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Planetarium Methods Based on the Research of Jean Piaget

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As planetarium interpreters we instruct elementary groups on such topics as why the sun shines, how to recognize constellations, and how to find directions, thinking that if we just explain it "right" the students cannot help but fully understand. After all, the planetarium provides visual supplement to our accurate explanations.

However, the in-depth research of the psychologist Jean Piaget over the last half century indicates that understanding is a function of maturation level and that some topics basic to planetarium astronomy should not be introduced (if we teach for understanding) until these levels of potential comprehension are reached. If students are on the verge of changing level, certain things done in the planetarium could accelerate the transitions. The following ideas are based on Piaget's data and conclusions.

Learning Levels and Planetarium Methods

What are some of the specific topics or techniques which should not be presented in the planetarium until appropriate levels have been reached? Piaget has learned that children up to about second grade practice transductive reasoning; i.e., for them one fact explains another. When a child, aged six, is asked, "Why does the sun stay up?" he replies: "Because it's bright" or, if slightly older, "Because it's daytime." If we try to explain to kindergarten-age children that the sun stays up for half of the time because the Earth rotates, most do not really understand. However, they may be able to repeat this as a "fact."

Until about age seven (second grade), most children are unable to organize their thoughts of time, motion, and space to correctly reconstruct a succession of perceived events. They are also unable to comprehend simultaneously moving objects which are advancing at different rates. Five and six-year-olds, shown the phases of the moon at half-week intervals during a synodic month, could not be expected to explain, identify, or draw a correct succession of moon phases. Nor can it be thought that children of this age will understand the simultaneous motions of the planets, even as they watch them in the planetarium sky. They will confuse distances moved with time intervals. If asked what happened after seeing this, they would reply that the planet which went farthest went for the longest time.

A definition, Piaget found, can first be comprehended as the child leaves the transductive (fused fact) stage at age seven or eight. The child is then more aware of relations between separate events. But definitions for children seven through twelve should be based on concrete experiences. Since Piaget found that students at this stage have the abilities to define, order, and classify, planetarium programs and their follow-up activities should center about categorizing information and observations. Following a program about the organization

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of different types of bodies in space, for example, children could draw, write (including question worksheets as well as essays), or tell that the Earth is a planet, planets orbit the sun, the sun is a star, and many stars form a galaxy. Drawings of the sun at different times of day or moon phases at different times of the month during planetarium presentations or grouping constellations on the basis of a number of different characteristics, are other examples of appropriate activity. Children between second grade and junior high learn basic concepts mainly by inference, rather than by deductive logic. Planetarium methods which require deduction should be withheld until sixth or seventh grade. An example of what should not be done at second or third grade for average students: The class is shown the effect of rotation on the sky over an accelerated period of 24 hours and then asked which way the Earth turned. This experience would be valuable at about fifth or sixth grade to "tease" or promote students' transition to the deductive reasoning level.

Astronomical ideas are bound up with concepts of great distances and times. Piaget learned that until a student reaches about age eleven or twelve, his ideas of infinite space and time cannot develop. An average five-year-old (kindergarten age) can imagine to only a certain size and then no larger. The fourth grader accepts the concrete information of "93,000,000 miles," "100,000 light-years," and "a billion years," but to such a child an idea of "forever" or "going on without end" as indicated by the (improbable) steady-state theory of the origin of the universe would be nothing but words.

One of the first things most of us do at the beginning of an astronomy lesson in the planetarium is point out directions. But prior to about eighth grade, one is continuously developing a sense of direction. Elementary children may be confused easily. Even the more basic idea of horizontal and vertical based on the Earth's surface and gravity direction do not completely develop until age nine. Not until about seventh grade do most students comprehend the correct relation of left or right, as dependent on the way one is facing. No wonder that students, even in sixth grade, have trouble understanding why east is on the left and west is on the right on activity sheets used for plotting the moon's motion along the southern half of the dome! But since a number of these students are approaching the idea of relativity of right and left, this planetarium experience can precipitate the transition. Thus the planetarium has value for fundamental learning. One further extrapolation of Piaget's research to planetarium directions: Until age seven, a child who learns that a star is in a position to the right or left of another object will not recognize it when direction is changed relative to the way the child is facing. Thus if the child turns or the sky turns (diurnal motion or projector rotation to cause planetarium direction change), kindergarteners would not realize that the "Seven Sisters" constellation should still be to the right of Orion, as seen from the Northern Hemisphere.

**Recognizing Constellations**

How about the ability to recognize constellations? Piaget finds that prior to age three, an age we usually do not admit to the planetarium, a child cannot distinguish closed shapes such as triangles, circles, and squares from one another. At age five the child can tell circles from rectangular shapes. He can distinguish among straight and curved lines, tell that angles are of different relative sizes, and explain relationships between sides of a figure. It is at this age that children generally begin using such words as "shorter" and "longer." At about age seven, the student further differentiates a six-pointed star from a hexagon and uses (although does not abstract) a fixed point of reference necessary for recognition and representation of a geometrical figure. The implications of these findings for constellation study are: Prior to age five for most, it is meaningless to try to teach shapes of constellations. The child will not "see" it differently from other star groups. At about first grade, simple, different shapes can be investigated, which can be assisted by the use of projected line segments to indicate difference in side length and angle size. (The projected lines can be useful throughout the concrete stage of mental development—ages seven to twelve as well.) At about third grade, the students can easily distinguish hexagons and crosses. The ability to recognize a complex pattern in a radically different orientation (e.g., inverted) is evidently an advanced skill, since the author has noted that many adults (including planetarians!) have difficulty recognizing Scorpius at a latitude near the South Pole.

What are the implications of Piaget's research for drawing constellations while learning them? Until the ability to handle abstract ideas is reached in junior high, motor activity is extremely important for the understanding of spatial relations. Whenever possible, young children should physically re-create their perceptions. This includes drawing. Piaget found that at about age seven or eight, a child can copy a two-dimensional model (e.g., a group of stars in a limited area of the sky) but that he is unable to preserve correct distances between objects. At age nine to ten, the student can reproduce correct intervals between objects or points. Thus if third graders draw a constellation map, such as the Big and Little Dippers, the distances in most cases are greatly distorted. Therefore it would be wrong to use their maps as
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a basis for later outdoor recognition, but the motor learnings which occur during its construction are very helpful. A fifth-sixth grade student has developed a feeling of scale and proportion which permits the construction of a more accurate star map. A grid (two perpendicular line segments) on the paper and also projected against the planetarium sky, would be very helpful to students at this stage of development. Finally, between ages 11 and 13 (sixth and eighth grades), students become able to abstract a reference system (grid) to correctly position objects in a field. Constellation maps will gradually improve as children between grades two and eight gain experience through interaction with the real world.

Viewpoints

Before age seven (second grade) most children do not have the idea of their having a particular space viewpoint, different from possible others. This is indicated by their inability to develop a sighting procedure with a string or table edge to determine straightness of a line. At about late third or early fourth grade for average-ability children, this ego-centrism is replaced by the ability to correctly imagine things as seen from many different points in space. At this time the student becomes able to imagine looking down on himself on the rotating Earth from a position above. A second-grade program which requires or is supposed to result in a dual perspective of looking into the sky and looking back on Earth or solar system or Milky Way Galaxy is inappropriate.

Prior to the stage of abstract thinking at about thirteen (eighth grade), students are incapable of combining different perspectives with another concept, such as motion. From about eighth grade onward it should be possible to have students learn moon motion as perceived from Earth and other points in space. Also possible then is the dual understanding of Earth's revolution: a view of the sun moving along the ecliptic through the Zodiac related to a distant perspective of the Earth-sun system. High school and college students, as well as most adults attending public programs, are potentially ready for these dual perspectives involving motion.

The deductive method becomes desirable in science-oriented planetarium lessons beginning in about eighth grade. After gathering data on moon phase and motion, a student should be able to predict future positions of the moon. After gathering data on planet positions, students should be able to match Earth-based planetarium data with heliocentric aspects.

The study of astronomy contains many examples of projective geometry (the apparent shape and size of objects related to their orientation and distance). Between ages eight and eleven (third and sixth grades), students develop the ability to predict that the apparent shape of a tipped circle will be an ellipse. The reason for the elliptical appearance of the Andromeda Galaxy then can be comprehended. Also at about fourth grade, the perspective sense develops, so that these students can understand the reason for a radiant of a meteor shower. Not until about age twelve can students accurately coordinate shapes of shadows formed by different three-dimensional objects, placed in different orientations between a light and a screen. Piaget's research indicates, therefore, that until about seventh grade, most students will not understand why the constant shape of the shadow of the Earth on the moon, as the full moon enters or leaves total eclipse, is a proof of the Earth's spherical shape. (I find it interesting that Carl Sagan, in The Cosmic Connection, speaks of visiting a class in which a first-grader says, "I saw an 'ellipse'. The shadow was round, it wasn't straight. So the Earth has to be round." As indicated by his other repeated comments from that class, the group had been coached or instructed. So perhaps this student was merely parroting."

Piaget has pointed out that different children pass through the stages of the sequence of mental development at different times, which can be accelerated by physical or social experiences. This may indicate that individualized activities for each child, in some planetarium programs, are desirable. But since present demands of efficiency of planetarium utilization require that we give planetarium lessons to groups, usually by grade level, it is valuable to be aware of what the average student at a particular level is potentially able to understand. School curricula should, of course, also reflect this awareness. Perhaps planetarium interpreters, aware of Piaget's findings, can be instrumental in guiding construction of the astronomy portions of the school science curriculum.

Planetarium research projects hopefully will help to establish evidence that particular planetarium activities promote transition between levels of thinking.

Learning in the Planetarium at Potential Comprehension Level

Piaget identifies two equal-but-opposite stages of non-learning in which many students are found. In the first,
the student is exposed to something he already knows in such a familiar way he is bored. In the second situation he is confronted with something which may be fascinating to the teacher but which the student cannot relate to his experiences. The trick for motivation is a tension between the familiar and the strange. This calls for creative teaching, touching upon personal relevance whenever possible. Regardless of potential for understanding at any mental stage, a person is not apt to learn if this situation does not exist.

What are some methods which provide the needed tensional situations for learning? One technique recommended by Synectics Educational Systems (SES) is the method of presentation by analogy. Some examples often applied to astronomical content related in the planetarium are comparisons of (1) stages of star evolution to stages of human life; (2) constellation figures to connect the-dot pictures; (3) a spiral galaxy to a pinwheel or a fried egg, depending on orientation; (4) the constellations that do not resemble their names to the state of Washington, which does not have boundaries producing the silhouette of George Washington; and, (5) the view of the sun moving along the ecliptic against the Zodiac constellations to the view of a campfire seen as you slowly walk counterclockwise around a group of friends sitting close to the fire.

Psychologists have found that a person cannot consciously recall and verbalize an experience, even if beyond the stage at which introspection appears—age seven—unless it has some relevance to his outlook. This implies that methods which aim at involvement will more likely result in learning. Multidisciplinary use of the planetarium is therefore desirable. Topics of mathematics, English, social and life sciences, languages, and the arts can and have been coordinated by many with planetarium capability. Gestalt philosophy and psychology ("The whole is greater than the sum of its parts.") also predicts that a program of astronomical poetry coordinated with views of the sky, or a presentation of circle-and-sphere applications of celestial navigation given to a geometry class which has just completed a unit on circles, will result in greater learning than a planetarium experience unrelated to topics studied elsewhere. (This, of course, implies that an effective planetarium programmer has a wide range of academic interests.)

Mythology is very interesting to children and adults alike. Perhaps this is due to the great amount of self-reference found in all literature. One engages in reflection as characters and situations are described.

Another method of creative teaching which results in introspection and a feeling of relevancy is simulation. Role-playing techniques can aid the development of problem-solving skills as well as promote concept-and-fact learning. William Chronister (The Science Teacher, October 1974) has simulated an observatory situation in the planetarium with a class playing roles as astronomers, chief physicist, photometry expert, librarians, and observatory caretaker. Additional simulation situations of the present which might be tried in the planetarium are (1) a solar eclipse expedition; (2) a meteor-shower counting party; (3) an imagined month at Bar Harbor, Maine, relating tides and moon position; and (4) a "lost at sea" (or desert) situation with the possibility of perishing unless celestial navigation is used.

Role-playing might also be applied to situations of the past, such as (1) the A.D. 1054 supernova observation by the Chinese or different civilizations, reflecting the differences in cultural outlook applied to astronomy; (2) appearances of Halley's Comet at various points in history; and (3) the view of the sky by the Egyptians circa 3000 B.C., with the problem of aligning the pyramids.

Planetarium projections into possible conditions of the future provide a unique application of science fiction. Even when the audience is passive, science fiction contains human relevancy. Probably this helps to explain why it has been so popular. A situation in which student visitors take roles (such as the characters in The Black Cloud by Fred Hoyle) may provide even greater interest.

In addition to greater conceptual learning, which is created by these tension-causing, relevancy techniques, there is opportunity present for greater affective learning. If groups enjoy the planetarium experience, they are more apt to return for additional programs. Role-playing situations can be the basis of discussions conducted in class prior to, following, and perhaps even during the planetarium visit. Additionally, open-ended simulations in which students must solve problems, select and hold views, and explain and defend decisions, provide learning which goes way beyond subject matter.

Although certain subject matter we judge as important today may become obsolete to the average citizen of tomorrow, the ability to solve problems, the ability to make decisions, and the acquisition of astronomy as an interest which may turn into a life-long leisure-time activity are possible outcomes of creative planetarium utilization for many of our visitors.

References


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* Synectics Educational Systems (SES), Cambridge, Massachusetts.