagetian levels of reasoning for the three ability areas discussed in this module. You should now be able to use this list to "rate" any presentation as requiring egocentric, concrete, or formal level reasoning. This approach can help you develop or revise programs to be more appropriate for your students.

New concepts and new reasoning skills are only useful to the degree that students use them in school, in daily life, and in their future careers. You can help students apply what they learn by providing as many real contexts as possible in their learning activities. Presentations on space science can include the very latest news about American, Soviet, or European space probes. Show slides of the women and men who carry out programs in science and technology around the world. In programs about the moon, planets, and constellations, give your students ideas about how they can apply what they learned by looking in the real night sky that very night.

The problem on the next page provides an opportunity to integrate all of the information provided in this module.

Teaching Reasons for the Seasons

Suppose your goal is to design education experiences so that by the time a child reaches high school he or she will be able to provide a formal level explanation for the seasons. Based on your knowledge of the various levels of reasoning ability, please outline the experiences and explanations you would provide during an individual's development to reach your goal.

FIRST GRADE

A. Experiences and explanations in the planetarium:

_____

_____

_____

_____

_____

_____

_____

B. Experiences and explanations in the classroom:

_____

_____

_____

_____

_____

_____

_____

C. Experiences outdoors:

_____

_____

_____

_____

_____

_____

_____

FIFTH GRADE

A. Experiences and explanations in the planetarium: _____

B. Experiences and explanations in the classroom: _____

C. Experiences outdoors: _____

TENTH GRADE

A. Experiences and explanations in the planetarium: _____

B. Experiences and explanations in the classroom: _____

C. Experiences outdoors: _____

Module 5: Questioning Strategies

The goals of this module are to introduce you to a scheme for classifying questions, to provide practice in identifying types of questions, and to illustrate how to draw profiles of types and sequences of questions that you ask during a planetarium program. These tools can help you increase the value of your dialog with students.

When properly phrased, questions can motivate and sustain interest, develop and modify attitudes, stimulate fresh ways to deal with ideas, and elicit specific cognitive processes such as recalling, inductive and deductive reasoning and speculating.

Although asking students questions is a valuable educational technique, it is not a common aspect of most planetarium programs. It may not be practical when audiences number in the hundreds. For a "school show" with one or two classes attending, or even public shows in small planetariums, questions can be a simple and effective means of increasing student participation. The Socratic organization plan discussed in Module 3 relies on your ability to question the visitors skillfully.

This module is designed to help you develop an effective questioning strategy. Section A provides a useful set of categories for examining question types. Section B applies these categories to dialog from a real planetarium program. Section C suggests strategies for sequencing questions. Section D provides a convenient form for planning or reviewing questioning strategies. Sections E and F apply a similar analysis to the instructor's responses to students' answers.

When conducting this workshop on questioning strategies, you may find that one or two teachers in your groups will be upset when they discover that the classification scheme presented here cannot easily be used to classify *all* questions, or that the questions they most frequently use may not be the best. Emphasize that the goal is not to offer a perfect classification system, nor to imply that any one type of question is better than another. Rather, the goal is to offer teachers a tool to examine their questioning strategies, and to decide when one kind of question might be more effective than another.

A. Categorizing Questions

A question is a question is a question until one recognizes differences among them. Different classes of questions require different classes of answers. Suggest a few tentative categories to classify these questions:

1. *What does a light-year measure?*
2. *What topics would you like me to cover in our next planetarium show?*
3. *Did you hear my last question?*
4. *Based on your observations of the setting sun during the last two weeks, where do you predict it will set one week from now?*
5. *What do you think your life would be like if you were an astronomer?*
6. *Planets certainly aren't as hot as stars, are they?*

The value of categorizing questions is to increase your awareness of how

Categories	Example Numbers

different questions can stimulate different kinds of thinking by the students. One question may flex their memories, another may challenge them to deeper thought, while a third may encourage them to make their own value judgments. This range of mental activity is certainly worth cultivating.

Most planetarium instructors' questions do not achieve this range. A research study by John T. Curtin[16] of 38 planetariums found that 98 percent of the questions instructors asked of students required only information recall. By examining your own mix of questions, you will be able to increase the range of questions you ask, and thus increase the range of mental processes stimulated by your planetarium programs.

Questions can be categorized many ways. You might find the categories you have proposed included in the classification scheme outlined on the following pages, developed by Lawrence Lowery. As you've probably observed in devising your own categories, no scheme is entirely satisfactory to everyone, but the particular categories below are the result of much testing and revision, and are quite useful.

[16] "An Analysis of Planetarium Program Content and the Classification of Demonstrator's Questions," 1967, unpublished doctoral dissertation

Types of Questions					
Narrow		Broad		Other	
Direct Info.	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial

Narrow Questions

A narrow question has a certain "correct" answer or a limited number of acceptable responses related to it. When you ask a narrow question, you are hoping for a response that matches something you know. There are two types of narrow questions: direct-information questions and synthesizing questions.

Direct-Information Questions

These questions require the student to recall information or to recognize information that is readily at hand. Examples:

"Which planet is farthest from the sun?"

"What does a light-year measure?"

"What did Viking discover about life on Mars?"

Such questions are useful if you want the student to recall a fact, define a term, or identify something seen before. Responses to direct-information questions will often be one word or short answers. Questions that can be answered "yes" or "no" fall into this category.

As part of a strategy, direct-information questions can be used to find out what students know, to reestablish what has gone on in a previous experience, or to establish a base of information upon which new knowledge will depend. These questions are generally effective at the beginning of a program to "set the stage" or to emphasize certain observations before proceeding to analyze them.

Synthesizing Questions

These questions require the student to relate information in a specified way. Examples:

"Based on your observations of the setting sun during the last two weeks, where do you predict it will set one week from now?"

"Using shadows on the moon's surface as a guide, which lunar features do you find to be the tallest?"

"If the astronaut is ten light-minutes away from earth, how long will it take to receive a reply to our message?"

Such questions are useful if you want the student to compare, contrast, associate, or state relationships.

To respond to synthesizing questions, the student must know certain facts, be able to associate and put them together, and describe the relationships in his or her own words.

Synthesizing questions can be used to help students pick out similarities and differences, classify, use previously learned information in a new way, or develop in his or her own terms an idea that you have suggested.

A broad question has a wide range of acceptable responses; when you ask a broad question, you are hoping for unplanned, divergent outcomes. There are two types of broad questions: open-ended and feeling questions.

Broad Questions

These questions allow the student to explore freely in his or her own terms, without restrictions and with only minimal guidance by you. Examples:

Open-Ended Questions

"Why do you think ancient civilizations created their own systems of constellations?"

"What topics would you like me to cover in our next planetarium show?"

"What is your conclusion about UFO's after hearing these reports?"

Responses to open-ended questions are rarely predictable, and the methods students use to find answers are selected by the students themselves.

As part of a strategy, open-ended questions can broaden the field of study and suggest new approaches. Open-ended questions allow you to develop an investigation through questions that don't limit the possible solutions.

To respond to open-ended questions, the student must believe that he or she is in a trusting situation—one in which responses will be accepted and not criticized.

Feeling Questions

Feeling questions ask the student to express an emotional attitude rather than make a purely objective response. Examples:

"How did you feel when you first looked at the rings of Saturn through a telescope?"

"How do you feel about the amount of money being spent on space exploration?"

"What do you think your life would be like if you were an astronomer?"

Such questions are useful if you want the student to formulate an opinion, share feelings, or become aware of the feelings of others.

As with open-ended questions, to respond to feeling questions the student must believe that he or she is in a trusting situation—one in which responses will be accepted and not criticized.

There are at least two other kinds of questions commonly used in the planetarium: rhetorical questions and managerial questions.

Other Types of Questions

Rhetorical Questions

These questions are used to reinforce a point or to provide emphasis. Examples:

"Earlier, I told you that a light-year is a measure of distance and not time, right?"

"That is true for most of us, isn't it?"

"Planets certainly aren't as hot as stars, are they?"

When such questions are asked, responses are not really expected although responses are sometimes given.

Other questions can function rhetorically when you supply the answer or when the question is not followed by enough time for students to respond.

Managerial Questions

Managerial questions are used to keep things moving smoothly. Examples:

"Can everyone hear?"

"Who has the pointer?"

"Who needs more time to find their constellation?"

B. Practice in Classifying Questions

A method that you might find helpful when trying to identify and classify questions is to decide first whether the question is narrow, broad, or other. If it is narrow, decide whether it is direct-information or synthesizing. If it is broad, decide whether it is open-ended or feeling. If it is other, decide whether it is rhetorical or managerial.

When deciding between direct-information or synthesizing questions, you might find it helpful to analyze what type of thinking the question requires: 1) recall and recognition of information (direct-information); or 2) analysis of clues and induction to arrive at a particular answer or idea (synthesizing). If the question is broad, you might ask yourself if the question requires: 1) free and undirected investigation (open-ended); or 2) personal opinions and emotional responses (feeling).

During this workshop, differences of opinion will often occur about how a given question should be classified. This is because it is sometimes difficult to know the questioner's intent. However, discussing these differences of opinion can be very useful, both to familiarize yourself with the various categories, and to recognize the ways your planetarium visitors can misunderstand what is expected of them.

Please classify the ten numbered questions on this transcript. Record your decisions by checking the appropriate boxes on the next page. The first two are already marked on the chart as examples.

I: "Good evening. As our planetarium sky darkens, can anyone recognize the Big Dipper?" (1)

S: "Oh, I see it." "Yeah, I see it too."

I: "Okay, will you please take this light pointer and show the rest of us where the Big Dipper is?" (2)

I: "Thank you. Well, that's the Big Dipper. Just about all of the stars that we can see in the sky belong to groups like the Big Dipper; and people have been naming the constellations for just about as long as there have been people. Why do you think people do that?" (3)

S: "Worship."

I: "Okay, worship; that's a good possibility. What's another?" (4)

S: "To go places."

I: "How would knowing the constellations help you to go places?" (5)

S: "You'd like to know which way to go from the stars. Directions."

I: "Yes, knowing the constellations does help you find your way. Does anyone know how to use the Big Dipper to find which way is north?" (6)

S: "I do, I think."

I: "Okay, will you show us please?" (7)

S: "It's this bright one at the end of the handle of the big dipper, the North Star."

I: "You've got the right idea, but the wrong star. These two stars at the end of the bowl point to the North Star, right here. Then, once you've found the North Star, look down at the horizon just below it. That direction is north. Okay?" (8)

I: "We've discussed at least two reasons that ancient people might have named the constellations: for worship, or religious reasons, and to find directions. How do you feel when you locate something you're familiar with, like the Big Dipper in the sky?" (9)

S: "Like I just saw a friend. Good."

I: "I'll tell you what. I will give each of you a star map and let you find the constellations right here in the planetarium. Is there anyone who has not yet received a star map?" (10)

Types of Questions

	Narrow		Broad		Other	
	Direct Info	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial
1	√					
2						√
3						
4						
5						
6						
7						
8						
9						
10						

Assuming this section of a planetarium program was typical of the entire program, please analyze the instructor's questioning strategy:

1. Are the types of questions and the kinds of thinking they stimulated satisfactory? How would you change the mix?

2. What specific parts of this series of questions could be improved?

3. What other general comments or suggestions for improvement can be offered to the instructor in this case?

C. Sequencing Questions

Questions you ask your students may be placed in different sequences to achieve different objectives. There are many possible questioning strategies, but you will probably find it helpful to identify just a few that work well for you. Here are two examples.

One strategy begins with narrow questions to give the visitors an opportunity to show what they already know, or to make some very simple observations. Then, after some of the facts have been established, you can ask the students to make comparisons and notice relationships by asking synthesizing questions. Once the students understand the basic ideas through these narrow questions, they can be led to think more creatively about the topic through open-ended and feeling questions. This strategy is illustrated by the following sequence of questions asked by a planetarium instructor during an activity in which the students observe light sources through hand-held diffraction gratings passed out during the program:

A different strategy can involve the students in open-ended thinking from the outset. These broad questions can be followed by synthesizing and direct information questions to examine the implications and details of the topic. This strategy is illustrated by the following sequence of questions asked after a planetarium dramatization of several classical UFO sightings.

Classify each of the questions by checking the appropriate column. Then draw a line between the check marks. This line is a visual representation of one questioning strategy. Do the same for the sets of questions on the next two pages.

	Direct Info.	Synthe-sizing	Open-ended	Feeling
1. What was the main color that you observed in the hydrogen gas? What colors do you recall from the helium gas tube?				
2. How do the colors of helium differ from those of hydrogen?				
3. What colors do you see in this artificial star?				
4. From your own observations, what kind of gas do you think this star is made of? How did you determine that?				
5. How might this technique of studying stars help astronomers learn more about the universe?				

	Direct Info.	Synthe-sizing	Open-ended	Feeling
1. What do you feel about people who report UFO's?				
2. What are some different explanations you can think of to explain these unusual sightings?				
3. What further information would you need to decide if a weather balloon or a plane is involved?				
4. If you observe a UFO, what information will you write down?				

Develop your own questioning strategies for the two problems that follow.

	Direct Info.	Synthe-sizing	Open-ended	Feeling
1.				
2.				
3.				
4.				
5.				

Problem #1: Suppose you just presented a public program summarizing US space research. List a sequence of questions that would lead the visitors to consider the potential uses of a permanent space colony.

Problem #2: Suppose you just presented a planetarium program in which you illustrate many of the characteristics of the planets. List a sequence of questions that will allow the students to discover for themselves why some planets have craters and others do not. (Relevant factors include whether or not we can see the planet's surface, the planet's atmosphere and weather, and volcanic action which has filled in craters.)

	Direct Info.	Synthe-sizing	Open-ended	Feeling
1.				
2.				
3.				
4.				
5.				

D. Recording and Improving Your Questioning Strategies

The methods described in the preceding pages of this module can be directly applied to planning planetarium programs. However, even the best-planned programs take unexpected turns. To improve your questioning strategies for such real-time situations, it can be very valuable to audiotape one or two of your planetarium programs and then analyze your "live" verbal interactions with the audience.

When you analyze your own audiotape, it will not be necessary to make a complete written transcript. It will be useful, however, to write out and number each question. Then you can use the form below to record the kinds and sequences of questions that you used during the program. Comparing the question patterns with your objectives for each part of the program will help you decide if you should change your questioning strategies.

Types of Questions						
	Narrow		Broad		Other	
	Direct Info	Synthesizing	Open-ended	Feeling	Rhetorical	Managerial
1	✔					
2						✔
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

E. Responding Strategies

Using Wait-Time

Most instructors wait only one or two seconds after asking a question in a class before they either: 1) call on another person; 2) ask another question; or 3) give the answer to the question themselves. Perhaps many feel that unless someone is talking, no one is learning.

Research indicates that if you wait a bit longer after a question is asked, there are observable differences in the behavior of the people being asked the question. For example, if you wait only a short time—one or two seconds—then one-word student responses result. These quick responses are often guesses, and are seldom complete sentences or contain complete thoughts. If, however, you wait for a longer period—four to six seconds—students tend to respond in whole sentences and with complete thoughts. There is increased speculation in the students' thinking, and they tend to justify answers more fully.

Sometimes a four to six second waiting period seems like an eternity, but wait-time research suggests great value in adjusting to this pattern. For more information about this research, see the articles "Wait Time in College Science Classes" by George Moriber (*Science Education*, 1971, vol. 55, no. 3, pp. 321-328) and "Science, Silence, and Sanctions" by Mary Budd Rowe (*Science and Children*, March, 1969, pp. 11-13).

Responding to Students' Answers and Comments

No matter how carefully a sequence of questions or activities is planned and executed, no significant thinking will occur if the students are worried about feeling "wrong" or "stupid" in front of others. How you react and respond to their ideas early in the planetarium program is crucial to the degree of participation you can expect during the remainder of the program.

Your response to a student's comment should be in harmony with the question or task that preceded the comment. For example, if you ask a narrow question (direct information or synthesizing) a positive or negative comment on the student's answer is expected and appropriate. However, if you ask a broad question (open-ended or feeling), neither praise nor criticism is appropriate and both tend to inhibit further participation. A more appropriate response to an answer to a broad or feeling question would be an accepting response. Three kinds of accepting responses are described in the following paragraphs:

Passive acceptance is a response which lets the student know that he or she has been heard, but without giving a value judgment about the quality of the statement. Examples of passive acceptance are: "Um-hmmm." "Okay." "That's a possibility."

Active acceptance involves rephrasing, translating, or summarizing what a student or several students have said or done. This kind of response demonstrates not only that you have heard the student's message, but also that you have understood it. This type of response is non-judgmental and encourages further participation. Examples of active acceptance are:

"What I hear you saying is that water on Mars could have soaked into the ground, so there may be Martian life underground."

"These four people seem to feel that the reddish star moved, but at least one person disagrees. Perhaps everyone should watch this one star next time to try and decide whether or not it moved."

Empathic acceptance involves feelings as well as ideas. By giving an empathic response, you indicate that you have heard and appreciate the students' feelings, emotions, or behaviors. Examples are:

"I understand why you are upset with money wasted on poorly-planned government programs, including space research."

"Don't feel embarrassed about having difficulty understanding Einstein's theory of relativity. In many ways it is contrary to common sense."

Replying to Students' Questions

Often slides, activities, or discussions provoke questions from the students during the planetarium program. Whether or not the questions are pertinent to your next point, they usually are related to the topic—at least in the student's mind. It is important, therefore, to satisfy the student's need for information, while maintaining the general flow of the planetarium program. This is hardly an easy task, but the following suggestions may help:

1. Sometimes a short, factual answer is all that a student really wants. For example, in response to the question "How far away is the moon?", you might resist the temptation to define mean distance and instead reply: "about a quarter of a million miles away." If a question would require a lengthy answer, you may also offer to answer it after the show is over.
2. You can sometimes invite audience participation by admitting you can't answer a student's question. For example: "I don't know what Native Americans call the Big Dipper. Does anyone else know?"
3. When the student really has the means of answering his or her own question, you might use the opportunity for further instruction. For example: "You can answer that yourself by looking at your star map. Which part of the horizon is Leo closest to? Okay, then that's the direction you must look tonight to find Leo, the Lion."
4. It may be appropriate to ask a student to hold a question until later, especially if the topic is dealt with later in the program. For example, in response to the question, *"Why are stars different colors?"* you could say, "We will be exploring that very question in a little while," if that is indeed the case.

F. Using Responding Strategies

Listen to an audiotape of a planetarium show that you presented. (You can use the same tape that you made to study your questioning strategies.) This time, attend to the responses that you made to the students' comments, ideas, and questions. Classify each response by checking the relevant box below.

Responsive Behaviors		Tallies
Wait time	Adequate	
	Should be longer	
Response to students' answers and comments	Praise	
	Criticism	
	Passive acceptance	
	Active acceptance	
	Empathic acceptance	
Replies to students' questions	Supplied answer	
	"Don't know"	
	Suggested strategy	
	Deferred answer	

1. Are most responses in harmony with the types of questions asked?

_____

_____

2. Which kinds of responses were used most frequently?

_____

_____

3. How did students react to different kinds of responses?

_____

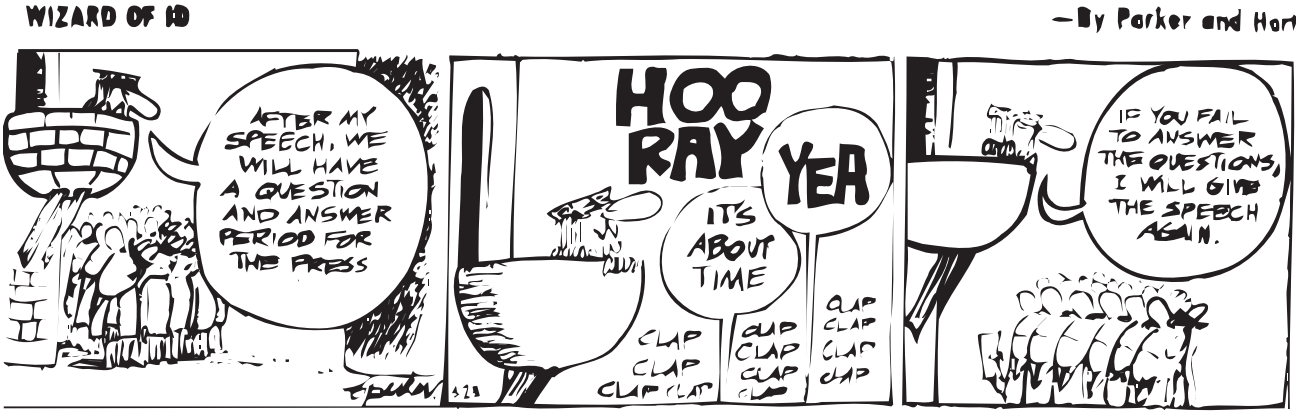
_____

4. Are there situations in which a different response might have encouraged more participation?

_____

_____

_____



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Start with questions about nature. Sound teaching usually begins with questions and phenomena that are interesting and familiar, not with abstractions or phenomena outside their range of perception, understanding, or knowledge.

—*Science for All Americans*, American Association for the Advancement of Science, 1989, page 147.

Module 6: Activities for the Planetarium

This module will help you to select, adapt, and invent activities that students can perform during the planetarium program.

Hearing about science, seeing it illustrated, and talking about it are fine—but few experiences of hearing, seeing, or talking can equal the excitement of actually doing science.

The core of a "participatory oriented planetarium" (P.O.P.*) program is an activity that involves the visitors in the process of science. By discovering something about the universe through their own actions, the students come closer to the real experience of science.

Activities provide several opportunities for learning that are not available in a program that is purely didactic. As an instructor, you can observe the difficulties your students encounter, giving you valuable feedback on how well you are communicating (see Module 1). The students have more opportunity to become directly involved with the subject and to interact with the instructor (as discussed in Module 2). Including activities in the program enables you to organize the planetarium experience in a variety of ways (as discussed in Module 3), and perhaps most importantly, concrete experiences are often essential for people of all ages to understand information in an unfamiliar area (as discussed in Module 4).

Students in the planetarium observing gas discharge tubes through diffraction gratings. After seeing the characteristic colors of hydrogen, helium, mercury vapor, and argon, the students can identify the composition of an unknown "star."

We will examine a range of activities, some suitable for general public shows, and others developed for students at specific grade levels. Activities can be used for single-visit programs as well as for multiple-visit classes.

Section A describes three typical activities that have been used successfully in single-visit programs for the public and for schools. Section B suggests how to use our categories of organization, reasoning ability, and questioning strategies to help you select activities appropriate to any audience. Finally, Volume 2 of the PASS series, *Planetarium Activities for Schools*, provides detailed examples for many more planetarium activities.

* The POP acronym was coined by several proponents of that technique during the August 1975 Planetarium Association of Canada meeting in Toronto. The original members of that POP group were Jeanne Bishop, Dale Etheridge, Samuel Farrell, Jane Geoghegan, Ron Hartman, Paul Knappenberger, Randy Mullin, Tom O'Brien, Ron Olowin, Dennis Schatz, Lee Simon, and Roger Woloshyn. Published references to POP include: Alan J. Friedman, Dennis L. Schatz, and Cary I. Sneider, "Audience Participation and the Future of the Small Planetarium" *Planetarian*, December, 1976; and Alan J. Friedman, "Participatory Planetarium Shows", *Planetarium Director's Handbook*, no. 32, May/June, 1975.

A. Inventing Activities

You can invent an activity by thinking about how the scientific information that you wish to present was discovered in the first place. Then, imagine how some aspects of that discovery could be shared by the students. For example, in planning a program about Mars, we began by thinking about how astronomers have made discoveries about Mars in the past. Eventually, we decided on three activities that would enable the students to rediscover information about Mars from the viewpoint of astronomers living at widely separated historical periods.

The Mars discovery activities form the core of the planetarium program, "The Red Planet Mars," included in PASS Volume 7. Below, we have briefly summarized three activities from that program. After reading each example, think how you might use a similar approach to communicate concepts that are of current interest to you.

Example #1 Find the Planet Activity

The instructor explains that the ancient Greek astronomers did not have telescopes, so to them stars and planets looked just the same. They observed, however, that a few "stars," including Mars, wandered among the other stars from night to night. They called these "wanderers," or in Greek, "planetes," which is the origin of our word "planet."

To discover the planet Mars in the planetarium sky, the students are asked to find a reddish or orangish star. After three Mars candidates are pointed out by the students using a portable light pointer, the instructor asks how we might tell which of these stars is a wanderer. "See what the sky looks like a few nights from now," "Compare with the stars around it," are suggestions from the audience.

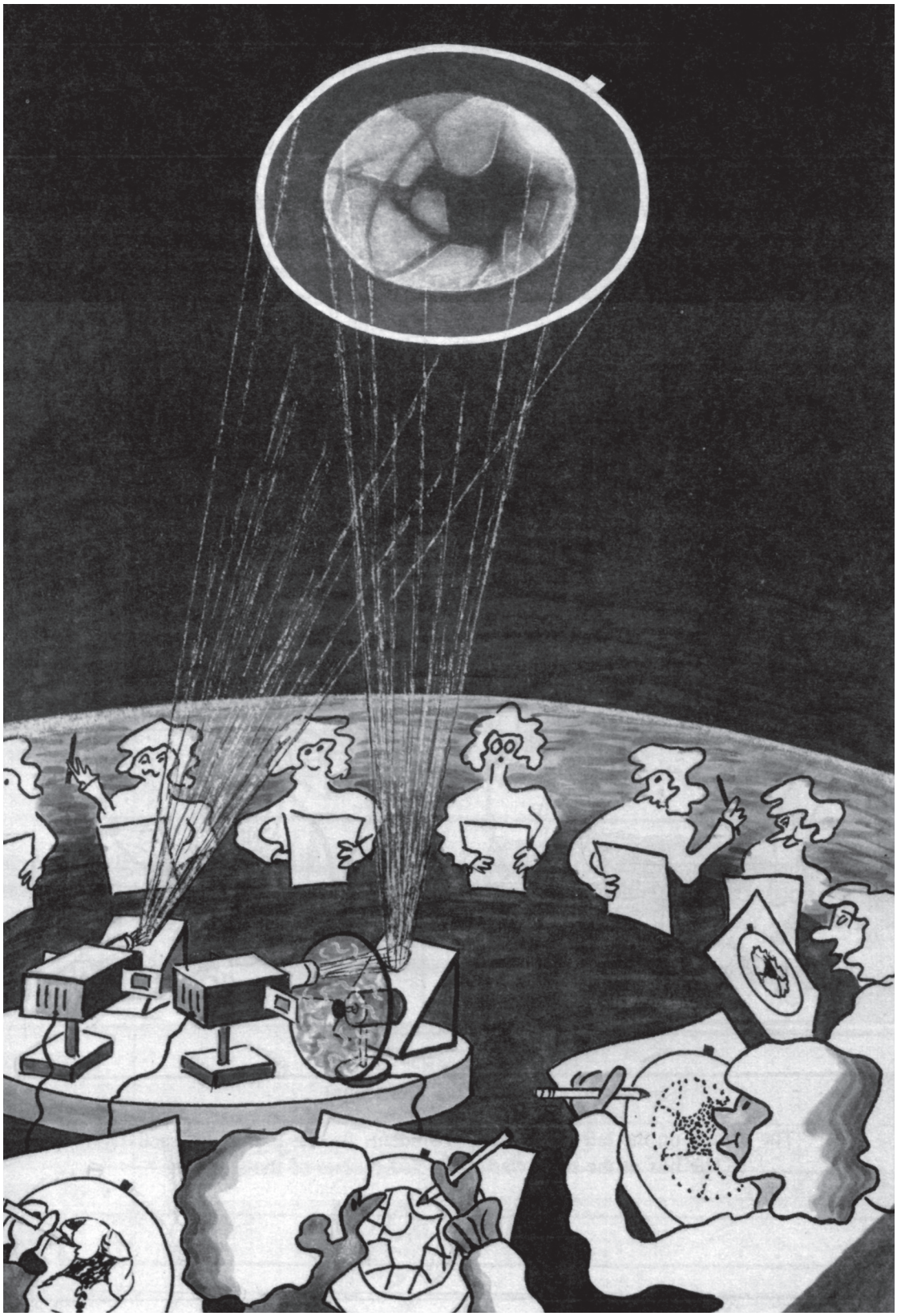
Next, the instructor divides the audience into three groups, each assigned to observe one of the three candidate stars. After simulating several weeks of elapsed time (by turning daylight up and down several times and advancing Mars inconspicuously), the instructor asks each group to report on whether or not its star "wandered" among the background stars. During two or three such observation periods, the students have an opportunity to check each others' results, and eventually agree on which of the three candidate stars is really Mars.

In the above activity, the students are not told by an authority which of the brilliant red stars above them is Mars. They discover it through their own collective efforts. This kind of activity not only teaches specific facts (planets were defined and detected by motion against background stars), but may make a significant improvement in students' attitudes toward science in general. Here is a chance for people who may be shy or frustrated about science to experience success: They can do science!

What other naked-eye phenomena can students in your planetarium discover, with planning and guidance from you?

Example #2 Mapping Mars Through A Telescope

After the telescope was invented, a great deal more information about Mars became available. To enable students to experience both the satisfaction and some of the difficulties encountered by Mars observers like Percival Lowell, students are asked to draw a map of Mars while looking at an image projected onto the dome. To simulate the effects of the Earth's atmosphere, the image of Mars first passes through a rotating plastic disk unevenly smeared with Vaseline.



What other observations can your students make through simulated or real instruments in your planetarium?

One fairly clear spot on the disc provides one especially clear moment of "seeing" every minute.

When the students are finished drawing, they compare their maps with their neighbors' maps.

Students find that some maps show straight lines and markings on the surface of Mars, while other students' maps show no such features. Discussions naturally develop about whether these features are "real" or due to observer error or the distortion caused by the Earth's atmosphere. The instructor facilitates discussion among the students to decide whether or not specific features really exist on the image of Mars they have been observing. An opaque projector is used to show students' work during the discussion. The general idea of controversy in science can be examined.

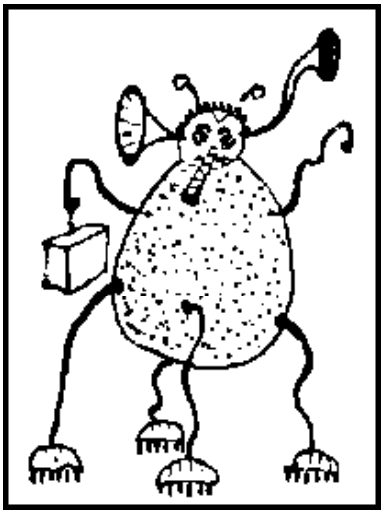
Example #3 Exobiology Activity

The Mars Mapping Activity in the previous example enables the students to experience the difficulties encountered by astronomers during the first half of the twentieth century. The Great Canal Debate which raged among the scientific community at that time was a direct result of the ambiguous data obtained by observing Mars through the earth's atmosphere. In the Exobiology activity, the students are invited to play the role of exobiologists who worked during this period, when the existence of Martian canals was a serious possibility.

If there were canal diggers, then how did they survive under conditions which Earthlings would consider hostile? The students each sketch their ideas about possible creatures that were naturally adapted to survive in: 1) lower gravity; 2) thinner atmosphere; and 3) much colder weather than we experience on Earth. There is no single "right answer" to this activity, since many different ideas are acceptable. This activity demonstrates the potential for creative play in science, guided by the rational evidence, but open to imaginative invention.

What other designs, models, or inventions can students create that are relevant to astronomy or space travel?

Here are some beings from the Earth.



Invent a being from a Mars-like planet which has:
1) weaker gravity,
2) thinner atmosphere, and
3) colder weather than Earth.

The picture on the left is provided to students for the Exobiology Activity. The box at the right was completed by one of the students.

B. Classifying Activities

In addition to inventing new activities for a particular program you wish to produce, it is often possible to select or adapt activities that have been developed by others. Collections of ideas for planetarium activities may be found in *Under Roof, Dome, and Sky*, issues of the *Planetarium Directors' Handbook*, the *Planetarian*, and a variety of other sources. (See also *Resources for Teaching Astronomy and Space Science*, PASS Volume 3.) Twenty additional ideas may be found in the next section of this module.

After selecting or inventing a small group of activities that might be incorporated into a particular program, we have found it useful to begin program planning by categorizing each activity according to the ideas presented in the previous three modules: organization scheme; reasoning ability level; and questioning strategy.

The different classifications are useful in determining the suitability of an activity for a particular audience and purpose, and to maintain variety. The categories are not unambiguous, especially for activities that have several parts and can be presented in many ways.

1) *Patterns of Organization* described in Module 3 helps you to visualize the ways that the students and instructor interact during the activity. Thinking about the possible choices of patterns (i.e. didactic vs. socratic, small group vs. individual task, group meeting vs. informal discussion) may also suggest ways of modifying the activity and may help you work the activity into your overall program.

Most activities are task-oriented (either individual or small group), but can also be classified as didactic ("Watch what I project on the dome right here") or socratic (instructor leads individual students step-by-step through an activity).

To practice classifying activities, list the dominant pattern of organization for the three Mars activities described in the previous section.

Activity	Pattern of Organization (didactic, small group or individual task, informal discussion, group meeting, or socratic)
Find the Planet	
Mapping Mars	
Exobiology	

2) *Reasoning Levels*, described in Module 4, help you to consider the level of reasoning ability (egocentric, concrete, or formal) that the students must use in order to perform the activity. Thinking about how to classify it may also suggest ways to modify the activity to make it understandable to a broader range of students.

How would you classify the three Mars activities according to the minimum intellectual level required to perform them as intended?

Activity	Reasoning Level (egocentric, concrete, or formal level)
Find the Planet	
Mapping Mars	
Exobiology	

3) *Activity Strategies* form a third dimension for classification. Since each activity poses a question for the students to answer, we can classify each activity by using the same categories developed for "questioning strategies" in Module 5 (direct information, synthesizing, open-ended, and feeling). Decide what Activity Strategy dominates each of the three Mars activities by thinking about the kind of response expected of the students. In a direct information activity you expect them to report a fact they immediately observe or recall. A synthesizing activity requires a result obtained by following a prescribed strategy. Open-ended activities have many acceptable procedures and/or results, while feeling activities allow for the students to express emotions.

Activity	Activity Strategy (direct information, synthesizing, open-ended, or feeling)
Find the Planet	
Mapping Mars	
Exobiology	

Now compare the way you have classified the three Mars activities with the way other people in the workshop classified them. The comparisons probably illustrate that some latitude in interpreting categories is unavoidable. Slight differences in interpreting category definitions, or in the particular objective you stress for each activity, can result in different choices. We hope you agree, however, that the general outline is helpful. A program that is mostly individual task, formal, and synthesizing, for example, would be useful for quite a different purpose from one that is mostly small group task, concrete, and open-ended.

People learn to do well only what they practice doing. If students are expected to apply ideas in novel situations, then they must practice applying them in novel situations. If they practice only calculating answers to predictable exercises or unrealistic "word problems," then that is all they are likely to learn. Similarly, students cannot learn to think critically, analyze information, communicate scientific ideas, make logical arguments, work as part of a team, and acquire other desirable skills unless they are permitted and encouraged to do those things over and over in many contexts.

—*Science for All Americans*, American Association for the Advancement of Science, 1989, page 146.

Module 7: Creating a Planetarium Program

The goal of this activity is for you to review the techniques presented in this workbook and to apply them to planning or improving a planetarium program.

A. A Brief Review

Three ways of viewing components of planetarium programs have been presented in this workbook. These schemes are briefly outlined below. The classifications are not ironclad distinctions, but are useful in helping match topic, student, and instructor to one another, and in maintaining variety.

Organization Patterns (Module 3)

1. *Didactic Organization*—Communication is entirely one-way: from the instructor to the students.
2. *Small Group Task Organization*—This organization allows students to interact with other students while working on a common task.
3. *Individual Task Organization*—Each student makes his own observation or solves a problem on his own.
4. *Informal Discussion Organization*—This pattern of organization allows free, uninhibited discussion by the students among themselves.
5. *Group Meeting Organization*—The group meeting is primarily problem-centered, with the instructor or a student acting as a facilitator.
6. *Socratic Organization*—The planetarium instructor takes the role of questioner and responder.

Students' Reasoning Skills (Module 4)

1. *Egocentric*—Students can imagine only their own point of view. Simple associations and human motives are attributed to inanimate objects, e.g., "The sun rises so we'll feel warm." Students can notice similarities and differences.
2. *Concrete*—Students can imagine another viewpoint only after a concrete experience. More complex relationships between various elements familiar to the individual can now be used to explain phenomena. New observations can be appropriately used in revising explanations. Beginning with classification by a single trait, they can later recognize that objects may belong to more than one class and can arrange objects along a continuum.
3. *Formal*—Students can imagine a situation from different points of view. Students can extend explanations to predict observations and objectively compare their own explanations with alternatives by controlling variables and making probability arguments. They can arrange objects in a hierarchy and then rearrange the objects in a new hierarchy.

Questioning and Activity Strategies (Module 5 & 6)

1. *Direct Information*—The student recalls information or recognizes information that is readily observable.
2. *Synthesizing*—The student draws some relationships from information that was recalled or observed.
3. *Open-Ended*—The student explores freely and comes up with one of a wide range of acceptable solutions.
4. *Feeling*—The student makes a judgement based on feelings.
5. *Other*—Rhetorical and Managerial.

B. Applying the Techniques

Outlining a Program

You can use the convenient chart on page 66 to outline a planetarium program in its formative stages. First, list each component of the program in the Subject column. Then, for each component, consider the form of Organization, the dominant Questioning or Activity Strategy (if appropriate), and finally the Reasoning Skills required of the students. The flow of the program can be judged by reading down each column. For example, does the sequence of subject matter ideas make sense from the students' point of view? Do the changing patterns of organization during the program provide variety and focus? Does the range of activities and questioning strategies allow the students to participate in several ways that further your objectives? Are the reasoning demands appropriate for the students who you expect will attend this program? Finally, does the latter part of the program encourage intellectual growth by challenging students to understand at a level slightly above their current reasoning ability?

Planning and Improving Verbal Interaction

As you plan the program script, consider sequences of questions that would most effectively communicate the content of the program. Then, try out the program with a live audience as soon as possible, even before all of the special accessories and the artwork are down pat. Audiotape one presentation and analyze the questioning and responding strategies as discussed in Module 5. Especially listen to the students' responses to questions and tasks that are intended to involve them in thinking at a high level. If the response is not what you expect, you may wish to reconsider the developmental level of the students as discussed in Module 4. You may decide to simplify the task, make it more challenging, or change your strategy for communicating that subject to the students.

Planetarium Program Title: _____

Concept/Topic: _____

Student Grade Level: _____

Objectives/Goals: _____

Author: _____

Time	Subject	Organization (didactic, group or individual task, informal discussion, group meeting, or Socratic)	Strategy (activities or questions are direct info, synthesizing, open-ended, or feeling)	Reasoning (requires egocentric, concrete, or formal level reasoning)

Module 8: Teaching Across the Curriculum

This module invites you to share ideas with your colleagues concerning the relationship of astronomy and space science to other aspects of your students' lives.

A. Connections Between the Sciences

The walls are coming down! Astronomers and space scientists realized decades ago that the life of a working scientist is rarely confined to a single field, or discipline of science. Sure, scientists specialize in solving certain kinds of problems, but in doing so they almost always employ the theories and techniques of many different sciences in helping them to achieve their objectives.

Educators at the highest levels are now recognizing the need to bring science education into line with science—by emphasizing the connections between the sciences instead of the differences. Efforts to reform the curriculum now focus on ways to break down the barriers and remove the study of science from the pigeonholes.

One of these reform efforts is entitled "Project 2061," and is being conducted by the American Association for the Advancement of Science (AAAS). Phase 1 of the project, which took three years to complete, involved panels of scientists from different fields who worked together to define the most important theories, concepts, and processes that should be taught in school. Chapter 4 of Project 2061's first report, entitled *Science For All Americans*, outlines the key ideas that are of special concern to astronomy and space science teachers.

However, the report goes far beyond identifying the most important topics that should be included in a K-12 astronomy and space science curriculum. The authors summarize research on teaching and learning, and emphasize the importance of activity-based science lessons to communicate the nature of science to students. This conclusion is consistent with the participatory approach to planetarium programming that has been emphasized throughout this volume.

Science for All Americans also emphasizes the connections among the sciences. The connecting threads are identified in the report as **themes** "that pervade science, mathematics, and technology and appear over and over again, whether we are looking at an ancient civilization, the human body, or a comet. They are ideas that transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design."

The report goes on to identify thematic ideas and how they apply to science under six headings: systems, models, stability, patterns of change, evolution, and scale. As an exercise in designing new planetarium activities which integrate various scientific fields through a thematic approach, discuss each of these headings with a partner, and jot down an idea for an activity which would illustrate that theme.

[Page references are to *Science For All Americans.*]

Systems

"Any collection of things that have some influence on one another and appear to constitute a unified whole can be thought of as a system.... In defining a system—whether an ecosystem or a solar system... we must include enough parts so that their relationship to one another makes some kind of sense.... For example, if we were interested only in a very rough explanation of the earth's tides, we could neglect all other bodies in the universe except the earth and the moon; however, a more accurate account would require that we also consider the sun as part of the system." (page 123) Please jot down an idea for a planetarium activity that would illustrate what is meant by a system.

Models

"A model of something is a simplified imitation of it that we hope can help us understand it better.... Whether models are physical, mathematical, or conceptual, their value lies in suggesting how things either do work or might work." (page 125) Please jot down an idea for a planetarium activity that would illustrate what is meant by a model.

Stability

"In science, mathematics, and engineering, there is great interest in ways in which systems do not change." (page 126) Three kinds of stability are discussed: equilibrium, conservation, and symmetry. Please jot down an idea for a planetarium activity that would show what is meant by stability.

Patterns of Change

"Descriptions of change are important for predicting what will happen... We can distinguish three general categories: (1) changes that are steady trends; (2) changes that occur in cycles; and (3) changes that are irregular." (page 127) Please jot down an idea for a planetarium activity that would illustrate what is meant by patterns of change.

Evolution

"The general idea of evolution, which dates back at least to ancient Greece, is that the present arises from the materials and forms of the past, more or less gradually, and in explicable ways. This is how the solar system, the face of the earth, and life forms on earth have evolved from their earliest states and continue to evolve." (page 129) Please jot down an idea for a planetarium activity that would illustrate what is meant by evolution.

Scale

"The ranges of magnitude in our universe—sizes, durations, speeds, and so on—are immense. Many of the discoveries of physical science are virtually incomprehensible to us because they involve phenomena on scales far removed from human experience." (page 130) Please jot down an idea for a planetarium activity that would illustrate what is meant by scale.

B. Connections With Mathematics

Of all the sciences, astronomy is one of the most enjoyable to teach, because so many people find it fascinating. Captivating photos of nebulae and galaxies never fail to thrill the students who come to our planetariums. On the other hand, how many math teachers are lucky enough to have their students "oooo!" and "ahhh!" over their equations?

We can do a great deal to assist our colleagues in mathematics, and they can do a lot to assist us in bringing the finest education possible to our students. We can help with both "real world" and imaginary contexts to teach a wide variety of mathematical concepts, while they can help us broaden our view of what mathematics is all about, and the skills our students need to learn.

Just as science education has been undergoing reform, so too is mathematics. Following are some aspects of this modern reform movement. Think about each one and brainstorm one activity related to astronomy or space science that will help your students develop that concept or skill. Work with a partner and build on each other's ideas.

Calculators

The advent of inexpensive calculators means that students no longer have to spend hours and hours practicing the long division algorithm. They can spend that time instead learning when to divide, or multiply or add, and if division is the operation of choice, which numbers are to be divided by which. Suppose you have a set of calculators in your planetarium. How could you use them?

Estimating

A very important mathematical skill is to estimate the answer to a problem. Especially now that calculators are in common use, it is very easy to misplace a decimal point and get an answer that is off by a factor of 10 or 100! Think of an activity that you can do in the planetarium that require students to make an estimate rather than a precise calculation, then see how close their estimate was.

Number Systems

We are so familiar with the base ten system, that we sometimes forget that it is just one of an infinite variety of number systems. (Would that have been true if we were born with three fingers on each hand?) In astronomy, space science, and computers, the base two (binary) number system is especially useful. Think of an activity that you can do in the planetarium that exercises students' abilities to use a binary or other number system.

Graphing

It takes many years for children to learn how to interpret graphs. One very effective approach is to give them opportunities to make graphs, including histograms, line graphs, and other kinds of graphs. Students can make graphs in the planetarium using clipboards, and see what they are doing with the use of red cove lights which maintain dark adaptation. Work with your partner to think of at least one quantity that students can measure or count in the planetarium, which they can record as a graph.

Geometry

How high is that flag pole? or that bird? or the moon? How far away is a star? One of the most useful methods for measuring distances in astronomy is with the geometry of triangles. Modern applications of geometry to astronomy include the curvature of space-time. Think of an activity that can be done in the planetarium which teaches a skill or concept in geometry.

Big Numbers

Astronomers work with really really big numbers. It is difficult for most people to grasp the size of such numbers, although we certainly try. For example, it makes more sense to most people to think about how many years it would take them to drive to the moon at 60 mi/hr than to just tell them how far it is. Think of an activity to help students grasp the meaning of some very big numbers.

Scale

The concept of scale relates to both geometry and numbers. Recalling a scale model railroad is an excellent way of introducing children to the notion of scale which they already understand intuitively. The classic scaling activity in astronomy is to create a scale model of the solar system which uses the same scale for the diameter and distances between the planets. Most students are amazed at how much space there is in space. Think of an activity that communicates the notion of scale.

C. Connections With Language

Reading and writing are key skills that students must master if they are to succeed in the modern world. In order for science educators to work effectively as team members in the school setting, we must help our students develop their understanding and use of language through science activities.

While there are many different approaches to integrating the teaching of science and language, this module invites you to think about four approaches today: connections with mythology, modern literature, writing, and drama.

Mythology

The mythological roots of astronomy help students understand where some of the ideas we take for granted came from. The most common mythological lessons that are taught in the planetarium involve constellation myths. A less common lesson relates to the myths that ancient peoples invented to describe the universe as a whole, and explain many of the phenomena that they could observe. While these myths were not subject to testing and validation procedures, they were the precursors of scientific theories, and illustrated the marvelous abilities of ancient peoples to synthesize information and invent creative explanations. Work with a partner to devise an activity in which students learn about particular myths, or invent their own myths.

Modern Literature

Connections between modern literature and science abound. One example is an activity entitled "The Trip to Treasure Island," included in Volume 2 of the PASS series, which teaches students to measure their latitude and longitude in the planetarium setting. This activity comes alive through references to the book Treasure Island, which many students adore. The students learn about conversations among mutinous pirates, and have an opportunity to navigate across the ocean to find treasure. Work with a partner to come up with one example of a connection between literature and science that could form the basis of an astronomy or space science activity.

Writing

Writing extensions can be invented for a wide variety of activities. A list of writing extensions can be offered to teachers so they can follow up with their students after a planetarium program. For example, after a program on the solar system, the students can write about what they might see and feel if they visited each of the planets, what they would see if they took a ride on a comet during its journey around the sun. Work with your partner to select a planetarium topic, and then brainstorm at least one writing extension.

Drama

Drama is a powerful technique for involving students in a topic. For example, they might imagine themselves to be contemporaries of Galileo, and act out what it must have been like to look through a telescope at the heavens for the first time. The students could take turns acting out what it would be like to be an evolving star, or work together as an entire class, acting out the birth of the universe. What drama activities can you think of?

D. Connections With Social Studies

Traditional science textbooks and courses often treat science in isolation from the historical, social, cultural, economic, and political context within which it must always operate. Any science program is enriched when you take care to incorporate elements of social studies into your programs. Following are some examples. We invite you to invent your own.

History of Science

The history of science not only humanizes lessons by introducing the people who have created the theories and concepts we present, but also provide insight into the process of human thought, and helps students to better grasp the concepts and theories. Consider, for example, how much students lose when we simply inform them that the earth turns on its axis once in twenty-four hours, and goes around the sun once a year. Hearing about the tremendous battle that Galileo fought on behalf of the Copernican theory that the earth actually moves, helps the students to see that the idea was not so obvious at all! Work with your partner and select an episode in the history of science that you could use as a setting for a science activity in the planetarium.

Politics

One of the most interesting chapters of recent history that combines politics, economics, and science is the history of the Apollo missions to the moon. Initiated by an idealistic President John F. Kennedy in a climate of international competition, the series of Apollo missions were an incredible human achievement. The achievement represented not only the brilliance of engineers and scientists, but the contribution of every American through their support of the political system and tax base. Perhaps the biggest mystery of all, however, is why the highly successful missions were canceled and the Saturn fleet mothballed, after the harvest of scientific information was well underway. Well- prepared students might debate the issue and gain insights into the interaction of science and society through this role playing activity. What other episode do you think would make a good topic for a role play, debate, or other kind of activity that would communicate insights about our political system?

New Social Structures

Space colonies are fertile grounds for imaginative scenarios that would enable students to project their own ideas about government and social groups, and to become more open to different ideas. For example, the students might be asked to meet in small groups to create plans for laying out towns and cities in a space colony of 10,000 colonists. What services would these people need? How about transportation? Communication within the colony and with earth? What social structures are we stuck with on earth that we might change with foreplanning? How would we select personnel for such a colony? What form of government should it have? Work with a partner to invent a particular scenario that might take place on a space colony or another location altogether in order to launch a stimulating class discussion about human society.

E. Connections With Your Students' Heritage

The final topic of this chapter was saved for last because it is perhaps the most important. As a nation, we have recognized that the current crisis in science and mathematics education means that we must educate our population—all of our population—as rapidly and effectively as possible. Yet to do so, we need our students' cooperation. They must be able to see science, mathematics, and other technical fields as a viable option that will lead to the rewards we all expect from life: a steady income, an interesting job, and respect and support from our fellows.

Yet that is not the message that many of our students receive despite our best intentions, because many do not see themselves portrayed in our programs. Perhaps the best known and flagrant example of our failure to include everyone in these fields is the very small proportion of women that are attracted to mathematics and the sciences. Blacks, Hispanics, Native Americans and the disabled are also underrepresented in graduate schools and professional positions in these areas.

Astronomy and space science teachers have the opportunity to increase the pool of individuals who are "turned on" to learning more about the universe, or of finding jobs in space science, engineering, or (heaven forbid) even teaching!

If our students are to see themselves in these roles, they naturally need to see role models—individuals whom they identify as like themselves. For example, the astronaut training corps includes a diversified group of individuals, representing all races. Several prominent women scientists, such as Sally Ride, might be featured in your programs, or the astronomers Henrietta Leavitt, or Margaret Burbidge. Photos and short biographies of Black, Asian, and Hispanic astronauts can be included in programs on the Space Shuttle.

Another approach is the increasing trend in planetarium programs that show the astronomical knowledge of ancient peoples. These programs counter the myth that because the European invaders of the New World were superior in weapons, they were also superior in all matters of science and technology. The field of ethnoastronomy has shown that various groups of Native Americans, Chinese, Egyptians, Polynesians and other peoples had sophisticated calendars, systems of navigation, and regularly observed the heavens. These programs help to kindle cultural pride and increase self-confidence.

People with physical disabilities can be encouraged through examples such as the eminent scientist, Stephen Hawking, who is one of the most creative thinkers of our time. Photos and videos are available which show his sense of humor and his achievements despite a debilitating degenerative disease. Even more important than including disabled role models in programs is to provide access for people in wheel chairs in our planetariums.

Please share your ideas! Meet in small groups to share ways you have discovered to increase the pool of individuals who are ready and willing to participate in the future with enthusiasm and hope. Jot these ideas down below, and increase the list as you hear new ideas that you'd like to try.

Module 9: Devising An Action Plan

The goal of this activity is for you to plan an effective strategy for improving astronomy and space science education in your school, district, or region.

Improving astronomy and space science education is a pretty big task. A good way to start is to decide what part of that task you would like to take on as your personal responsibility. Discuss each of the following questions with a colleague. Help each other to view the challenge as broadly as possible, and to select tasks that you each have a reasonable chance of accomplishing. Write down your answer after discussing each question. Use additional sheets of paper if necessary.

Your responsibilities within your school, district, or region will limit the scope of what you can reasonably hope to accomplish. Take a moment to discuss and write down what these responsibilities are, or could become over the next three years, with regard to the following.

1. What Are Your Responsibilities?

My responsibilities are to improve astronomy and space science education in my_____(classroom, school, district, region).

_____

_____

_____

I have the following responsibilities for curriculum design and adaptation:

_____

_____

_____

Programs that I devise and/or present should conform to the following state or local guidelines for teaching science:

_____

_____

_____

I am expected to deliver the following programs for students each year:

_____

_____

_____

I can reasonably expect to present the following workshops to teachers:

_____

_____

_____

I expect to present the following plans to administrators:

My other responsibilities related to astronomy and space science are: _____

_____

_____

2. What Are Your Goals?

Imagine that it is three years in the future, and you have been enormously successful in achieving your goals with respect to astronomy and space science education. Briefly describe how the following people are different as a result of your efforts.

Primary students (K-3): _____

_____

_____

Upper elementary students (4-6): _____

_____

_____

Middle school students (7-9): _____

_____

_____

High school students (9-12): _____

_____

_____

Teachers: _____

_____

_____

Administrators: _____

_____

_____

Happily, we are not alone. As astronomy and space science educators, we have many other human and material resources on which to draw. Make a list of as many resources you can think of:

3. What Are Your Resources?

Individuals in my school, district, and region:

Other individuals who might help:

Equipment already in my district:

Astronomy and space science text materials:

Equipment I might be able to purchase over the next three years:

Some good astronomy and space science curricula that I can obtain for the classroom and planetarium:

Periodicals that I could use to keep abreast of new developments:

Other resources (museums, corporations, government agencies, etc.):

4. Plan a Course of Action

There are a variety of things that you might do to accomplish your goals. Make a list of what you would like to accomplish over the next three years.

Conducting Teacher Workshops

The power of planetarium programs to motivate and inform students can be greatly expanded through classroom experiences that prepare students before coming to the planetarium, and that reinforce and extend the concepts during the days following the planetarium program. Consequently, the Action Plan that you developed in the first part of this module is likely to include workshops for your colleagues.

Volumes 5 through 8 of the PASS series were developed with a combination of planetarium programs and classroom lessons in mind. In most school districts, achieving this mix requires that the person who is responsible for planetarium programming conduct workshops for teachers who will do the classroom activities with the students. In other school districts, teachers will be involved in presenting planetarium programs, so that a far more extensive training is required for colleagues to learn how to use the planetarium and create their own programs.

In this section, we provide some general tips on arranging and conducting workshops, from brief, two-hour workshops in conducting specific classroom activities, to summer institutes, lasting several days.

Workshops on Presenting Classroom Activities

Starting a workshop with an overall schedule and what you hope to accomplish helps participants to feel comfortable about what is going to happen. If the participants do not already know each other, take a few minutes for introductions.

One rule applies to all presentations: do hands-on activities and start them right away. Like children and other people, teachers learn best by doing. This technique of modeling activities enables teachers to appreciate the problems and triumphs their students are likely to encounter, and to be ready to teach the very next day.

Most workshop situations will not provide enough time for you to model all of the activities you would like to present. We have found that it is better to present one or two activities thoroughly, and give a brief overview of the rest of the units, rather than allot equal but inadequate time for every activity. On occasion it is expedient to demonstrate an activity, without taking time to do the activity completely.

While the most important part of any workshop is doing activities, a dynamic introduction to astronomy and space science will involve a mixture of discussion, activities, and sharing experiences. Timing and variety are very important in maintaining interest. You can alternate activities with discussion about the educational value of those activities. If you have general comments, save them until after the teachers have experienced the activities. Allow time for teachers to share their own experiences. Make sure to plan breaks at appropriate times. Teachers like recess too!

A teachers' workshop requires a room with tables and chairs; theater seating will not do. You will need a table near the front of the room for equipment and demonstration. A table for showing other astronomy and space science materials provides a nice browsing station. A chalkboard is useful.

Plan a way to conclude so participants feel a sense of resolution. This could be done by having them say what they expect will be most useful to them, what

they might need to implement the activities, or if there are other astronomy and space science activities they would be interested in learning about in the future.

If at all possible, provide your participants with written descriptions of the activities you presented and data sheets for use by students, and, if possible, science kit materials. If you present any of the classroom activities in PASS Volumes 5-8, you may photocopy the activity descriptions and all data sheets for your participants. Any way that you can make it easier for the teachers to present the activity to their students will increase the likelihood that the activities will actually occur in the classroom.

Learning how to use a planetarium, presenting participatory programs, and developing new planetarium programs requires an extensive set of skills. However, very successful planetarium presentations can be done by people who have had just a few hours of experience.

Workshops on Presenting Planetarium Programs

Below is a sample agenda for a three-day intensive institute utilizing the entire PASS Series. Presenting the same material in a five-day format would, of course, be much more relaxing.

Day 1

9:00am—Overview and Introductions.

9:15am—**MODULE 1: Communication.**

Teachers switch roles with students and experience different levels of instructor-student interaction.

11:00am—**MODULE 2: Framework for Examining Planetarium Programs.**

Participants describe their own goals and strategies. Group discussion about goals (knowledge, skills, attitudes) and strategies to achieve them.

12:00pm—Lunch Break.

1:00pm—**MODULE 3: Patterns of Organization.**

Meet in the planetarium. A variety of ways to organize the planetarium experience for students are illustrated with excerpts from programs from *PASS Volumes 5-8*.

2:30pm—Break.

3:00pm—**MODULE 4: How the Students See It.**

Activities, slides, and lectures present the different types of reasoning used by students at various stages of intellectual development.

4:00pm—Discuss plans for participant-designed activities.

EVENING SESSION

Participants practice setting up and taking down a portable planetarium, using *PASS Volume 4*.

Day 2

9:00am—**MODULE 4 (continued) How the Students See It.**

10:30am—Presentation of a full participatory program, such as *Red Planet Mars*, followed by a discussion of the program.

11:45am—Lunch Break.

1:00pm—**MODULE 5: Questioning Strategies.**

Participants consider various ways of asking questions to stimulate the students' thinking.

3:15pm—Break.

3:30pm—**MODULE 6: Activities for the Planetarium.**

Various categories of activities can be used, like the various questioning categories, to stimulate different kinds of thinking and learning. Examples previously demonstrated from *Red Planet Mars* and Module 3 are discussed. Participants receive a copy of *PASS Volume 2* which provides many other activities which can be done in the planetarium.

4:00pm—Participants work in small groups to plan their own 5-minute activity for presentation on Day 3.

EVENING SESSION

Participants work on activities to be presented on Day 3, gaining more practice in using the planetarium.

Day 3

9:00am—Participants present and discuss their own activities.

12:30pm—Lunch Break.

1:30pm—**MODULE 7: Creating A Planetarium Program.**

The activities presented in the morning are discussed and classified according to the categories developed during the workshop. Methods for designing a complete program and classroom activities are discussed, and a sample activity is presented.

3:00pm—**MODULE 8: Teaching Across the Curriculum.**

Participants share their own experiences and ideas for using participatory planetarium activities as a vehicle for teaching across the curriculum.

3:30pm—Formative evaluation of this workshop.

4:00pm—Adjourn as a group. Workshop staff available until 5:00pm for individual consultation.

EVENING SESSION

PASS Volume 3 Resources. The teachers have an opportunity to browse through this rich collection of resources for teaching astronomy and space science at the elementary and middle school level. If possible, have actual materials referred to in the guide for them to see. You might end the institute with a "Star Party," using binoculars and telescopes.

A few items on the agenda don't appear in this volume. At the end of each day we had a "wrap-up" of the day's activities. This was an opportunity for the workshop leaders to summarize the material covered, and to express their own views on its importance, and for participants to comment and share related activities that they have done.

On the afternoon of the first day, we discussed plans for "participant-designed activities." This was a popular feature in which the participants worked together in small groups to present short student-participation activities that they use, or think they could use. The participant-designed activities were presented on the final day of the workshop. After live demonstrations in the planetarium, each of the activities was critically discussed in terms of the strategies presented in the workshop. The discussions proved to be a most effective way of reviewing and clarifying the techniques as they apply in actual practice.

The presentation of *Red Planet Mars* on the morning of the second day serves as an example to be analyzed by the techniques of the workshop. "Mars" is a practical example of an audience participation single-visit planetarium show illustrating many of the strategies presented in these modules.

Notes on Presenting the Individual Modules in Volume 1

Here are suggestions for presenting each module in PASS Volume 1. There are also answers to the questions in each. You and the participants in your workshop may disagree with the answers given here. Our goal is to stimulate thinking about the educationally effective techniques for presenting planetarium programs. A healthy amount of disagreement is welcome.

Module 1: Communication

This is a delightful and even amazing activity. You will find that you and the other participants very quickly get into the spirit of the workshop. We have also found this activity makes an excellent social icebreaker.

For every three participants, you will need two crayons or felt tip markers, two manila file folders (to serve as "barriers"), and half a dozen sheets of blank paper. (We recycle used computer paper.) One participant has to play leader and post the master drawings. The masters should be prepared in advance. We usually use simple geometric patterns including some astronomical motifs like the ones shown in Module 1.

Several of the insights that can be gained from this activity are described in the module itself. The use of analogies almost always comes up. The need for instructor-student interaction to check on how your students are understanding and enjoying the program is another major topic.

One technique for communication that may arise is the use of an "advanced organizer." That's a short introduction to the overall message the instructor wishes to communicate to the student. If the advanced organizer is successfully done, it can make students feel more comfortable with what follows. If the advanced organizer is misinterpreted in any fashion, the rest of the lesson may be spent correcting the students' misinterpretation of what is supposed to be happening.

We hope you will enjoy Module 1 as much as we do, and at its end, your workshop participants will have a list of fundamental issues about communication in the planetarium.

Module 2: A Framework for Examining Planetarium Programs

This is a very "talky" unit and may take less time than any other module. There are two main functions of Module 2 in the context of the workshop. First, the module introduces the framework of Topic-Student-Instructor. Looking at interactions between pairs or all three of these elements is the basic pattern of the following modules.

The second function is to let the participants in your workshop describe to each other their own work and goals. We found that the remainder of the workshop went more smoothly if participants knew of their colleagues' interests.

The only materials you need for Module 2 are a blackboard and chalk, or an overhead projector and marking pen for recording the participants' ideas.

This module occasionally catches fire if participants find they have basic philosophical disagreements. At one workshop, participants were equally divided between those who felt that classical, visual astronomy was the only legitimate subject for a planetarium, and those who felt that recent developments in astronomy were most important even if they were not related to what the basic planetarium projector could show.

While we have no resolution to offer, we believe that the techniques in the workshop will help planetarium educators achieve their goals regardless of the particular subjects to be presented.

Module 3: Organization Patterns

Many participants found this the most exciting module because it immediately gets down to practical demonstrations of planetarium education techniques.

One strategy for presenting this module entails the workshop leaders modeling each of the organization patterns in the appropriate example activity. This takes a lot of preparation since the workshop leaders need to prepare the planetarium to present fragments of several different programs. The fragments come from *PASS Volume 2, Activities for the Planetarium*, Activity #7, and from *PASS Volume 5, Constellations Tonight*. Please examine the materials and preparation needed which are fully described in these other *PASS* Volumes. Reading lights are needed for some of the activities. In some cases, under-the-cove lighting was suitable. In other planetariums you may need to use extension cords and half a dozen clamp-on light sockets with red bulbs.

The table that opens Module 3 is to be filled out by the participants as they finish each section of the module. The advantages and disadvantages of each technique will depend greatly on the particular program in which the technique is used, but here are some overall guidelines.

In the Didactic Organization the instructor can select and order all of the ideas to be included in the program, and present them rapidly and efficiently. The principal disadvantage is that the instructor may not know whether any of that information is reaching the student.

The Small Group Task Organization is a good way to start audience participation. This technique has the advantage of providing group support for students who might be intimidated if asked to do the task alone. A disadvantage is that small groups really must be small—preferably three to six people each—so that no student is lost in the group. With huge audiences, this may mean that there are too many groups and that the instructor cannot give each group time to report its results. As with all activity organizations, there is always the difficulty of finding an activity that is sufficiently challenging and at the same time practical for everyone.

In the Individual Task Organization each student's accomplishments can engender a sense of personal pride. Individual tasks work well with either small or large audiences. Hearing a student call out "I got it!" is a delightful confirmation of the benefits of this organization. A disadvantage of this technique is the possibility that some individuals may not succeed at their assigned task. This danger can be avoided by carefully selecting and testing each activity.

The Informal Discussion Organization gives students an opportunity to express their feelings and reduce the formality and rigid structure of the planetarium visit. Students also appreciate the opportunity to confirm their feelings about how a program or activity is going. This organization, however, gives you no guarantee of just what will happen, and indeed, whether the informal discussion is valuable or not may vary from group to group.

The Group Meeting Organization allows students to talk with each other in a controlled atmosphere with clear goals in mind. The group may amaze itself with its ability to find answers that no one member of the group could have determined alone. The group meeting does require some skill on the part of the facilitator. The group may take a long or a short time to reach its conclusions, so this organization may not be easy to fit into a rigid time schedule.

The Socratic Organization is like the didactic in that the instructor controls the progress and the rate of information presented. Unlike the didactic organization, however, the questions and students' responses in the socratic scheme allow some student participation and give the instructor continuous feedback on how well the responding students are following the program. This technique does require great skill on the part of the instructor so that the organization does not become too authoritarian and intimidating.

An easier strategy for presenting this module is suggested by Jacqueline Hall. In this approach, the workshop participants model the Patterns of Organization. Participants work in small groups (6-7 per group). They are not required to read every strategy, and yet they have the opportunity to learn about and identify each of the strategies. This method takes about an hour and a half.

1. Divide into small groups with 6 or 7 people per group. Assign each person in the group a number from 1 to 6. There may be two members with the number 1 if the group has 7 people in it.
2. Give all the #1 members "Didactic" strategy description; give the #2 members "Small Group Task;" give the #3 members "Individual Task;" give the #4 members "Informal Discussion;" give the #5 members "Group Meeting;" and give the #6 members "Socratic." While they are in the whole group setting, have them read the strategies independently.
3. Have six areas for participants with the same number can meet and informally discuss their strategies. Within these groups they will plan a method for presenting/teaching the assigned strategy to the whole group. Group members will also fill out the enlarged Organizational Patterns chart which will be posted at the front of the room. This step takes about 15-20 minutes.
4. Have all the groups reassemble in the main meeting area. At this time, give everyone a copy of the Organizational Patterns chart. Each group models their method for presenting with the assigned strategy. Participants take notes on their charts. Problems, suggestions, and questions can be discussed in this group setting.

◄

Materials needed are:

- **Organizational Patterns chart (p. 8) — one per group.**
- **One enlarged Organizational Patterns chart on chart paper or overhead transparency.**
- **One set of marking pens.**
- **Paper and pencils for each group.**
- **Pre-cut organizational strategy descriptions (from pp. 8-12; one per participant)**

As a nonthreatening form of evaluation, the questions on page 13 can be used as a "quick-quiz."

The authors' answers for the examples of organization skills on the last page of the module are: 1) Socratic, 2) Didactic, 3) Individual Task, 4) Small Group Task, 5) Group Meeting, and 6) Informal Discussion.

Module 4: How the Students See It

This is the most theoretical and perhaps the most fundamental module because it presents a serious philosophy about how people learn. The applications that have been found for these theories go far beyond the planetarium, and participants may find these ideas useful both inside and outside of a starry dome.

The required materials are those to set up the "Martian Dilemma Problem." You will need three small spheres on stands. Styrofoam balls and cardboard or wooden mounts will do. You also need a small plastic or paper figure to stand on the Mars sphere and a bare light bulb to represent the sun.

Many of the questions asked in this module are answered in the text itself. On page 28, Question 1 should be answered "egocentric" and "formal." For Question 2, a student would have to imagine himself observing the objects in each picture from within the plane of the picture itself to understand the concept. That's a formal level task, but it could be made concrete if a three-dimensional model of a spiral galaxy could be passed around the audience or if a continuously rotating projection could be shown so that the students actually see a single galaxy as their observation point moved in and out of the galactic plane. The figure on Page 29 clearly requires formal level reasoning because the sets of individual pictures can be understood only if the student realizes that they are presented from three different frames of reference.

On Page 33, the explainer in the center of the first frame is thinking egocentrically. In the second cartoon, the wizard on the right is displaying formal reasoning.

In Section D, Classification 1 is Formal, 2 is Concrete, 3 is Concrete, and 4 is Egocentric.

Module 5: Questioning Strategies

Many participants found the strategies described here to be as useful in classroom work as in the planetarium. Questions and answers are useful both as an alternative to didactic lectures and as a means of finding out what your students know.

The main difficulty with this module is that the categories of questions are not ironclad, and it's easy to get into arguments about how a particular question should be classified. However, the process of analyzing one's own questioning strategy is extremely useful even if the category system is not precise. This is another "talking" module, and no physical materials are required. On page 48, we would classify the questions in the sample transcript as: 1) D, 2) M, 3) O, 4) O, 5) D, 6) D, 7) M, 8) R, 9) F, 10) M.

Module 6: Activities for the Planetarium

Module 6, like Module 3, gets down to practical examples of activities in the planetarium. Three sample activities are discussed, all from The Red Planet Mars program given earlier. Please consult PASS Volume 6, pages 3-5 for a list of materials that you will need. You must determine whether the planetarium projector has a satisfactory Mars for the first activity.

We expanded this module by inviting participants to work on a "small group task" to develop and present an activity to their colleagues. We limited each presentation to fifteen minutes, followed by fifteen minutes of open discussion about how the activity might be expanded, improved, and incorporated into an entire program. For many of the participants, the presentation and discussion of these activities was the highlight of the workshop.

We would classify the three sample activities from *The Red Planet Mars* as follows.

Activity	Pattern of Organization	Reasoning Level	Activity Strategy
Find the Planet	small group task	concrete	synthesizing
Mapping Mars	small group task	concrete	direct info
Exobiology	individual task	concrete	open-ended

Module 7: Creating a Planetarium Program

Module 7 is a review of the entire workshop. To provide examples of how the concepts presented in the modules are applied, we found it useful to center discussion around the participants' activities, presented in Module 6.

Before beginning the discussion, draw an Outline like that on page 66, on a blackboard or overhead projector. In the left-hand column, list each of the activities that were presented. When the group assembles, start by briefly reviewing the categories developed in Modules 3, 4, and 5, which form the headings for the next three columns of the Outline. Then, present the "group meeting" task of classifying each activity according to the categories listed at the head of each column. Your job is to facilitate the discussion and list one or more answers for each cell in the Outline.

According to many of the participants, this final discussion was the most helpful of the workshop in understanding the implications of many of the techniques that were presented in previous sessions.

If there is sufficient time you might wish to present one of the classroom activities that are described at the end of each of the planetarium programs *PASS, Volumes 5-8*. One of the most popular activities, that can be done in about a half-hour, is "Creatures From Omicron," described in *PASS Volume 6*.

Module 8: Teaching Across the Curriculum

Module 8 provides opportunities for the participants to share what they already do, and to build on each others' ideas in using the planetarium as a tool for teaching a broad range of subjects.

Organize the participants into pairs or small groups who will read each section and brainstorm ideas. Tell each group to appoint a recorder who will take notes. Allow all the groups to work at their own pace, but walk around the room, keeping tabs on how they are doing. If a group appears to be spending too much time on one topic, urge them to finish the module and return to that topic later if there is time.

After about 45 minutes, convene into a large group and have the participants share insights and ideas. Structure the discussion so that all groups share their ideas about the first topic before going on to the next area of the curriculum.

When Your Workshop Is Over

We recommend that you prepare an evaluation form on which participants can indicate what they liked and didn't like about each module. A summary of these evaluation forms will be very useful to you or to any of the participants who may wish to present a workshop in the future.

Finally, we'd like to hear what happened. Your experiences can help us improve these materials, and we'll pass your comments on (if you wish) to others who may be trying their own versions of the workshop. Our address is on the back of the title page.

Appendix: Workshop and Institute Participants

In l977, we obtained support from the National Science Foundation to develop and implement workshops to share these techniques with the planetarium community. We prepared a first draft of this workshop guide and presented five workshops during the summer of 1978, at Berkeley, California; Staten Island, New York; Cleveland, Ohio; Herndon, Virginia; and Dallas, Texas. In 1989 and 1990, four 3-week-long institutes were conducted in Oakland, California, by Lawrence Hall of Science and New York Hall of Science. Each institute had 25 teacher-leader participants. The grant was renewed for the summers of 1992, 1993, and 1994. All of the participants have suggested improvements that were included in drafts of this guide. The workshop participants are now prepared to present this program to their colleagues. The particular workshops or institutes in which the individuals participated are given parentheses.

CANADA

Claude Faubert, Ontario Science Center, Ontario, Canada (1978)

Allan Fawcett, Centennial Planetarium, Calgary, Alberta, Canada (1978)

John Musgrave, Provincial Museum of Alberta, Alberta, Canada (1978)

NORWAY

Marit W. Pettersen, Tromsdal Skole, Th. Widdins Vei, N-9020 Tromsdalen, NORWAY (1989)

PUERTO RICO

Delores Balzac, University of Puerto Rico, Physics Department, Mayaguez Campus, Mayaguez, Puerto Rico (1978)

Richard Hugh Roettger, Ramey School, Ramey, Puerto Rico 00604 (1994)

SAMOA

Sosone Faiai, Manulele-Tafuna Elementary School, American Samoa Government, P. O. Box 3417, Pago Pago, American Samoa (1990)

SPAIN

Fernando Gruas Ibanez, Generalitat de Catalunya, Departament d"Ensenyament, Spain (1994)

US Virgin Islands

Patricia Hodge, Emanuel Benjamin Oliver School, St, Thomas, US Virgin Islands 00801 (1994)

USA

Alabama

Anita Ard-Jordan, Mobile Public Schools,Mobile, Alabama (1994)

Anna M. Goodson, Leeds Elementary School, Leeds, Alabama 35094 (1994)

Dianne Sirmon Martin, Environmental Studies Center, Mobile, Alabama 36693 (1992)

Harriet Wesley, Univ Place Elem, Huntsville, AL (1993)

Alaska

Ted Pederson, The Imaginarium, Anchorage, Alaska 99517 (1992)

Stephanie Rudig, Weller Elementary, Fairbanks, AK (1993)

Arkansas

Roberta May, Carver Magnet School, Little Rock, Arkansas 72202 (1992)

Mary Lou Kahler, Washington Magnet School, Little Rock, AR 72206 (1992)

Homer Peters, Marion JHS, Marion, AR (1993)

Gordon Smith, AHLF JHS, Searcy, AR (1993)

Arizona

Ruby Bjornholt, Rhodes, JHS, Mesa, AZ (1993)

Robert Campbell, Cartwright Preschool & Gifted Center, Phoenix, AZ 85031

Juanita Diggins, Santa Clara Elementary School, Tucson, AZ 85706 (1994)

Bill Smith, Science Resource Center, Mesa Public Schools, Mesa, AZ (1990)

California

Diane Bonilla-Lether, Nightingale Middle School, Los Angeles, CA 90065 (1994)

Gail Chaid, Independence High School Planetarium San Jose, California 95133 (1992)

Lorene Crawford, Fuerte Elementary, El Cajon, CA 92019 (1992)

Edna K. Devore, Independence HS Planetarium, San Jose, CA (1978)

Barbara Emberson, Sacramento Science Center, Sacramento, CA 95821 (1992)

Alan J. Friedman, Holt Planetarium, Lawrence Hall of Science, University of Calif., Berkeley, CA (1978)

Michael Guelker-Cone, Jackson Elem, Fresno, CA (1993)

Jacqueline A. Hall, Moreno Valley Unified School Dist., Moreno Valley, CA (1990)

Jean Henry, Shreder Planetarium, Shasta County Schools, Redding, CA (1978)

James G. Jones, Valley View School, Coachella, CA (1990)

Anne Kennedy, Las Flores Environmental School, Hesperia, CA (1990)

Victoria Lindsay, San Francisco State University Planetarium, San Francisco, CA (1978)

Lawrence Lowery, School of Education, Tolman Hall, University of CA, Berkeley, CA (1978)

Jim McDonald, Monte Gardens Elementary, Concord, CA (1993)

Karol L. McQuery, 186th St. School, Gardena, CA (1989)

Cheryl J. Moxley, Lake Arrowhead Elementary, Lake Arrowhead, CA (1990)

Anne Marie Nelson, South Oceanside Elementary School, Oceanside, CA (1990)

James Park, San Luis Obispo Senior High School Planetarium, San Luis Obispo, CA (1978)

Rita A. Perre-Davis, Hinkley School, Hinkley, CA (1990)

Richard Poremba, Astronomy for America, Inc., San Bruno, CA (1978)

Steven Pulos, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA (1978)

Michael Rafferty, Castle Park MS, Chula Vista, CA (1993)

Sonia Silva, Science Center, Sierra College, Rocklin, CA (1978)

Cary I. Sneider, Holt Planetarium, Lawrence Hall of Science, University of California, Berkeley, CA (1978)

Marvin J. Vann, Foothill College Planetarium, Los Altos Hills, CA (1978)

Don Warren, City College of San Francisco, San Francisco, CA (1978)

Lori Warren, Rosicrucian Planetarium, San Jose, CA (1978)

Kingsley Wightman, Chabot Science Center, Oakland, CA (1978)

Kenneth Wilson, Morrison Planetarium, Golden Gate Park, San Francisco, CA (1978)

Kay Woolsey, Santa Barbara Museum of Natural History, Santa Barbara, CA (1978)

Colorado

Richard Baker, Olathe Elementary, Montrose, CO (1993)

James G. Beaber, Ft. Lupton High School, Ft. Lupton, CO (1989)

Cindy Beller, South Park Elementary, Pueblo, CO (1990)

Tina Farmer, Academy Charter School, Castle Rock, CO 80104 (1994)

Rhea Joyce Hill, Thornton Middle School, Thornton, CO 80229 (1994)

Betty Moellenberg, Idalia School, Idalia, CO 80735 (1994)

Charles Percival, Venus Planetarium, Pueblo, CO (1978)

Mark S. Sonntag, Fiske Planetarium, University of Colorado Boulder, CO (1978)

Connecticut

James Backus, Rogers Park Middle School, Danbury, CT 06810 (1994)

John S. Boccuzzi, Rippowam Center, Stamford Public Schools, Stamford, CT (1990)

Rachel P. Fitch, New Canaan High School Planetarium, New Canaan, CT (1978)

Russell Harding, Norwalk High School, Norwalk, CT (1990)

John F. Lindholm, Gengras Planetarium, Hartford; New Milford High School Planetarium, New Milford, CT (1978)

Pauline Stankey, High Horizons Magnet School, Bridgeport, CT 06610 (1994)

Delaware

Henry Bouchelle III, Colonial School District Planetarium, New Castle, DE (1990)

Nancy DiBiaso, Forest Oak Elementary School, Newark, DE 19711 (1994)

Jeffrey L. Feidler, P.S. du Pont School, Wilmington, DE (1990)

Helen K. Moncure, Christiana High School Planetarium, Newark, DE (1978)

Florida

Chet Bolay, Cape Coral High School, Cape Coral, FL 33991 (1992)

Stephanie Holmquist, Great Explorations, St. Petersburg, FL (1989)

Nedra A. Lexow, Discovery, Ft. Lauderdale, FL (1978)

Barbara Lopes, Oakridge Elem, Hollywood, FL (1993)

Thomas J. Sarko, Palm Beach Day School, Palm Beach, FL (1990)

Suezan Turknett, Shadeville Elem, Crawfordville, FL (1993)

Georgia

Linda E. Delano, Simpson Middle School, Marietta, GA (1989)

Robert B. Delano, William Milton Davis Elementary, Cobb County Public Schools, Marietta, GA (1989)

Dennis Holt, Fairplay MS, Douglasville, GA (1993)

Kenneth Watkins, Pioneer RESA, Cleveland, GA (1990)

Gwendolyn Williams, W. L. Parks Middle School, Atlanta, GA 30310 (1994)

Cheryl A. Zimmerman, National Science Center, Ft. Gordon, GA (1990)

Hawaii

Katherine Fujii, Bishop Museum Planetarium, Honolulu, HI 96720 (1992)

Janet Luh, Hawaii District Office, Hilo, Hawaii 96720 (1994)

Idaho

Steve Holland, Craters of the Moon National Monument, Rock Creek Nature Center, Arco, Idaho (1978)

Mary Post, Whittenberger Planetarium, Caldwell, ID 83605 (1992)

Illinois

Barbara Bergmann, Summit Hill School District #161, Frankfort, IL 60423 (1992)

Vivian Crawford, Hufford Junior High School, Joliet, IL (1990)

Linda Hall, Educ. Service Center #11, Macomb, IL (1993)

Susan Hudson, Discovery Center Museum, Rockford, IL (1990)

Kathleen Nassery, Quincy Public Schools, Quincy, IL 62301 (1992)

Georgia Neff, Lakeview Museum, Peoria, IL (1989)

Zoris Soderberg, Daniel Webster Elementary School, Chicago, IL 60624 (1994)

Indiana

Jon Bennett, East Side Elementary, Bluffton, IN 46714 (1992)

Susan Bickel, Rossville Elementary, Rossville, IN 46065 (1992)

Sheryl J. Braile, Burtsfield Elementary, West Lafayette, IN (1989)

Dayle L. Brown, Hudson Lake Elementary, IN (1989)

Robert J. Ernst, Young Junior High School, Mishawaka, IN (1990)

Dan Goins, Martinsville High School, Martinsville, IN (1989)

Jennie Howe, Washington Township Planetarium, Indianapolis, IN (1978)

James V. Pierce, Floyd Central Planetarium, New Albany, IN (1989)

Diann Robinson, St. Boniface Middle School, Lafayette, IN (1989)

D. Keith Shafer, Lawrence North High School, Indianapolis, IN (1990)

Elvia Solis, Meridian Middle School, Indianapolis, IN 46217 (1992)

Linda Vines-Bright, Indiana DOE, Indianapolis, IN (1993)

Sara Wells, Central Elementary School, Martinsville, IN (1989)

Iowa

Alice Clinton Boyd, Cattell Elementary School, Des Moines, IA 50316 (1994)

Dr. John B. Cook, Area Education Agency 6, Marshalltown, IA (1989)

Denny Eige, Franklin Elementary, Marshalltown, IA (1989)

Bonnie A. Hopkins, Sunnyside School, Burlington, IA (1990)

Joe R. Moore, Keystone Area Education Agency, IA (1990)

Kansas

Sharon Crouch Adams, Heritage Elementary, Olathe, KS (1989)

Stan Adams, Black Bob Elementary, Olathe, KS (1989)

Mary Jane Butler, Hutchinson Planetarium, Hutchinson, KS (1978)

Mike Ford, Holton High School, Holton, KS 66436 (1994)

Mark Jarboe, Shawnee Hts HS, Tecumseh, KS (1993)

Robert Pearce, Cherryvale Middle School, Cherryvale, KS 67335 (1992)

Linda Weichel, Kickapoo Nation School, Powhattan, KS 66527 (1994)

Samuel Wine, Eureka Junior-Senior High School, Eureka, KS 67045 (1992)

Dean Zollman, Department of Physics, Kansas State University, Manhattan, KS (1978)

Kentucky

Sandra Darnell Audubon Elementary, Owensboro, KY (1993)

Patsy Gilmore, Hager Elementary, Ashland, KY 41102 (1992)

Benjamin Malphrus, Morehead State University, Morehead, KY 40351 (1992)

Normia Stevens, David Williams Middle School, Louisville, KY 40216 (1994)

Louisiana

Isadore Inman, St. Martin Planetarium, St. Martinville, LA (1989)

Gary D. Kratzer, Maplewood Middle School, Sulphur, LA 70663 (1989)

Marie Montgomery, East Baton Rouge Parish School Broad, Baton Rouge, LA (1990)

Judy O'Dell, Peabody 6th Grade Center, Alexandria, LA (1993)

Nancy Rideaux Key Elementary, Sulphur, LA (1993)

Patrice Pruitt Saucier, I. S. Cooley Magnet School, Lake Charles, LA (1989)

Jesse W. Scott, Arabi Park Middle School Planetarium, Arabi, LA (1978)

Maine

Paula McAfee, Fifth Street Middle School, Bangor, ME 04401 (1994)

Maryland

Jane A. Bubeck, Patapsco Middle School Planetarium, Ellicott City, MD (1978)

David Candey, Jr., Oberlin College Planetarium, Oberlin, Ohio (1978)

Lora Chamblee, North East High School Planetarium, Elkton, MD (1978)

Teresa Dempsey, J. Frank Dent Elementary School, Ft. Washington, MD 20744 (1994)

Joseph DiRienzi, Kathleen Price Bryan Planetarium, Baltimore, MD (1978)

Rodney Martin, Washington County Planetarium, Hagerstown, MD 21740 (1992)

Edwin Saunders, Tench Tilghman Elementary School, Baltimore, MD 21205 (1994)

Massachusetts

W. Russel Blake, Plymouth-Carver Planetarium, Plymouth, MA (1978)

Michael Burke, Plymouth-Carver Planetarium, Plymouth, MA (1978)

Jose Cantillo, Fort River Elementary, Amherst, MA (1993)

Jo Ann Coplin, Basset Planetarium, Dept. of Astronomy, Amherst College, Amherst, MA (1978)

Kelly Fitzgerald, Decius Beebe ES, Melrose, MA (1993)

Greg Gansz, Learning Technologies, Inc., Cambridge, MA (1993)

Stephen Jackson, Stoneham High School, Stoneham, MA (1989)

George "Skip" Price, Frontier Regional Sch., South Deerfield, MA (1993)

Frank Scofield, Kennedy Memorial MS, Waltham, MA (1993)

Mary V. Velluto, North School Elementary, Stoneham, MA (1989)

Michigan

Garry Beckstrom, Exhibit Museum Planetarium, University of Michigan, Ann Arbor, MI (1978)

Ruth Cummins, Miami Elementary, Clinton Twp., MI (1993)

Beverly Palo, L'Anse Creuse Public School, Mt. Clemens, MI (1990)

Steve Rea, Plymouth Canton High School, Plymouth, MI (1990)

Dwight Sieggreen, Cooke Middle School, Northville, MI 48167 (1994)

Minnesota

LaReau Carlson, Central Junior High School, Alexandria, MN (1990)

Randy Furman, Milaca Intermediate School, Milaca, MN 56353 (1994)

Richard Hinrichs, BOLD Junior High School, Bird Island, MN (1990)

Chelen Johnson, Breck School, Minneapolis, MN 55422 (1992)

Joyce A. Kloncz, Valentine Hills Elementary, Arden Hills, MN (1989)

Lawrence B. Moscotti, Como Planetarium, St. Paul, MN (1978)

Bradley Randall, Osseo Junior High, Osseo, MN (1990)

Missouri

Jody Bay, Volker Learning Magnet, Kansas City, MO (1993)

Bob Bihr, Rock Bridge Senior HIgh, Columbia, MO 65203 (1992)

Bess J. Ellis, Carmen Trails Elementary School, Manchester, MO (1990)

Susan Hayden, North Rock Creek/ Korte Academy, Independence, MO (1993)

Judy Shubkagel, Marlborough Science & Math Magnet, Kansas City, MO 64131 (1992)

Mississippi

Wilma Butler, Lake Elem, Jackson, MS (1993)

Delphine Williams Colman, Siwell Road Junior High School, Jackson, MS (1990)

Carolyn Fowler, Grove Street Elementary School, Vicksburg, MS 39180 (1994)

Missouri

Wilma Slaughter, Hixson Middle School, Webster Groves, MO 63119 (1994)

Montana

Sherry Marsillo, Meadow Hill Middle School, Missoula, MT 59801 (1992)

Amy Rusek, Frank Brattin Middle School, Colstrip, MT 59323 (1994)

Nebraska

Judith M. Brown, Rockbrook School, Omaha, NE (1989)

Norman Melichar, Holling Heights Elementary, Omaha, NE (1989)

Gale A. Miller, Friend Public School, Friend, NE (1989)

Henrietta Pane, Westgate Elementary School, Omaha, NE (1989)

Carl Rump, Dale Planetarium, Wayne State College, Wayne, NE (1978)

Dirl H. Steffe, Chadron State College Planetarium, Chadron, NE (1978)

Bart Wormington, Millard Junior High School, Omaha, NE (1989)

Nevada

Carolyn Dufurrena, Denio Elementary, Denio, NV (1993)

Dave Hostetter, Fleischmann Atmospherium and Planetarium, University of Nevada, Reno, Nevada (1978)

Dorothy Moore, Caughlin Ranch Elementary, Reno, NV 89509 (1992)

New Jersey

Rosendo Abreu, C.S.D. Planetarium at I.S. 184, Union City, NJ (1978)

Levelle E. B. Alexander, Liberty Science Center, Jersey City, NJ (1990)

Mary Capriotti, Buena Regional High School, Buena, NJ 08310 (1992)

Terry Dunn, Hawes School, Ridgewood, NJ 07450 (1992)

Carol Gentalen, Ridge Ranch Sch., Paramus, NJ (1993)

Karl Hricko, Carteret High School, Carteret, NJ 07008 (1992)

Edward O'Connor, Watchung School, Montclair, NJ 07042 (1994)

Beverley Pierson, H. C. Sharp, Camden, NJ 08105 (1994)

Higinio D. Rodriguez, C.S.D. Planetarium at I.S. NJ (1978)

Mark Worobetz, Sparta High School, Sparta, NJ 07871 (1992)

Tena R. Wright, Supervisor's #9, Deerfield Terrace School No. 9, Linden, NJ (1990)

New Mexico

Alberta Brown, Laguna Elementary School, New Laguna, NM 87026 (1994)

Sara Corlett-Roberts, Capshaw MS, Sante Fe, NM (1993)

Rosamund Evans, Torreon Day School, Cuba, NM 87013 (1994)

Kathy Price, Naaba Ani Elementary, Bloomfield, NM 87413 (1992)

Raymond Richard Romero, Carroll Elementary School, Bernalillo, NM 87004 (1994)

Barbara Roybal, Pojoaque MS, Santa Fe, NM (1993)

Patsy Trowbridge, Space Center, Alamogordo, NM (1993)

New York

Steven M. Bernstein, P.S. 24 Planetarium, Bronx, NY (1978)

Terry Buchalter, Northeast Bronx Planetarium, Bronx, NY (1989)

Sadie Caldwell-Crenshaw, PS #161, New York, NY (1993)

Jacques Chaput, Arlington Elementary School, Poughkeepsie, NY (1989)

Victor Chung, Physics Department, City College of New York, NY (1978)

Tyra Clyburn, M L King Jr., Sch #9, Rochester, NY (1993)

Frederick A. Fisher, Red Hook Central School, Red Hook, NY (1989)

Juan Fonseca, I.S. 184, Bronx, NY (1978)

Lawrence Glass, Deer Park Public Schools, Deer Park, NY (1990)

Michael Gosiewski, Marlboro Central High School, Marlboro, NY (1978)

Joann Bryant Green, Public School 327, Brooklyn, NY 11223 (1992)

Tom Hamilton, Wagner College Planetarium, Grymes Hill, Staten Island, NY (1978)

Eugene G. Harple, Lindenhurst Schools Planetarium, Lindenhurst, NY (1978)

Allan Hirsch, JHS 240, Brooklyn, NY (1993)

Bill Kinsella, Schenectady Museum Planetarium, Schenectady, NY (1978)

Kent T. Leo, I.S. 184—District 7, Bronx, NY (1978)

Billie Leveson, Bemus Point Central School District, Bemus Point, NY (1990)

Rose Loftin, PS 125, New York, NY (1993)

Glyn Marryshow, Intermediate School 271, Brooklyn NY 11223 (1992)

Charles S. Neleson, Kryger Planetarium, PS 31, Plainview, NY (1978) (1989)

Steven Orcutt, Webster Central School District, Webster, NY 14580 (1994)

Sue Reynolds, Onondaga-Cortland-Madison BOCES, Syracuse, NY (1989)

Maureen A. Rice, Onondaga-Cortland-Madison BOCES, Syracuse, NY (1989)

Murray Spindel, Freeport High School Planetarium, Freeport, NY (1978)

Samuel A. Storch, Edwin P. Hubble Planetarium, E. Murrow High School, Brooklyn, NY (1978)

Peter J. Thomas, Peerskill High School, Peerskill, NY (1989)

Lorna Waddell-Kremer, Monroe #2-Orleans BOCES, c/o Strasenburgh Planetarium, Rochester Museum & Science Center, Rochester, NY (1989)

Carmen M. Williamson, P.S. 30/31 Manhattan, New York, NY (1989)

North Carolina

Scott Niskach, Nature Science Center, Winston-Salem, NC 27105 (1992)

Michael C. Jackson, Camp Lejeune Dependents' School, Camp Lejeune, NC (1990)

Ohio

Robert Andress, Warrensville Heights High School Planetarium, Warrensville Heights, OH (1978)

William Badders, Cleveland Pub. Schs., Cleveland, OH (1993)

Ron Derewecki, Coshocton Public Schools Planetarium, Coshocton Middle School, OH (1978)

Joan W. Hall, Summit Country Day School, Cincinnati, OH (1989)

Bill D. Kobel, Fairview High School Planetarium, Fairview Park, OH (1978)

Bud Linderman, Midpark Planetarium, Middleburg Heights, OH (1978)

Gary E. Mechler, Cincinnati Museum of Natural History, Cincinnati, OH (1978)

Carolyn Peel, Longfellow Middle School, Massillon, OH 44646 (1992)

Gloria Smith, Amherst Elem, Massillon, OH (1993)

Nancy A. Varian, East Canton Elementary, East Canton, OH (1990)

Elissa Young, Oakdale Elementary School, Barberton, OH 44203 (1994)

Oklahoma

Dayna Bryant, Kirkpatrick Plan., Oklahoma City, OK (1993)

Jolene Ingram, Oklahoma City, OK (1978)

Ron P. Olowin, Omniplex, Kirkpatrick Planetarium, Oklahoma City, OK (1978)

Cindy Strathman, Vance Elementary, Findlay, OH 45840 (1992)

Oregon

Gary M. Bogner, H.C. Kendall Planetarium, Oregon Museum of Science and Industry, Portland, OR (1978)

Cheri Clausen, Aiken Elem, Ontario, OR (1993)

Darien Gould, Lane Educational Service District, Eugene, OR (1989)

Ken Krause, tubman Middle School, Portland, OR 97267 (1992)

Dr. Sam Miller, Leonardo DeVinci Alternative, Eugene, OR (1989)

Karen Schofield, Talent Middle School, Talent, OR 97540 (1992)

Pennsylvania

Ismael "Izzy" Alvarez Hamilton School, Lancaster, PA (1993)

Michael A. Angelo Jr., W. Robert Paynter Elmentary, Pittsburgh, PA (1989)

Susan Blanco, Springfield Elementary, Quakertown, PA 18951 (1992)

Nancy Burkhardt, Cathedral Center, Erie, PA (1990)

Paul R. Conway, Glendale Junior-Senior High School, Flinton, PA (1990)

Henry D. Dobson, Central Colombia High School Planetarium, PA (1978)

David Farina, St. Anne School, Philadelphia, PA 19125 (1994)

Robert O. Jesberg, Klinger Jr. High School, Southampton, PA (1989)

Donald O. Knapp, McDonald Elementary, Warminster, PA (1989)

Jack Lefkowitz, Interboro Senior High School Planetarium, Prospect Park, PA (1978)

Gerald L. Mallon, Methacton School District Planetarium, Arcola Intermediate School, Norristown, PA (1978)

Hazel Nestleroth, Doe Run Elem, Manheim, PA (1993)

Thomas P. O'Brien, Fels Planetarium, Philadelphia, PA (1978)

George Reed, West Chester University Planetarium, West Chester PA (1978)

Ruth Ruud, Chestnut Hill School, Erie, PA 16509 (1992)

Deborah K. Seng, Cathedral Prep School, Erie, PA (1989)

Timothy S. Spuck, Oil City Senior High School, Oil City, PA (1990)

Thomas Charles Stec, Central Bucks Planetarium, Buckingham, PA (1989)

William White, Fort Couch Middle School, Upper St. Clair, PA (1990)

South Carolina

Charles Phillip (C. P.) Gause, Virginia Pack Elementary School, Columbia, SC 29204 (1994)

Garrison Hall, Taylors Elementary, Taylors, SC 29687 (1992)

Arthur Holmes, Cahrles Cotesworth Pinckney Elementary, Ft. Jackson, SC 29207 (1994)

Rex Smith, Roper Mountain Science Center, Greenville, SC 29615 (1992)

South Dakota

Terry Lewis, South Dakota Discovery Center and Aquarium, Pierre, SD 57501 (1994)

Tennessee

Janet Smith, Chattanooga Vly MS, Chattanooga, TN (1993)

Texas

Barbara Baber, Morgan Jones Planetarium, Abilene, TX (1978)

Christine Castillo-Comer, Longfellow Middle School, San Antonio, TX 78228 (1992)

Jim Clements, St. Mark's Planetarium, Dallas, TX (1978)

Susan Forthman, Hoelscher Elementary, San Antonio, TX 78226 (1992)

Wynn Godwin, Richardson I.S.D. Planetarium, Richardson TX (1978)

John Hicks, Mariam Blakemore Planetarium, Midland, TX (1978)

Lecie Huff, Richardson I.S.D. Planetarium, Richardson, TX (1978)

Lois Hunt, Christie Elementary, Plano TX (1990)

Keith H. Johnson, Poole Planetarium, Odessa College Odessa, TX (1978)

Eloise Koonce, Richardson I.S.D. Planetarium, Richardson, TX (1978)

Bill Lawson, Garland I.S.D. Planetarium, Garland, TX (1978)

Roy Anthony Narvaez, Rudder Middle School, San Antonio, TX 78240 (1994)

Sandy Nobles, Richardson I.S.D. Planetarium, Richardson, TX (1978)

Jack C. Pemberton, La Porte High School Planetarium, La Porte, TX (1978)

Donna C. Pierce, Dallas Health and Science Museum, Dallas, TX (1978)

John Pogue, Grand Prairie I.S.D. Planetarium, Grand Prairie, TX (1978)

Scott Pohl, Nimitz High School Planetarium, Irving, TX (1978)

Denise M. Ralph, Goodnight Jr. High School, San Marcos, TX (1990)

Dr. Glenda F. Roberson, Univ. of Texas at Tyler, School of Ed. & Psychology, Tyler, TX (1989)

James Rusk, Mesquite I.S.D. Planetarium, Mesquite, TX (1978)

Barbara Soder, Dallas Health and Science Museum, Dallas, TX (1978)

Patricia A. Thielemann, Leon Wolters Bldg., Deer Park, TX (1990)

Holly Trantham, Langford Elementary School, Austin, TX 78744 (1994)

Gail Tynes Brushy Creek Elementary, Round Rock, TX (1993)

Jane Wallace, Witchita Falls Museum and Art Center Planetarium, Witchita Falls, TX (1978)

Walter Wilholt, Haynes Elementary, Lubbock, TX (1989)

Utah

Irvin G. Bassett, Brigham Young University, Provo, UT (1978)

Robert Hillier, Sunset JHS, Sunset, UT (1993)

William H. Lowry, Logan, UT (1978)

Vermont

Debra Paul, Tuttle Middle School, Burlington, VT 05401 (1994)

David White, Barre Town Elementary School, Barre, VT 05641 (1994)

Virginia

Darrel G. Ardoin, W.T. Woodson High School Planetarium, Fairfax, VA (1978)

Bonnie Bracey, Arlington Career Center, Arlington, VA 22204 (1994)

Albert Byers, Virginia Tech, Blacksburg, VA 24061 (1994)

Elvira A. Euler, West Springfield Planetarium, Springfield, VA (1978)

George W. Hastings, Mathematics and Science Center, Richmond, VA (1990)

Linda Hawkins, Asbury Elem, Hampton, VA (1993)

Lee Ann Hennig, Fort Hunt High School Planetarium, Alexandria, VA (1978)

Evelyn Holmes, Aberdeen Elem, Hampton, VA (1993)

Richard L. Joyce, Penninsula Astronomy Society, Newport News, VA (1978)

John W. Kritzar, Edison High School Planetarium, Alexandria, VA (1978)

Gina Lynch, Defense Mapping School, Department of Survey, Fort Belvoir, VA (1978)

Susan McBurney, School Administration Center, Hampton, Virginia 23663 (1992)

Herbert D. Teuscher, Plaza Jr. High School Planetarium, Virginia Beach, VA (1978)

John W. Trissel, Jr., Augusta County Schools Planetarium, Waynesboro, VA (1978)

Chris Vagnos, Hayfield Planetarium, Alexandria, VA (1978)

Paul D. Wilson, Defense Mapping School, Department of Survey, Fort Belvoir, VA (1978)

Washington

N.A. Higginbotham, Department of Physics, Eastern Washington University, Cheney, WA (1978)

Judith Jones, Mason School, Tacoma, WA 98407 (1994)

Keith Olive, Wilson Middle School, Yakima, WA (1990)

Janell Ramos, Quincy JHS, WA (1993)

Dennis Schatz, Pacific Science Center, Seattle, WA (1978)

Washington, D.C.

Alvinna Bouknight, Simon Elementary School, Washington, D.C. (1990)

Linda Ehnes, Hamilton Middle School, Seattle, WA 98103 (1992) new school

Stella Gomes, Howard University, Washington, D.C. 20059 (1992)

Gloria Warren Tucker, Beers Elementary, Washington, D.C. 20020 (1992)

Robert Wehrli, Model Secondary School for the Deaf, Kendall Green, Washington, D.C. (1978)

West Virginia

Elizabeth S. Wasiluk, Hedgesville High School, Hedgesville, WV (1989)

Richard Wonkka, Alderson-Broaddus College Planetarium, Philippi, WV (1978)

Wisconsin

Karl Beighley, Southwestern Wisconsin Community Schools, Hazel Green, WI 53811 (1994)

Susan Berce, Wauwatosa Lincoln, Wauwatosa, WI (1989)

Peter Chard, University of Wisconson, Fox Center, Menasha, WI (1978)

Barbara J. Decker, Longfellow Middle School, Wauwatosa, WI (1989)

Patrick Hermans Glenbrook Elementary, Pulaski, WI (1993)

Donald Lutz, Marathon Area Elementary, Marathon, WI (1990)

Terry Mattson, Frederic Middle School, Frederic, Wisconsin 54837 (1992)

Mary Ann Mullahy, Madison High School, Milwaukee, Wisconsin 53218 (1992)

John W. Surendonk, Gifford Planetarium, Racine, WI (1990)

Paul A. Taylor, Buckstaff Planetarium, University of Wisconsin, Oshkosh, WI (1978)

Wyoming

Timothy Maze, Tongue River Middle School, Ranchester, WY 82839 (1994)

Jim Roufs Big Piney MS, Big Piney, WY (1993)

West Germany

Bernadette J. Kollbrand, Vilseck Elementary School, Dept. of Defense Dependents' Schools, APO, NY, NY (1990)

Anita A. Sherrill, Bad Kreuznach Elementary School., Dept. of Defense Dependents' Schools, APO, NY, NY (1990)

Staff of the 1989-1994 Summer Institutes:

Terry Boykie and John Hammer, New York Hall of Science, Corona, NY

Kevin Cuff, Lisa Dettloff, John Erickson, Alan Gould, Jennifer Lipyanik, Chris Harper, John Hewitt, Precious Perry, JohnMichael Seltzer, Cary Sneider, Gregory Steerman, Debra Harper, Michelle Wolfson, and Kevin Charles Yum, Lawrence Hall of Science, University of California, Berkeley, CA

David Cudaback, Dept. of Astronomy, University of California, Berkeley, CA

Edna DeVore, Independence High School Planetarium, San Jose, CA

Robert Jesberg, Klinger Jr. High School, Southampton, PA

John Radzilowicz, Krista McAuliffe Planetarium, Concord, NH

Joseph Snider, Dept. of Physics, Oberlin College, Oberlin, OH

Jacqueline Hall, Moreno Valley Unified School District, Moreno Valley, CA

Dayle Brown, Pegasus Productions, South Bend, IN

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