AN EXPERIMENTAL STUDY OF THE SCIENCE CURRICULUM IMPROVEMENT STUDY INVOLVING FOURTH GRADERS' ABILITY TO UNDERSTAND CONCEPTS OF RELATIVE POSITION AND MOTION USING THE PLANETARIUM AS A TESTING DEVICE

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This is to certify that the

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AN EXPERIMENTAL STUDY OF THE SCIENCE CURRICULUM IMPROVEMENT STUDY INVOLVING FOURTH GRADERS' ABILITY TO UNDERSTAND CONCEPTS OF RELATIVE POSITION AND MOTION USING THE PANETARIUM AS A TESTING DEVICE

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ABSTRACT

AN EXPERIMENTAL STUDY OF THE SCIENCE CURRICULUM IMPROVEMENT STUDY INVOLVING FOURTH GRADERS' ABILITY TO UNDERSTAND CONCEPTS OF RELATIVE POSITION AND MOTION USING THE PLANETARIUM AS A TESTING DEVICE

By

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This study was undertaken because of a need to evaluate the Science Curriculum Improvement Study (SCIS) program at the fourth grade level. The SCIS unit titled "Relativity" is presented to fourth graders enrolled in the program and is the particular unit under investigation.

The Science Curriculum Improvement Study is a K - 6 course content improvement project supported by the National Science Foundation. The program was initiated in 1962 by Robert Karplus, a professor of theoretical physics at the University of California, Berkeley. One of the overall objectives of the SCIS program is to develop scientific literacy, i.e., a sufficient knowledge and understanding of the fundamental concepts of both the biological and physical sciences. The program attempts to introduce science materials and concepts compatible with children's reasoning abilities by providing equipment for the children's own investigations, and by giving freedom to discover the value of the concepts for themselves.

The unit "Relativity" consists of four parts. The first two parts deal with relative position and the last two with relative motion. The main concept through the entire unit is that relative motion is a change in relative position.

In order to evaluate the effect of this unit, an examination had to be created that was not of the traditional style of a written test. There has been little evidence of success achieved in testing the SCIS objectives by the use of written tests. At the elementary school level, traditional types of written tests mainly measure recall since comprehension and operation with written test items require mental processes that usually arise between the ages of eleven and fifteen years.

An alternative to the written test is a planetarium oriented evaluation process whereby the student is shown examples of relative position and motion (the unit under investigation) that are different from those examples previously seen in the classroom. In this novel setting the student would have to depend less on recall and more on his ability to understand the concepts of the unit "Relativity".

A thirty item planetarium test was created and used as a pretest and a posttest. An item analysis revealed that the test had a reliability coefficient of .6995 based on the posttest data. The test was administered to nine classes of SCIS fourth graders and six classes of non-SCIS children (control group). The fifteen classes were from the school districts of East Lansing, DeWitt, and Grand Ledge, Michigan.

Analysis of covariance was used to test the null hypothesis of no significant difference in adjusted mean scores between the SCIS and non-SCIS groups.

Both groups of students improved their mean score on the posttest. However, the SCIS students showed a gain from pretest to posttest that is more than twice as large as the non-SCIS group gain. The analysis indicates that this difference is significant at the .05 level. Therefore, the null hypothesis was rejected.

It was concluded that the fourth graders enrolled in the Science Curriculum Improvement Study after having received the material presented in that program's unit titled "Relativity" had a significantly greater ability to understand the concepts of relative position and motion than a comparable group of students who had not received such instruction.

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CHAPTER I

INTRODUCTION

Purpose of the Study

The purpose of this study is to determine whether fourth grade children enrolled in the Science Curriculum Improvement Study (SCIS) program develop a greater understanding of concepts of relative positon and motion than do non-SCIS fourth grade children.

Background of the Study

The Science Curriculum Improvement Study is a course content improvement project supported by the National Science Foundation. The program was initiated in 1962 by Robert Karplus, a professor of theoretical physics at the University of California, Berkeley.

One of the overall objectives of SCIS is to develop scientific literacy, i.e., a sufficient knowledge and understanding of the fundamental concepts of both the biological and physical sciences.

The project attempts to introduce science materials and concepts compatible with children's reasoning abilities by providing equipment for the children's own investigations, and by giving them freedom to discover the value of the concepts for themselves.

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[1]SCIS will be used throughout this study as the abbreviation for Science Curriculum Improvement Study.

The methodology of SCIS is to prepare sequential physical and life science programs for the elementary (K - 6) programs which in essence turn the classroom into a laboratory. The child must be brought into contact with abstractions that are directly related to the objects of his own experience. Through manipulation of these objects, it is hoped that later the child will be able to work with abstractions in his mind without having to anchor them to immediate sensory experience.

Each unit in the program has been evaluated subjectively by the SCIS staff as it progressed from the exploratory stages to the published edition. The units originate as scientists' ideas for investigations that might challenge children and that illustrate key scientific concepts. Through interaction with teachers at trial centers these ideas are then adapted to fit the elementary school and the resulting units are then actually used by the teachers in the classroom. This process is sometimes repeated and thus the units are tested several times in the elementary schools before they are published. Figure 1 shows all six levels of the SCIS program in final edition along with the concepts introduced in each unit.

The concept of relativity is usually presented at the fourth grade level in a unit titled "Relativity". This unit consists of four parts. The first two parts deal with relative position and the last two with relative motion. The main concept through the entire unit is that relative motion is a change in relative position.

In Part One of "Relativity" the children learn about the position of objects relative to reference objects in their environment. In Part Two an artificial

ORGANISMS		**MATERIAL OBJECTS**	
organism	habitat	object	serial ordering
birth	food web	property	change
death	detritus	material	evidence
LIFE CYCLES		**INTERACTION AND SYSTEMS**	
growth	biotic potential	interaction	system
development	generation	evidence of interaction	interaction-at-a-distance
life cycle	plant and animal		
POPULATIONS		**SUBSYSTEMS AND VARIABLES**	
population	plant eater	subsystem	solution
predator	animal eater	histogram	temperature
prey	food chain		variable
community	food web		
ENVIRONMENTS		**RELATIVE POSITION AND MOTION**	
environment	range	reference object	reference frame
environmental factor	optimum range	relative position	polar coordinates
		relative motion	rectangular coordinates
COMMUNITIES		**ENERGY SOURCES**	
photosynthesis	producer	energy transfer	energy source
food pyramid	consumer	energy chain	energy receiver
community	decomposer		
ECOSYSTEMS		**MODELS: ELECTRIC AND MAGNETIC INTERACTION**	
ecosystem	oxygen-carbon dioxide cycle	model	electrochemical cell
water cycle	pollution	electric current	series/parallel circuits
		magnetic field	
		electrode	

Figure 1 -- Final edition program

Source: Suzanne Stewart, ed., "Science Curriculum Improvement Study," SCIS Newsletter, No. 18 (Summer, 1970), p. 2.

observer, Mr. O, establishes a central reference object. Mr. O is a cardboard figure of a person and can be manipulated by the children to any desired position. The position of any other object can be described relative to Mr. O. In Part Three the concept of motion relative to Mr. O is introduced. In all four parts of the unit there is a cycle of exploration, invention and discovery, interrelated with the main concept. A film loop titled Fun House is used extensively in Part Four to entice students to make additional discoveries.

Need for the Study

There exists a need for a continuing evaluation process in the Science Curriculum Improvement Study program. There has been little evidence of success achieved in testing the SCIS objectives by the use of written tests (see Chapter II). At the elementary school level, traditional types of written tests mainly measure recall since comprehension and operation with written test items require mental processes on the formal level. Since these processes arise between the ages of eleven and fifteen,[2] elementary school children are very unlikely to be able to carry them out.

A possible alternative to the written test is an evaluation process whereby the student is shown examples of relative position and motion (the unit under investigation) that are different from those examples previously seen in the classroom. In this novel setting the student would have to depend less on recall and more on his ability to conceptualize the ideas behind relative position and motion.

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[2]John P. DeCecco, The Psychology of Learning and Instruction (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1968), p. 92.

One substitute for written tests has been to probe for the understanding of concepts involving relative motion through personal interviews.[3] This method is very time-consuming if it is to be given to a large number of students. Another method of evaluating this concept might be to create a film that meets the criterion of being novel to both groups of SCIS and non-SCIS children. The problem of cost is in this case prohibitive.

In summary, if an evaluation process can be created to meet the criteria of being non-written, novel, and efficient, i.e., capable of being presented to large groups simultaneously, the task might be solvable.

Plan of the Study

This investigator's approach to the problem of collectively testing a group of SCIS fourth graders is to use the planetarium as the testing device. Its audio-visuality is more realistic than motion pictures since the pupil is in effect surrounded by the action. The planetarium permits the simultaneous testing of a large number of students. Most important, the planetarium is an ideal setting for showing concepts of relative position and motion since the equipment is designed for this purpose. Questions can be devised concerning concepts of relativity that would be different from any that might have been experienced previously by the pupils in this age and grade level in the planetarium or the classroom. Thus it is assumed by the investigator that if the SCIS student understands the concepts of relativity in the classroom setting he should be able to transfer this knowledge to a

[3]Robert Karplus, ed., What is Curriculum Evaluation (Berkeley, Calif.: The Regents of the University of California, 1968), pp. 3-8.

different setting where the concepts can be tested, providing that the ideas are comparable in difficulty.

Fifteen classes of fourth grade students from the Lansing, Michigan area were used in the study. Nine of these classes were from schools that were currently using the SCIS unit on relativity, and the remaining six were designated as control classrooms; that is, they did not have any formal instruction on the concepts of relativity. Comparisons were made of the effectiveness of the two arrangements. All of the instructors of the SCIS unit on relativity had received workshop training in teaching this unit prior to the experiment. These summer workshops are an integral part of the SCIS program and are administered at Michigan State University, one of five trial centers for the program.

Certain astronomical phenomena were selected by the investigator to be used for testing purposes. Each met the following criteria:

1. Each of the selected phenomena is based on the concept of relative position and motion.

2. Each phenomenon is not usually presented to students of this age level and, therefore, is novel to both SCIS and non-SCIS students.

3. An introductory lesson regarding each phenomenon can be presented in a short amount of time (approximately five minutes) and followed by one or more questions related to the concept.

A thirty item examination was developed to test for the concepts of relative position and motion and was designed to be given in the planetarium as both a pretest and posttest. Confidence in the examination was established through the subjective judgment of experts and through an analysis of data obtained in a trial use.

The schools from which the classes were drawn were selected with a view toward making the SCIS and non-SCIS groups comparable in the general socioeconomic level of the children. Because the SCIS program has been in existence in the area for several years, the classes were not assigned to the groups randomly. Random assignment is sometimes necessary for assumptions of equality between groups but as will be pointed out in Chapter III this assumption has been alternatively satisfied to some extent.

Hypothesis

Fourth grade students who receive instruction utilizing the SCIS unit titled "Relativity" will score higher on a planetarium oriented test of the concepts of relative position and motion than fourth grade students who do not receive this instruction.

Basic Assumption

This study began with the assumption that any significant differences in understanding achieved between SCIS and non-SCIS students would be attributable to differences in the curriculum.

Definition of Terms

Planetarium. A planetarium is understood to be a device which uses projectors to produce a model of the sky for audiences seated beneath a domed projection screen.

SCIS. Science Curriculum Improvement Study.

Relativity. "Relativity" is a unit usually presented at the fourth grade level in the SCIS program and deals with concepts of relative position and motion.

Fourth grade. The fourth grade as defined in this study is the fourth grade level of students from the school districts of East Lansing, DeWitt, and Grand Ledge, Michigan.

Significant difference. A significant difference is defined as being a difference probably not due to chance, i.e., probability less than .05.

Scope of the Study

The population of this study consisted of children enrolled in the fourth grade in the seventeen elementary schools of the public school districts of East Lansing, DeWitt, and Grand Ledge, Michigan. The sample studied consisted of 331 students from fifteen classrooms. The original sample consisted of more than 370 students but due to absenteeism the total was reduced to 331.

CHAPTER II

REVIEW OF RELATED LITERATURE

A brief historical summary of the SCIS program from its conceptual beginning to the present time is presented in the International Clearinghouse Report. It states:

> The Science Curriculum Improvement Study was established in the winter of 1962 by Robert Karplus, at the University of California, Berkeley. Since that time the project has maintained a full time staff of physicists, biologists, psychologists, and teachers. The staff has developed ideas for units, tried out these ideas during exploratory teaching in Berkeley Trial Center schools, observed trial edition units being taught by regular classroom teachers, and revised them for final edition.[4]

The general objectives of the SCIS program have been expressed by Karplus and Thier[5] to include intellectual development and scientific literacy. Their belief is that scientific literacy should be the principal objective of elementary science education, and this belief is articulated in the total SCIS program.

Thier's definition of functional scientific literacy states:

> The individual must have a conceptual structure and a means of communication that enable him to interpret the information as though he had obtained it himself.[6]

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[4]J. David Lockard, ed., Seventh Report of the International Clearinghouse on Science and Mathematics Curriculum Developments 1970 (College Park, Maryland: University of Maryland and AAAS, 1970), pp. 532-33.

[5]Robert Karplus, and Herbert D. Thier, A New Look at Elementary School Science (Chicago: Rand McNally and Company, 1967), p. 14.

[6]Ibid., p. 24.

Thomson and Voelker[7] have summarized the psychological basis of SCIS in the May, 1970 issue of Science and Children. They point out that the importance of utilizing concrete manipulatory experiences for children of elementary school age is based on the findings of educators such as Piaget, Bruner, Hunt, and Almy.

Piaget's review of the theory on the development of knowledge in children is presently in the Journal of Research in Science Teaching.[8] The following paragraphs serve as a synopsis of that article.

> To understand the development of knowledge, we must start with an idea which seems central to me--the idea of an operation. Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed. An operation is thus the essence of knowledge; . . . In other words it is a set of actions modifying the object, and enabling the knower to get at the structures of transformation.[9]

Piaget also characterizes the operation as an interiorized action. But, in addition, a reversible action; that is, it can take place in both directions, for instance adding or subtracting, joining or separating. An operation, above all, is always linked to other operations, and as a result it is always part of the total logical structure.

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[7]Barbara S. Thomson and Alan M. Voelker, "Programs for Improving Science Instruction in the Elementary School," Science and Children, VII (May, 1970), p. 30.

[8]Jean Piaget, "Development and Learning," Journal of Research in Science Teaching, II (September, 1964), pp. 176-86.

[9]Ibid., pp. 176-77.

According to Piaget there are four stages of development of the operational structures in the life of the child. The first is a sensory-motor pre-verbal stage, lasting approximately 18 months from birth. During this stage is developed the practical knowledge which constitutes the substructure of later representative knowledge.

In the second stage, there is the pre-operational representation--the beginnings of language, of the symbolic function, and therefore of thought, or representation. However, in this stage, the sensory-motor actions are not immediately translated into operations. During all this second period of pre-operational representations there are yet no operations as previously defined.

In the third stage the first operations appear but Piaget calls these concrete operations because they operate on objects, and not yet on verbally expressed hypotheses. His examples of concrete operations are classification, ordering, the construction of the idea of number, spatial and temporal operations, and all the fundamental operations of elementary logic of classes and relations, of elementary mathematics, of elementary geometry, and even of elementary physics.

Finally, in the fourth stage, these operations are surpassed as the child reaches the level of what Piaget calls the formal or hypothetic-deductive operations. That is, the child can reason on hypotheses, and not just objects. He constructs new operations, operations of propositional logic, and not simply the operations of classes, relations and numbers.

One of the main conclusions of Piaget in his studies of how the child learns follows:

> My first conclusion is that learning of structures seems to obey the same laws as the natural development of these

> structures. In other words, learning is subordinated to development and not vice-versa . . . [10]

Bruner points out that Piaget is often interpreted in the wrong way by those who think his principal mission is psychological. "It is epistemological. He (Piaget) is deeply concerned with the nature of knowledge per se, knowledge as it exists at different points in the development of the child. He is considerably less interested in the processes that make (intellectual) growth possible . . ."[11] Bruner's concept of how a child learns is that the heart of the educational process consists of providing aids and dialogues for translating experience into more powerful systems of notation and ordering.[12]

Almy[13] has attempted to assess the young child's thinking processes in various replications of Piaget's experiments. In Piaget's experiments, the child manipulates objects or materials either of a sort likely to be found in any moderately well equipped classroom or in the home kitchen, sewing, or carpentry kit.

> As described by Piaget, most of the experiments are carried on with a single child, but there are many possibilities for the teacher to work with several children at the same time. Obviously, since the goal of experimentation is to furnish information about the thinking of the individual child, whatever procedures are used must insure freedom for each child to reveal his own thoughts, rather than repeating, parrot-like, a response that he suspects is the one the teacher wants.[14]

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[10]*Ibid.*, p. 184.

[11]Jerome S. Bruner, *Toward a Theory of Instruction* (New York: W.W. Norton and Company, 1968), p. 7.

[12]*Ibid.*, p. 21.

[13]Millie Almy, *Young Children's Thinking* (New York: Teachers College Press, Columbia University, 1966).

[14]*Ibid.*, pp. 132-33.

Almy's conclusions have substantiated certain aspects of Piaget's theory and experimentation. Her findings have demonstrated the relevance of this theory to the education of the young child. In constructing a curriculum Almy suggests the following guidelines:[15]

> Sequence: Piaget's work clearly implies an ordering among conceptual tasks that suggest certain priorities for instruction. However, the fact that there is an order in the way the child comes to grasp these concepts does not mean that his educational experiences are to be entirely limited to those that are within his immediate understanding. One does not have to wait for evidence that new information has been effectively assimilated before providing opportunity for accommodation to additional information. But neither should the new come so fast as to preclude integration of the old.
>
> Manipulative activity and language: Piaget's theory stresses the importance of learning through activity. Demonstrations, pictured illustrations, particularly for the youngest children, clearly involve the child less meaningfully than do his own manipulation and his own experimentation.
>
> Social interaction among children: A child may learn more readily from a peer, or somewhat older child whose views are less distant from his own than are an adults, than from adult instruction. The social exchanges that a child has with his peers tends to correct the tendency to take an egocentric view of the world.
>
> The role of discovery: While a child may accommodate his thought to the ideas of others, it is only as he tries those ideas out within the context of the ideas he has previously acquired that he makes them his own. However, there is no reason to believe that a discovery is more meaningful if the child has had to flounder aimlessly for a period before making the discovery. The essence of Piaget's method is the assessment of the childs' readiness to make a particular discovery, and the pacing of his educational experience to that readiness so that he will have both the intellectual content and the cognitive abilities needed to make it.

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[15]Ibid., pp. 137-39.

Thomson and Voelker point out that the SCIS designers looked closely at these findings and proceeded to build an elementary school program based on the following beliefs:

1. The child's elementary school years are a period of transition as he continues to explore the world he begins in infancy.

2. He develops confidence in his own ideas.

3. He builds abstractions with which he interprets the world.[16]

Thomson and Voelker then state that by using this rationale the SCIS designers concluded that the elementary school years should provide a diversified science program in which the child is exposed to many concrete manipulatory experiences. In addition, these experiences should build upon one another in order to construct a conceptual framework that permits the child to integrate his inferences into more meaningful generalizations. Thus each lesson has two functions: to provide a new experience; and to establish or reinforce an abstract concept.

The nature of the conceptual framework cited above is consistent with Gagné's hierarchy of learning conditions. These conditions,[17] in the order of their appearance, i.e., temporal order of observable behavior, are as follows: signal learning where the individual acquires a conditioned response to a given signal; stimulus-response learning; chaining (skill learning); verbal association; multiple discrimination, in which the student must learn different responses for stimuli which might be confused; concept learning; principle learning; and problem

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[16]Thomson and Voelker, "Programs for Improving Science . . .", p. 30.

[17]John P. DeCecco, The Psychology of Learning and Instruction (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1968), pp. 47-50.

solving. Each of these learning types can only come about if the previous types have been accomplished.

Because of the sequential nature of SCIS, evaluation at each level of the K - 6 program is vital. Students cannot be expected to advance to new levels of learning if they have not achieved the necessary fundamentals of a prior level. Also, a sequential program requires a great amount of evaluation time since some of the objectives have not been achieved until a student has progressed through an entire year. Thus, a K - 6 evaluation might take at least seven years. This type of structure also means that a school would start the program at the kindergarten or first level and would add a level each year over a period of six or seven years. Thomson and Voelker[18] report that although the SCIS program is still less than a decade old, the quality and quantity of the studies indicate that the development of evaluation has not been neglected. The information gleaned from the various studies has been classified into two categories: descriptive feedback; and experimental.

Karplus[19] has compiled and edited the findings of Ness, Flory, and Tresmontan, all of which deal with descriptive feedback in the SCIS program. All three investigators utilized their findings either for revising instructional materials or increasing teacher sensitivity to pupils and their interaction with these materials.

The SCIS program has generated several studies in the area of experimental research. One of these studies, by Siegelman and Karplus, pertains

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[18]Thomson and Voelker, "Programs for Improving Science . . .", p. 34.

[19]Karplus, What is Curriculum Evaluation?

directly to the unit "Relativity" and is presented in the book What is Curriculum Evaluation?[20] The following paragraphs summarize this study.

Two different designs were employed in two successive school terms. In 1966-67, a comparison between SCIS and non-SCIS students on a posttest was observed. In the 1967-68 term only one group (SCIS students) was observed on a pretest, posttest design, i.e., no control group was used.

The instrument that was developed for this study involved two testing situations; a group test and an individual test.

The group test was on the concept of relative position. Each child was given a test booklet with picture pages and question-answer sheets. In the 1966-67 experiment, Mr. O figure was briefly described before the test was administered in order to give the non-SCIS children a better comprehension of the questions. All questions were read aloud to the students before they were permitted to answer. The test required about twenty minutes of class time.

The individual test was actually an interview of the concept of relative motion. This was carried out with one child at a time in a separate testing room and required about ten minutes per child. The individual interview included several problems posed by a system of moving objects and by pictured situations. An example of the first set of tasks, i.e., a system of moving objects, follows:

> A demonstration of relative motion was presented by using a wheel turned by the investigator; one Mr. O figure is on the table near the wheel and a second is attached to the wheel. The children were asked to do the following:
>
> (a) State whether or not a paper clip is moving relative to Mr. O on the table.
> (b) State whether or not the same paper clip is moving relative to the Mr. O on the wheel.

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[20] Ibid., pp. 3-8.

(c) Place a piece of tape so the Mr. O on the wheel would report it is not moving.
(d) State or indicate a general rule for all possible placements compatible with item (c).
(e) Recognize the impossibility of placing the tape so that both Mr. O's would report that it is not moving.[21]

The results of this task are presented in Table 1.[22]

TABLE 1

Relative Motion
(Percent Correct Responses)

Mr. O and turning wheel	1966-67 non-SCIS N = 15	1966-67 SCIS N = 50	1967-68 pre-test N = 28	1967-68 post-test N = 28
(i) paper clip "moving"	100	88	97	82
(ii) paper clip "not moving"	53	74	21	79
(iii) correct placement of tape	60	74	36	71
(iv) states rule for tape	40	56	18	50
(v) recognizes impossibility	20	38	4	18

A second set of tasks was based on a picture of a burning house with a lady slumped at a window. A firetruck is parked beside the house with one fireman on a rescue platform extending from the truck. The platform and second fireman are on a separate hinged piece of cardboard and can actually be moved relative to the truck. The children were asked to describe the motion of the lady relative to the fireman on the rising platform. The types of responses and their respective percentages are presented in Table 2.[23]

[21]Ibid., p. 6.

[22]Ibid., p. 7.

[23]Ibid.

TABLE 2

Relative Motion
(Percent Responses)

Fireman and lady (response options)	1966-67 non-SCIS N = 15	1966-67 SCIS N = 50	1967-68 pre-test N = 28	1967-68 post-test N = 28
(i) lady moving	13	46	4	36
(ii) lady not moving	14	18	0	21
(iii) position of lady	0	20	21	14
(iv) narrative answer	73	16	75	29
	100	100	100	100

The investigators of this study concluded:

> It is clear, therefore, that the "Relativity" program orients the children strongly toward spatial relationships, even though position and motion were not yet clearly and correctly separated at the time of the tests, shortly after the unit was concluded. The data presented in this report indicates further that of the five objectives tested on the unit, objectives 2 (understanding and using major directions in description of relative position) and 4 (observing and identifying motion relative to Mr. O) were attained successfully. Only partial attainment was noted for objectives 1 (identifying objects relative to reference objects in the environment), 3 (using one, two or three major directions in a description of relative position) and 5 (identifying motion relative to systems other than Mr. O). At the same time, it was found that these objectives were not trivial. In fact, the comparison groups showed a strong bias <u>against</u> the correct performance on several items. The findings were useful in suggesting revisions necessary for the Preliminary Edition of "Relativity."[24]

Discussion of Previous Research on Relativity

This investigator has attempted to create a research design and an instrument that improve upon the ones used by Siegelman and Karplus.

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[24] *Ibid.*, p. 8.

In their 1966-67 research design the two investigators attempted to compare two groups of students (SCIS and non-SCIS) on a posttest. No pretest prior to the treatment was administered. Campbell and Stanley[25] point out some of the weaknesses of this type of design under the heading of "The Static-Group Comparison". Briefly, these include possible biases such as interaction between the selection of students and the treatment; interaction between the selection of students and their maturity factor; mortality, i.e., loss of subjects might influence the outcome; and others.

The 1967-68 version of this experiment contained no control group but the design did utilize a pretest. This pretest enabled the investigators to see how the subjects gained over a period of time but the lack of a control group did not permit any comparisons across groups to be investigated.

An improved design would be a pretest-posttest utilizing a control group. The advantages of this design are pointed out by Campbell and Stanley.[26] For example, the influences of mortality and maturation differences between groups can somewhat be controlled. The following statements are presented to clarify what type of experiment should utilize this design:

> One of the most widespread experimental designs in educational research involves an experimental group and a control group both given a pretest and a posttest, but in which the control group and the experimental group do not have pre-experimental sampling equivalence. Rather, the groups constitute naturally assembled

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[25]Donald T. Campbell and Julian C. Stanley, <u>Experimental and Quasi-Experimental Designs for Research</u> (Chicago: Rand McNally & Company, 1963) pp. 12-13.

[26]<u>Ibid.</u>, pp. 47-50.

> collectives such as classrooms, as similar as availability permits but yet not so similar that one can dispense with the pretest. The assignment of X (treatment) to one group or the other is assumed to be random and under the experimenter's control.[27]

The last statement above presents a problem in an experiment involving SCIS classrooms. In the present study the schools containing the fourth grade SCIS classrooms have, in most cases, been using the SCIS program for at least three years prior to the beginning of this experiment. Therefore,it became necessary to make the alternate assumption that the non-SCIS classrooms used in this study could have just as easily been likely candidates for the SCIS program. This assumption has been met and will be explained in Chapter III.

The instrument used by Sielgelman and Karplus attempted to test the knowledge gained by SCIS students by using some examples that were familiar to the SCIS students (e.g., Mr. O). Although the investigators tried to familiarize the non-SCIS students to these types of examples before the posttest was administered, the SCIS students had been using these same examples for several weeks prior to the posttest and thus were probably more familiar with them. As an alternative to this problem, this investigator attempted to create an instrument that would test the concepts of relative position and motion by using examples novel to both groups.

Summary

The history of the SCIS program has been one of continuing evaluation including both descriptive and experimental types of research. The unit "Relativity"

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[27]Ibid., p. 47.

has been evaluated somewhat by Siegelman and Karplus but the research designs utilized have had certain possible weaknesses. These possible weaknesses were due to a lack of a pretest in the 1966-67 study and a lack of a control group in the 1967-68 study. The instrument used in these studies incorporated some examples that were possibly more familiar to the SCIS students than they were to the non-SCIS students used as a control group. The present investigation attempts to improve upon the prior study by: utilizing a more suitable design; and by creating an instrument that tests the concepts of "Relativity" but uses examples novel to both the SCIS and non-SCIS subjects.

CHAPTER III

DESCRIPTION OF THE EXPERIMENT

The General Procedure

The following steps were taken:

1. The generation of an experimental design.

2. Determination of a method of statistical analysis consistent with the design.

3. Solicitation of three school districts for cooperation in the experiment.

4. Development of eight astronomical situations involving the concepts of relative position and motion.

5. Development of a trial version of a multiple choice test to measure the understanding of the concepts.

6. Establishment of the content validity of the test.

7. Administration of the trial version of the test.

8. Determination of the difficulty and the discrimination power of each test item in addition to reliability of the test.

9. Revision of the trial version of the test.

10. Selection of fifteen classes of fourth grade students.

11. Administration of the pretest to SCIS and non-SCIS classes.

12. Unit "Relativity" presented to SCIS fourth grade classes.

13. Administration of the posttest to SCIS and non-SCIS classes.

14. Statistical analysis of pretest and posttest data to test the null hypothesis of no group differences ascribable to differential treatment.

Planetarium Facilities

The Abrams Planetarium, used in this study, is located on the campus of Michigan State University in East Lansing, Michigan. The star projector is the Spitz Space Transit Planetarium model and can be utilized in three axes of motion. A realistic representation of the day and night sky can be produced for any latitude on the earth. The heading axes enables the viewer to face any desired direction and thus the seating arrangement in this planetarium is unidirectional. Other equipment includes peripheral projectors, a zoom projector, two overhead projectors, carousel projectors for 35 mm slides, small driven mirrors to move images across the dome, and a sound system. The sky theater contains a 50 foot diameter projection dome under which 254 seats are available. The console containing the controls for the various equipment is placed on the perimeter of the room in back of the viewers.

Grade Level of Pupils

Abrams Planetarium receives well over 20,000 K - 12 visitors per year in addition to viewers for various types of university programs and weekend public programs. Over 7,000 third and fourth grade students came to the planetarium in the school year of 1969-70, indicating the wide use of the facility by elementary school systems in the area. Most of the fourth grade pupils involved in this experiment have visited Abrams Planetarium at various times prior to this experiment and have received lessons on astronomy. Therefore,

care was taken in formulating test items of concepts in astronomy that are not normally experienced by this age level of student.

Selection of Astronomical Phenomena

Eight examples of astronomical phenomena were selected for the purpose of creating an examination to test the concepts of relative position and motion. Each of these examples met the following criteria:

1. They could easily be produced in this planetarium with available equipment.
2. One or more test items concerning relative position or motion could be devised for each phenomenon.
3. Because of the degree of difficulty, each of the examples is usually presented at higher grade levels than fourth grade.
4. None of the examples are used in the SCIS unit on relativity.

The strategy involved in using the examples was to create a lesson module centered on each example and followed by questions related to the concept of relative position and motion. In this manner it was hoped that the test would serve a dual purpose--a gain in knowledge by the pupil due to his exposure to the lesson modules, and to learn how well the pupil understands the concepts of relativity pertaining to each lesson module.

Following is a list of the eight examples:

1. The location of the zenith in the planetarium sky.
2. The phases of the moon and/or earth caused by the relative positions of the observer and the sun.
3. The sun's apparent annual motion through the zodiac due to the motion of the earth around the sun.
4. The apparent motion of the sky depicted by an idealized drawing of a man standing on a rotating earth against a background of stars.

5. A view of the sun's position and of satellite motion as seen from the center of a transparent earth.

6. Roll, pitch, or yaw determination by an astronaut in a space ship.

7. The relative motion of three objects (asteroids) and a space ship in an outer space setting.

8. Planetary motion due to the combined factors of planetary orbital velocity, orbital position, and observer position.

Development of the Examination

A thirty item examination was designed to be used as both a pretest and posttest. The items were drafted with due consideration for the concepts of relative position and motion. A detailed description of this test is found in Appendix A.

After the rough draft of the examination was created, a panel consisting of planetarium personnel, SCIS coordinators, and a testing specialist, reviewed the items. The planetarium personnel consisted of Mr. Von Del Chamberlain, Director; Mr. Robert C. Victor, Staff Astronomer; Mr. D. David Batch, Planetarium Specialist; Mr. LeRon W. Cobia, Planetarium Specialist; Mr. John Hare, Chief Technician; and Mr. Zenon Billeadeaux, Art Supervisor. The chief technician and art supervisor served the purpose of insuring that the special effects and artwork to be used in the test were feasible. The other planetarium personnel insured that the concepts were astronomically correct and that the vocabulary was within a fourth grader's range. In addition to the planetarium staff, the panel consisted of Dr. Glenn Berkheimer, Trial Center Coordinator of SCIS; Mr. Donald Maxwell, SCIS Implementation Consultant; and Professor Clarence Nelson, Evaluation

Consultant. These members helped establish the content validity and the reliability of the examination.

The test items were then redrafted into a thirty item multiple choice test incorporating the suggestions of the panel.

Each item utilized projections on the domed ceiling of the sky theater. These visual aids included the example of the concept, e.g., moon phases, the question of the item, and the choice of answers. Therefore, a great deal of artwork and photography had to be accomplished before the trial version of the test could be administered. All of the equipment necessary to project and mobilize these images was on hand prior to the test.

Abrams Planetarium has a seating capacity of 254 seats. After close examination of the seating arrangement it was discovered that of these 254 seats only 129 seats were available that did not have obstructions for any of the projected visuals. Only these 129 seats were used in all testing.

A method of testing the students in the chamber had to be developed whereby the lighting and writing problems had to be alleviated. Masonite lap boards were cut in sizes of 9" x 12.5". Each student would use this lapboard as a surface on which to write. The lighting problems at first posed a minor problem. The students would have to be dark adapted for the lesson modules and the questioning period following the module. At the appropriate time the chamber would have to have enough light so the student could circle an answer choice on his answer sheet. Following this brief period of time of answering in the presence of light, the chamber had to be immediately darkened again for the next sequence of the test. Therefore the student had to retain most of his night vision. Several solutions to

this problem were posed but it was finally decided that red lighting mounted above and behind the students would give optimum lighting for answering the questions and at the same time not hinder the night vision of the students. The control for this lighting was on a variable rheostat (dimmer) and was operated by the test administrator. This lighting arrangement was then put to trial on various subjects and found to be successful.

The trial version of the test was then administered to twenty-three third and fourth graders. These children were volunteers from a community of student married housing at Michigan State University. After the planetarium trial test was administered, this same group of children participated in the SCIS summer workshop conducted at M.S.U. The purpose of this trial version of the test was to check for weaknesses in the test design. Following the test the group of children were interviewed by the investigator. It was discovered that a few questions were vague and this point was verified by an item analysis of the test. This item analysis was made with a computer which also furnished a reliability coefficient and other statistical information. A test expert, Professor Clarence Nelson of Evaluation Services at Michigan State University, was consulted and with his advice some items were changed for the final version of the test.

The following data were obtained from the trial use of the thirty item test.

Mean = 12.47

Standard deviation = 4.34

Variance = 18.9

Mean item difficulty = 59

Mean item discrimination = 33

Kuder Richardson Reliability #20 = .6827

Standard Error of Measurement = 2.4446

Concerning the appropriateness of reliability coefficients, Lincoln states that "when group results only are sought, a test with a reliability of .50 or .60 will do . . ."[28]

Establishment of the Two Groups

The population of the study consisted of fourth grade classes from the school districts of East Lansing, DeWitt, and Grand Ledge, Michigan. All three districts are suburbs of Lansing, Michigan. Because the elementary schools serve neighborhoods, the typical socioeconomic level of the families varies from school to school. Therefore, care was taken in selecting schools comparable in socioeconomic level. Classes were not assigned randomly to the two groups of SCIS and non-SCIS. The reasons for this non-random assignment were due to the fact that the SCIS schools were already in operation several years prior to the commencement of this study. The procedure of selecting the schools follows.

Letters requesting cooperation in the study were sent to the appropriate administrators of the three school districts. Full cooperation was established by all contacted personnel and interviews were arranged with principals of the participating school districts. The DeWitt school system had four classes of fourth grade students. All four classes were previously designated to receive the SCIS science program. Therefore, no non-SCIS classes within this district were

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[28]Edward A. Lincoln, "Educational Measurements," in Educational Psychology, ed. by Charles E. Skinner (New York: Prentice Hall, Inc., 1945), p. 422.

available for use as a control group. The Grand Ledge school district has only one school involved in the SCIS program and it contained three classroom units of fourth grade students. However, the Grand Ledge district contained six other elementary schools not involved in the SCIS program. It became necessary to identify schools within this subgroup that had the important characteristic of being "just as likely" target schools for the SCIS science program. Upon interviewing the assistant superintendent of this district it was disclosed that two elementary schools would be possible candidates for a control group because of meeting the criterion mentioned above. One of these elementary schools in fact had been previously designated as being the one school to which the SCIS program was going to be used. However, the construction of this school was not completed in time and an alternate school was chosen to receive the SCIS program. From the Grand Ledge district therefore, three schools participated in the study. It was the opinion of the principals of the participating schools in the districts of Grand Ledge and DeWitt that their respective schools were a good match for socioeconomic similarity and that the control schools could have been "just as likely" candidates for receiving the SCIS science program.

The East Lansing school district contains nine elementary schools, all of which utilize the SCIS program in various grade levels. It was decided to use two schools within this district for the study. Central School was chosen at random to be the SCIS representative and Bailey Elementary was chosen to be the control school. Bailey Elementary was a candidate for a control group because the development of the SCIS program in this school was only at the first and second grade level. The third through six grades had not received SCIS training due to the fact that the SCIS program had been developed over a two year period prior to this study. Therefore, when the present fourth graders were in first grade the program had not yet been established. In summary, the total sample consisted of fifteen classroom units of fourth graders. Nine of these classroom units were to receive the SCIS unit "Relativity" and the remaining six classrooms were designated the control group. The complete listing is shown in Figure 2.

SCIS Schools	Non-SCIS Schools
Fuerstenau (DeWitt) 4 classes	Hayes (Grand Ledge) 2 classes
Delta Center (Grand Ledge) 3 classes	Delta Mills (Grand Ledge) 2 classes
Central (East Lansing) 2 classes	Bailey (East Lansing) 2 classes

Figure 2 -- List of schools participating in study

All schools involved in the study were in predominantly white middle class neighborhoods. Intelligence scores were not available in some schools due to a policy of administering intelligence tests at higher grade levels than the one used in this study. However, results from the Otis-Lennon intelligence test are reported with a mean of 111.34 and a standard deviation of 13.64. This test was administered to approximately 95% of all students representing the seven classes from the Grand Ledge, Michigan school district. Otis and Lennon[29] report

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[29]Arthur S. Otis and Roger T. Lennon, Otis-Lennon Mental Ability Test--Technical Handbook (New York: Harcourt, Brace and World, Inc., 1969), p. 19.

a mean of 94.9 and a standard deviation of 17.1 for third graders of comparable size school districts. Of the East Lansing classes that had available intelligence scores, results of the Lorge-Thorndike Intelligence Level A, Form 1 are reported. The median percentile on the verbal test is 73.67. The median percentile on the non-verbal test is 85.33. These tests were administered in the year prior to this study.

Administration of the Experiment

Classes were involved in the study only when the principals and teachers were completely satisfied to have them participate. The investigator contacted all teachers and principals individually. The study was described to each individual and the investigator received complete cooperation from all the contacted individuals.

The investigator explained the study to the teachers and principals in the following way: (1) He would give a pretest in late September, 1970 that utilized the planetarium and tested for the concepts of relative position and motion. (2) Following this pretest, the SCIS fourth graders would receive the unit "Relativity". The non-SCIS classroom teachers do not ordinarily give any formal training on the concept of relative position and were instructed not to go out of their way to do so. (3) The investigator would then give a posttest identical to the pretest, in late February, 1971 as a comparison with the pretest. (4) It was explained that only group means would be announced, and individual teachers or students would not be used as data. (5) The only instructions that the teachers would give to the students regarding the test would be to try their best to answer the questions and not to create any disturbances. (6) No teacher would be permitted to see the pretest and they were instructed not to discuss the pretest with the children.

(7) All personnel involved were invited to see the presentation of the posttest.

(8) All principals were told that both the pretest and the posttest had small astronomy lessons within them and the experience would be worthwhile to the students.

The investigator is not associated with the SCIS program or in its implementation and/or advisory capacities. Therefore, he did not participate in any instruction of the SCIS unit "Relativity". He and one planetarium staff member administered all presentations of the test. All test answer sheets were machine scored. The data were then key punched onto computer cards and analyzed by the IBM 3600 computer.

Testing Arrangements

All participating school districts provided bus transportation to and from the planetarium. The scheduling of participating classes had to meet the bus scheduling of each school district. To meet the restrictions of bus scheduling and available seating in the planetarium, the pretest was administered on four different occasions spanning three successive days. A similar procedure was followed on the posttest that was presented five months later.

Each participating student was given a pencil, lapboard, and answer sheet upon entering the planetarium chamber. All students were directed into the predesignated seats by members of the staff. The unusable seats were those in which any part of the visual aids could not be seen clearly. These seats were clearly marked with tape and were avoided. It can be argued that the location of the individual seats that were used might possibly influence the perspective of the view. Therefore, on each successive administration of the test, the SCIS classes and non-SCIS classes were alternately seated on different sides of the chamber. It was also desirable to have both types of groups present for each administration of the test. The reason for this type of arrangement is that the test was presented live, i. e., not recorded. A program script was followed by the investigator but if in the event that mechanical failure or any other digression from standardization of the test might occur, it was hoped that both types of groups would be influenced similarly. In all eight presentations of the pretest and posttest, no such incidence was noted.

At the beginning of each session the investigator introduced the test to the children in the following manner: (1) He welcomed the group to the planetarium. (2) He described the test as being an experiment that would try to find out how well children of their age can answer certain questions. (3) The ground rules of taking the test were set, such as doing their own work, not talking to others and in general not creating disturbances. (4) It was pointed out that their science grades would in no way be influenced by the outcome of the test, nor that their individual scores would be known to anyone but the investigator. In general, the investigator attempted to alleviate anxiety and a threatening situation. (5) Monitors were placed around the room for the purpose of replacing broken pencils and were introduced to the children. (6) Instructions were then given as to the procedure of answering the questions.

Test Instructions

The children were given a detailed description of what they would experience and the method in which they would answer the questions presented to them. This procedure follows: (1) The light intensity was lowered and an example copy of the

answer sheet was projected on the dome (see Appendix A). (2) Instructions were given as to how to fill in the heading. (3) The light intensity was raised and time was given to the student to accomplish this detail. (4) It was then explained that a brief lesson would be presented and during this lesson the lighting would be at a low level. Therefore, no writing should be attempted. (5) At the conclusion of the lesson a series of questions related to the lesson would be presented in two ways; each question would be read aloud with the accompanying visual aids, and then the question would be projected on the dome and read aloud simultaneously. (6) A choice of answer possibilities was labeled "a" through "d" or "e" and was projected on the dome with the question. (7) A short period of time would be allowed for the student to select what he thought was the best possible answer. (8) At the conclusion of this short period of time, the lecturer would announce "prepare to answer" and and bring the red lights to an intensity that would enable the student to circle the proper letter on his answer sheet. Approximately 15 seconds of time would be permitted for actually circling the answer choice. (9) The light intensity would then be lowered and the next question would be presented to them in a similar manner.

All of the preceding instructions were demonstrated to the students. At the conclusion of both the pretest and posttest the students' answers were translated onto optical scanning type computer sheets and machine scored by the Opscan 100.

Statistical Procedure

The variable that was taken into account in the analysis of the data was initial understanding of the concepts of relative position and motion. Analysis of covariance was used to test the null hypothesis of no group differences ascribable to the type of group to which the student belonged. One of the assumptions necessary for this analysis is independence between experimental units. Therefore the unit employed in this study was the individual class. The total degrees of freedom is thirteen, accounting for the fifteen classes. Variables such as intelligence, sex, or reading ability were not examined in this analysis due to the manner in which the classroom unit is organized, i.e., they are heterogeneously grouped. Treating the individual student as the experimental unit would permit the use of the previously mentioned variables but would have violated the assumption of independence between units.

Reliability data was obtained by an IBM 360 computer for both the 30 item pretest and posttest and is summarized in Table 3.

TABLE 3

Reliability Data For 30 Item Pretest and Posttest

	Pretest N = 331	Posttest N = 331
Mean Item Difficulty[a]	58	41
Mean Item Discrimination[b]	33	37
Kuder Richardson Reliability #20	.6400	.6993
Standard Error of Measurement	2.5016	2.4785

[a]The index of difficulty is defined as the percentage of the total group marking a wrong answer or omitting an item.

[b]The index of discrimination is the difference between the percentage of the upper group marking the right answer and the percentage of the lower group marking the right answer. The upper and lower group each contain 27% of the total.

Hypotheses

Null hypothesis: No difference will be found in the understanding of the concepts of relative position and motion between fourth grade students who have received instruction using the SCIS unit titled "Relativity" and fourth grade students who have not received this instruction, both groups being measured by their adjusted mean performance on a test of these concepts.

Alternate hypothesis: The SCIS group adjusted mean score on a test measuring the concepts of relative position and motion will exceed the adjusted mean score of the non-SCIS group.

Summary

This study utilized a two group, pretest-posttest design in which the experimental group consisted of fourth grade pupils who received the SCIS unit titled "Relativity" and a control group consisting of fourth grade pupils not receiving this unit of instruction. The sample of subjects involved fourth grade classrooms from the school districts of East Lansing, DeWitt, and Grand Ledge, Michigan. The analysis of covariance was applied to the data to detect any differences between the mean scores of the two groups on a planetarium oriented test. This test was designed to measure the ability of the student to understand the concepts of relative position and motion. Reliability coefficients were established for the pilot test, the pretest, and the posttest. These coefficients are .6827, .6400 and .6993, respectively. In Chapter IV, the results and interpretation of the analysis are discussed.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

This chapter, discussing the data collected in the study, is divided into three sections: restatement of the hypothesis; analysis of the data concerning the hypothesis; and interpretation and discussion of the results.

Null hypothesis: No difference will be found in the understanding of the concepts of relative position and motion between fourth grade students who have received instruction using the Science Curriculum Improvement Study (SCIS) unit titled "Relativity" and fourth grade students who have not received this instruction, both groups being measured by their adjusted[30] average performance on a planetarium oriented test of these concepts.

Alternate Hypothesis: The SCIS adjusted group mean score on a planetarium test of the concepts of relative position and motion will exceed the adjusted group mean score of the non-SCIS group.

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[30]Posttest mean scores are adjusted for the effect of the concomitant variable (pretest means) when using the analysis of covariance.

Analysis of Data Concerning the Null Hypothesis

All statistical computations were made with IBM data processing equipment in the Michigan State University Computer Center. Dr. Howard Teitelbaum, a research consultant at Michigan State University, organized the data for analysis by the 3600 IBM computer.

Tables 4 and 5 list the means of individual classes on both the pretest and posttest. A cursory examination of some of the data presented in Table 6 suggests that both groups scored higher on the posttest. Some possible reasons for this gain that are common for both groups are: both groups might have been better mentally equipped for the posttest due to the pretest experience; both groups matured through the five month period between the pretest and posttest; or perhaps the investigator was better skilled with his delivery of the posttest than the pretest (both tests were the same) due to the increased number of administrations of the test. Also, it can be noted that the SCIS gain in raw score from pretest to posttest is more than twice as large as the gain of the non-SCIS group.

The analysis of covariance presented in Table 7 reveals that the difference between the two groups is significant at the .05 level. In light of this analysis the null hypothesis is rejected.

Interpretation and Discussion of Results

The SCIS students as compared to their non-SCIS counterparts seem to have a better comprehension of the astronomical concepts of relative position and motion as presented in the planetarium. Although both groups of students generally

TABLE 4

SCIS Class Means on 30 Item Pretest/Posttest

Class[a]	Pretest Mean	Posttest Mean
S_1	9.92	18.08
S_2	11.96	20.73
S_3	11.42	17.69
S_4	10.89	18.59
S_5	16.81	21.16
S_6	16.07	19.76
S_7	11.17	18.96
S_8	13.08	18.58
S_9	13.00	16.70

[a]SCIS classroom

TABLE 5

Non-SCIS Class Means on 30 Item Pretest/Posttest

Class[a]	Pretest Mean	Posttest Mean
N_1	15.68	17.45
N_2	15.39	17.60
N_3	12.09	15.33
N_4	11.87	17.00
N_5	12.27	13.92
N_6	12.96	15.82

[a]Non-SCIS classrooms

TABLE 6

Group Means on Pretest/Posttest

Group	n[a]	Pretest Mean	Posttest Mean	Gain[b]
SCIS	9	12.70222	18.91667	6.21445
Non-SCIS	6	13.37667	16.18667	2.81000

[a]n = number of classes

[b]Gain = posttest score less pretest score

TABLE 7

Analysis of Covariance of Posttest Scores Adjusting for Pretest Scores

Source of Variation	Df Adjusted	Mean Square Adjusted	F
Between Groups	1	31.3142	20.9933[a]
Within Groups	12	1.491629	
Total	13		

[a]$F_{1, 12}$ at .05 = 4.75; significance probability of F = 20.9933 is .0007

did better on the posttest, the SCIS students are reported to have gained significantly in their ability to answer the questions presented to them. This significant gain is interpreted to mean that the Relativity unit, or the instruction by the SCIS teachers, or both, contributed to the ability of the SCIS students to conceptualize relative position and motion. It should be pointed out that part of this ability could be due to the fact that the pretest items might have served as cues for the SCIS children in aiding them to understand certain aspects of the unit on relativity. That is, the pretest might have increased the respondent's sensitivity or responsiveness to the experimental variable. For the reader's benifit, three charts are presented in Tables 8-10 in order to establish how the two groups of students responded on each item of the pre-test and posttest. Refer to Appendix A for a description of each item.

Two areas of the pretest apparently were more difficult for both groups when compared to other parts of the test. The questions pertaining to the moon (items 2-5) and the planets (items 25-30) were answered correctly by relatively smaller percentages of both the SCIS and non-SCIS groups (see Tables 8 and 9). This was to be expected since these items were, in general, more abstract than other groups of items. Concerning the previously mentioned items, the SCIS children showed greater pretest-posttest gains than did the non-SCIS children--more so than any other area of the test (see Table 10). A speculation as to why they did better is that the concepts presented in these two areas of the test possibly approached the classroom material more closely than other areas of the test. Table 11 is the numerical data pertaining to each item. In conclusion, it can be noted from Table 11 that the SCIS students showed a larger percent correct

TABLE 8

Percent of SCIS Students Marking Correct Response On Pretest and Posttest Items

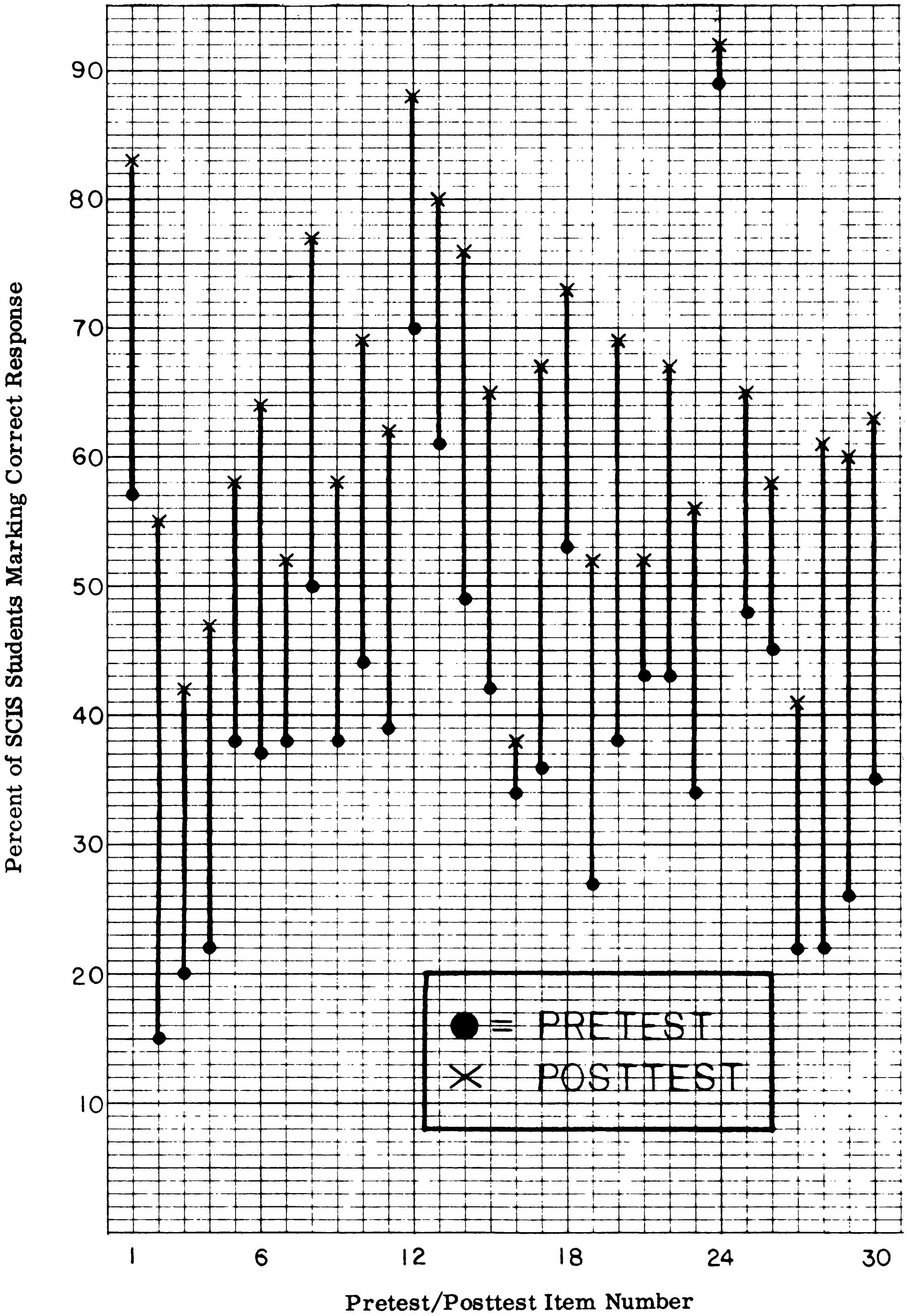


TABLE 9
Percent of Non-SCIS Students Marking Correct Response
On Pretest and Posttest Items

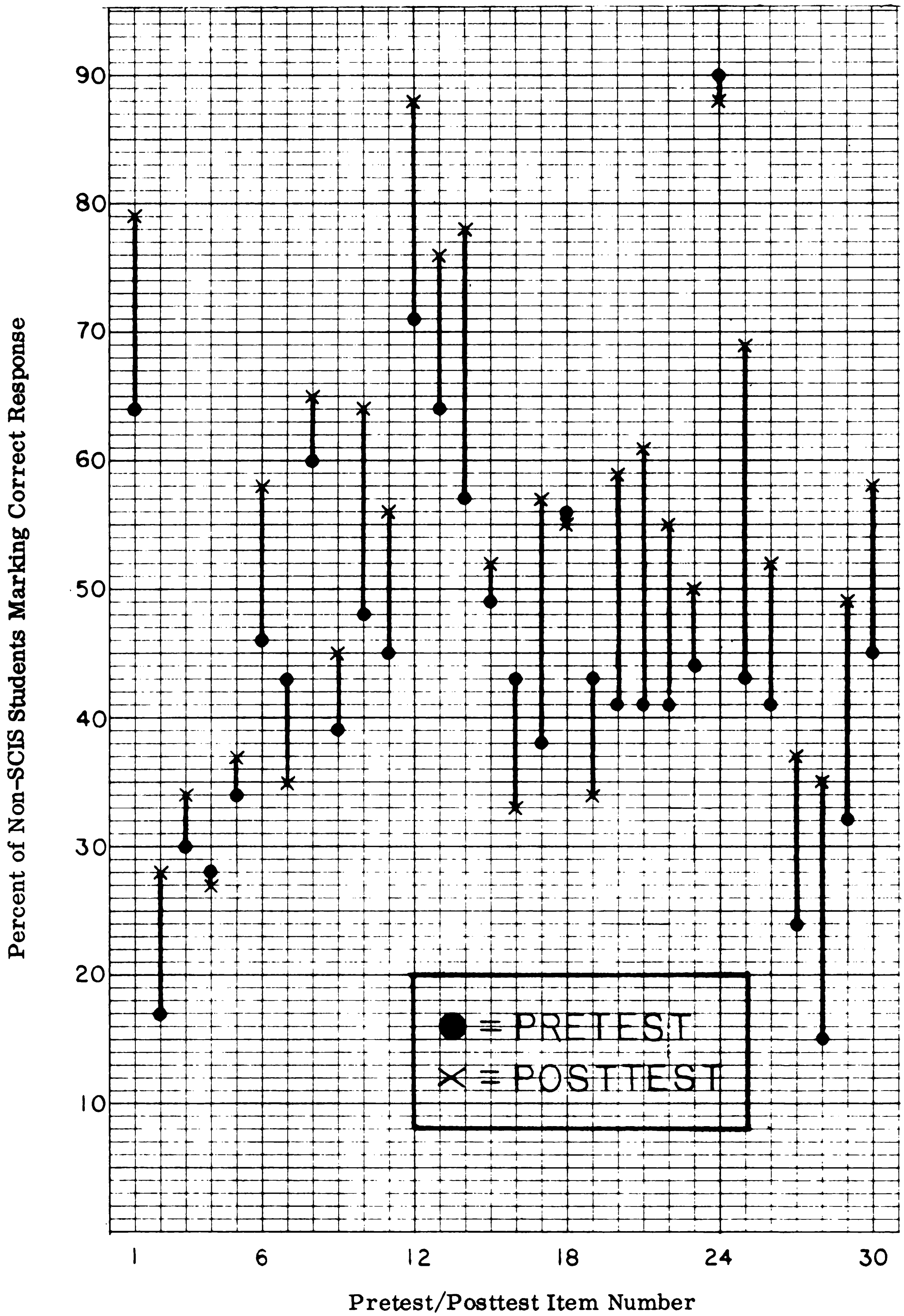
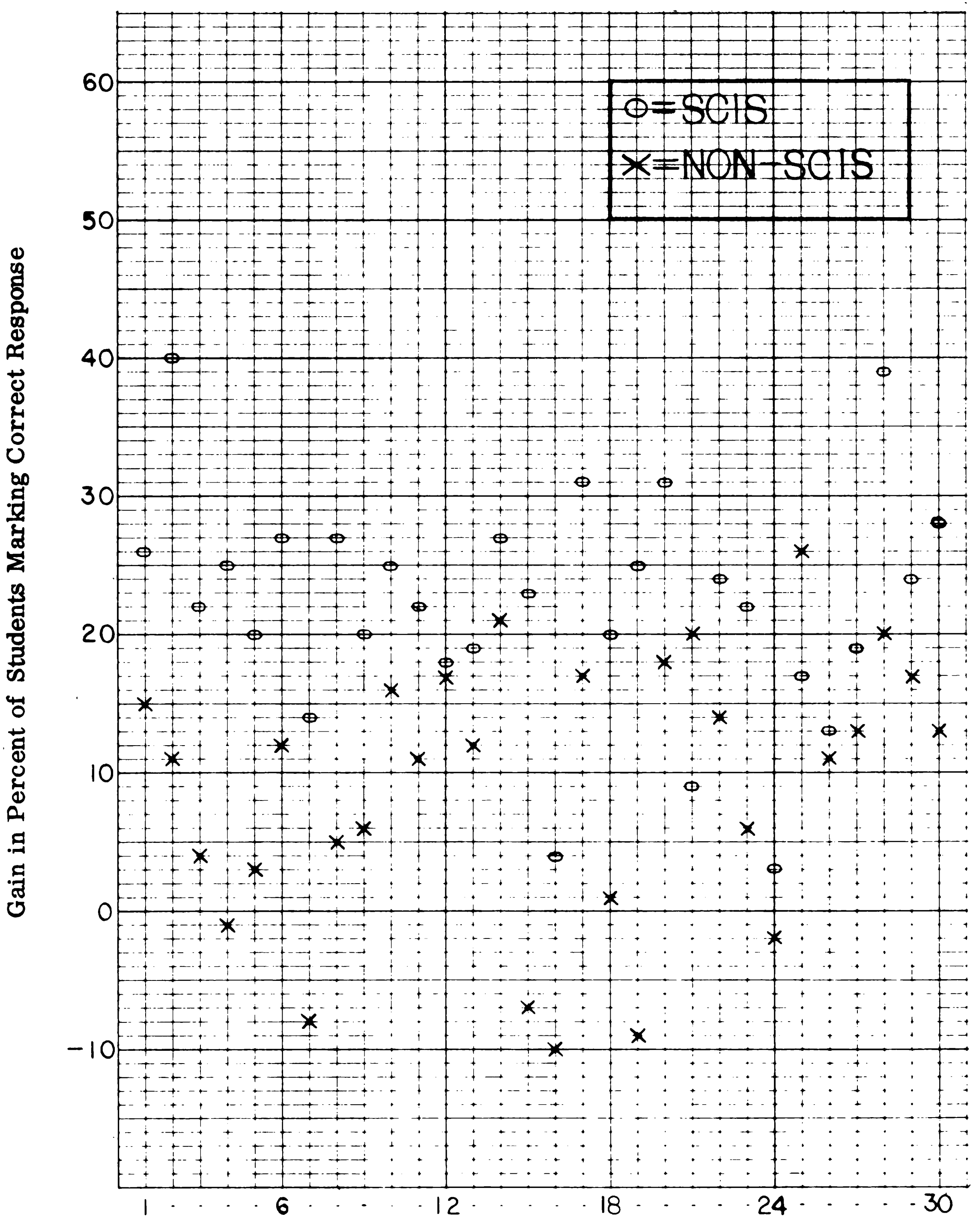


TABLE 10

Comparison of SCIS and Non-SCIS Percent Gain[a]



[a]Gain = Posttest percent of correct responses minus pretest percent of correct responses.

TABLE 11

Percent of Students Marking Correct Response

Item Number	SCIS Pretest	SCIS Posttest	Non-SCIS Pretest	Non-SCIS Posttest	SCIS Percent Gain	Non-SCIS Percent Gain
1	57	83	64	79	26	15
2	15	55	17	28	40	11
3	20	42	30	34	22	4
4	22	47	28	27	25	-1
5	38	58	34	37	20	3
6	37	64	46	58	27	12
7	38	52	43	35	14	-8
8	50	77	60	65	27	5
9	38	58	39	45	20	6
10	44	69	48	64	25	16
11	39	62	45	56	23	11
12	70	88	71	88	18	17
13	61	80	64	76	19	12
14	49	76	57	78	27	21
15	42	65	49	52	23	3
16	34	38	43	33	4	-10
17	36	67	38	57	31	17

TABLE 11- Continued

Item Number	SCIS Pretest	SCIS Posttest	Non-SCIS Pretest	Non-SCIS Posttest	SCIS Percent Gain	Non-SCIS Percent Gain
18	53	73	56	55	20	1
19	27	52	43	34	25	-9
20	38	69	41	59	31	18
21	43	52	41	61	9	20
22	43	67	41	55	24	14
23	34	56	44	50	22	6
24	89	92	90	88	3	-2
25	48	65	43	69	17	26
26	45	58	41	52	13	11
27	22	41	24	37	19	13
28	22	61	15	35	39	20
29	26	60	32	49	24	17
30	35	63	45	58	28	13

response gain for all items except one (item 25), indicating that they seem to be able to transfer the concepts of the unit "Relativity" to the novel examples presented in the planetarium. In Chapter V, the entire study is summarized with implications of results.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine whether fourth grade children enrolled in the Science Curriculum Improvement Study (SCIS) program develop a greater understanding of the concepts of relative position and motion than do non-SCIS fourth grade children.

The SCIS K - 6 program attempts to introduce science materials and concepts compatible with children's reasoning abilities by providing equipment for the children's own investigation, and by giving them freedom to discover the value of the concepts for themselves. Thus, the program must have a firm psychological background on the various stages of how and when children learn. The SCIS designers have looked at the results of educators such as Piaget, Almy and Bruner to provide such a background and have proceeded to build a sequential K - 6 science curriculum.

Most of the evaluation of the SCIS program has been of a descriptive feed-back nature, e.g., discussions with teachers of what occurs in the classroom. Experimental research has been done in evaluation of various levels of this program but to a far less degree than the type previously cited. One of the major factors contributing to the difficulty in evaluating the earlier units of this program is that written tests cannot be used extensively. At the elementary school level, traditional types of written tests mainly measure recall since comprehension and operation with written test items require mental processes that usually arise between the ages of eleven and fifteen years and are thus beyond the scope of younger children. This study was an attempt to evaluate quantitatively the SCIS program at the fourth grade level by using methods other than the traditional test.

The SCIS unit titled "Relativity", usually presented at the fourth grade level, is designed to get students to see and describe the position and motion of objects in reference frames other than their own. In Part One of "Relativity" the children learn about the position of objects relative to reference objects in their environment. In Part Two an artificial observer, Mr. O, establishes a central reference object. Mr. O is a cardboard figure of a person and can be minipulated by the student to any desired position. The position of any other object can be described relative to Mr. O. In Part Three and Part Four the concept of motion relative to Mr. O is examined. In all four parts of the unit there is a cycle of exploration, invention, and discovery, interrelated with the main concept.

In this study a planetarium oriented examination was created to test the students' ability to understand the concepts of relative position and motion from examples that had not previously been seen in the classroom. The planetarium offers a natural setting in which to demonstrate these concepts and simultaneously test a group of students.

In the thirty item test the students were asked to imagine themselves in various viewing locations. From these new viewpoints the students would have a different frame of reference and thus be asked to answer questions that would demonstrate their ability to understand the concepts of relative position and motion. The test was designed with built-in lessons on astronomy, and it was hoped that the experience was not only evaluative but also educational for the students.

The design employed in this experiment was of a two group pretest-posttest structure. The thirty item test mentioned previously was used as both the pretest and posttest. The two groups of students, designated as SCIS and non-SCIS, were selected from the school districts of East Lansing, Grand Ledge, and DeWitt, Michigan. Because the SCIS program had been established in these school districts prior to this experiment a random assignment of classrooms to treatment levels was not used. In its place, control schools were identified with the characteristic of "just as likely" candidate SCIS schools and a group of students similar in socioeconomic background to the SCIS children were designated the control group and used as such. Fifteen classrooms of fourth graders participated in the experiment, nine of which received the SCIS unit "Relativity" and the remainder used as the control group. The pretest was presented to both groups in September, 1970, prior to the administration of the SCIS unit, and the posttest was presented in February, 1971 approximately two months after the conclusion of the unit. An item analysis of the thirty item posttest revealed the test has a reliability coefficient of .6995 (Kuder-Richardson Formula #20).

Analysis of covariance was used to test the null hypothesis of no significant difference in adjusted mean scores between the SCIS and non-SCIS groups. Both groups of students improved their mean score on the posttest. However, the SCIS students showed a gain from pretest to posttest that is more than twice as large as the non-SCIS group gain. The analysis indicates that this difference is significant at the .05 level. Therefore, the null hypothesis was rejected.

Conclusions

The SCIS students as compared to their non-SCIS counterparts seem to have a better comprehension of the astronomical concepts of relative position and motion as presented in the planetarium. Although both groups improved their mean score on the posttest, the SCIS group gain was revealed to be significantly higher than the non-SCIS group gain. These results are interpreted to mean that the "Relativity" unit, or the type of instruction by the SCIS teachers, or both, contributed to the ability of the SCIS students to conceptualize relative position and motion. This assumption is based on the fact that the planetarium examples were different in nature than any provided in the unit "Relativity", therefore the students had to rely more on conceptualization rather than rote memory.

Part of the gain in mean score shared by both groups and common to both groups might be explained by the following possibilities: both groups might have been better mentally equipped for the posttest due to the pretest experience; both groups matured through the time between the pretest and posttest; or the delivery of the planetarium posttest might have been more efficient than the pretest due to the increased experience of administering the same test.

It can also be pointed out that a possible rival hypothesis exists, i.e., the higher gains on the posttest exhibited by the SCIS children could be due to the point that a pretest sometimes increases the respondent's sensitivity or responsiveness to the experimental variable. This situation is more likely to exist if the experimental variable and the pretest items are closely related in appearance. This is one of the reasons why the novelty of the planetarium test was important.

In conclusion, the results of this study confirm the findings of a previous study by Siegelman and Karplus[31] in that the "Relativity" program orients the children strongly toward spatial relationships and that the objectives of this unit are being achieved.

Recommendations

The following recommendations are submitted:

1. A similar planetarium test might be created that has a higher reliability than the test used in this study. The method by which this might be accomplished is to develop a greater number of items and omit much of the time consuming astronomy lesson modules. Recall that these modules were basically presented to give the students involved in this study a direct educational experience and as a result it is assumed that the experience was more attractive to the principals of the schools participating in the experiment.

2. Providing that funding is possible, a film might be developed in which novel examples of relative motion are examined, i.e., a film different from that of the one used in the unit "Relativity" titled "The Fun House." This new film could be used only for testing the objectives of the unit, not for instruction purposes and it would be more easily used by the classroom teacher than would be the planetarium

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[31]Karplus, What is Curriculum Evaluation?

test. Although the initial cost of such a film might be high, it would be less prohibitive in the long run than transportation costs of sending students to and from the planetarium at the conclusion of the unit.

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APPENDIX A

THE EXAMINATION

APPENDIX A

NAME ____
Last   First

SCHOOL ____

GRADE ___________________________ AGE ____________

TEACHER ____

1.	A	B	C	D	E	16.	A	B	C	D	E
2.	A	B	C	D	E	17.	A	B	C	D	E
3.	A	B	C	D	E	18.	A	B	C	D	E
4.	A	B	C	D	E	19.	A	B	C	D	E
5.	A	B	C	D	E	20.	A	B	C	D	E
6.	A	B	C	D	E	21.	A	B	C	D	E
7.	A	B	C	D	E	22.	A	B	C	D	E
8.	A	B	C	D	E	23.	A	B	C	D	E
9.	A	B	C	D	E	24.	A	B	C	D	E
10.	A	B	C	D	E	25.	A	B	C	D	E
11.	A	B	C	D	E	26.	A	B	C	D	E
12.	A	B	C	D	E	27.	A	B	C	D	E
13.	A	B	C	D	E	28.	A	B	C	D	E
14.	A	B	C	D	E	29.	A	B	C	D	E
15.	A	B	C	D	E	30.	A	B	C	D	E

Figure A1 - Sample answer sheet

Introduction

The planetarium examination on the concepts of relative position and motion was administered in the following manner:

1. A background lesson concerning a particular concept was used to introduce the concept to the students. The text under the heading "Background" is presented as if the reader were to play the role of the investigator.

2. The students are given instructions concerning a given situation. In this situation the student usually is told to imagine himself in various positions and viewpoints. The heading titled "Set-up" indicates how the investigator introduced the stimuli for each item.

3. The "item" is the question or statement that was used by the investigator. These statements were spoken orally and then the printed question was projected on the dome and read to the students.

Following the examination is an answer key listing the correct answers for each item.

I. Concept - Zenith in the planetarium.

Background for item 1: A definition of the zenith is presented to the students. They are told that if they are standing straight, a point in the sky directly over their own head is called the zenith. This definition pertains to the outdoor sky. Inside the planetarium theater the "sky" is just a model of the outdoor sky and is of much smaller scale, i.e., the projection of the stars and planets, etc., are very close to them. For this reason the zenith of the planetarium sky is not defined in the same way as the zenith of the outdoor sky. The students are asked to identify the zenith of the planetarium sky, given a set of four letters, each of which is projected in a different spot and one of which is projected directly over the center of the circular room.

Item 1 set-up: Lower the intensity of the sky light and project four letters (A, B, C, D) onto the dome. Explain that one of the letters is closest to being nearer to the zenith of the planetarium sky than any of the other letters.

Item 1: "Which one of these letters is closest to the zenith of the planetarium sky?"

II. Concept - Students will attempt to see what phases of the moon or earth would be apparent to the observer at different vantage points.

Background for items 2-5: A brief explanation will be given on the reasons for the different phases of the moon. The instructor will first use four separate diagrams of the earth-moon system as seen from "above" (meaning north in relation to the earth). See Figure A2 for a composite drawing of these four positions.

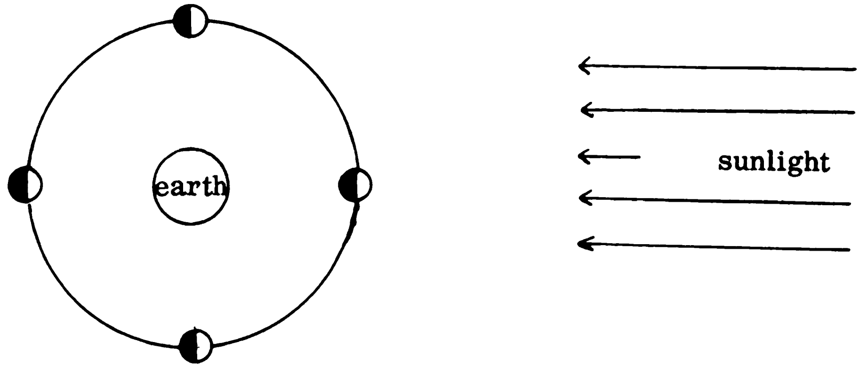

Figure A2 -- Composite drawing of four positions of the moon

With these diagrams will be four pictures of the moon in these various phases to reinforce this idea. After each earth-moon position diagram is presented, a realistic view of the moon as seen in the sky from earth is shown to the students.

Item 2 set-up: The student will observe a realistic view (as seen from earth) of the full moon on one side of the room and the sun in the opposite direction. With these images projected, the following situation is presented to the students.

"An astronaut on the moon sees the earth going through phases just as we have seen the moon do. Here is a picture that will illustrate what I mean (slide of gibbous earth). This was taken by an astronaut while orbiting the moon. That is the earth and you will notice that it appears to be in a particular phase." (slide removed)

Item 2: "As was previously mentioned, we are viewing a full moon as seen from earth. Now imagine yourself standing on the moon, here, (point) looking toward earth. Which one of the following diagrams best shows what you would see while standing on the moon looking toward the earth?" Answer choices are then projected (see Figure A3).

Figure A3 -- Answer choices for item 2

Item 3 set-up: Change the earth-moon system so that the moon is at first quarter and show the students the situation as viewed from the earth. Than have them imagine that they are standing on the moon at the location to which you point.

Item 3: "Again, you will now imagine yourself standing on the moon, here, (point) looking toward the earth. What phase would the earth appear to resemble?" Answer choices are shown in Figure A4.

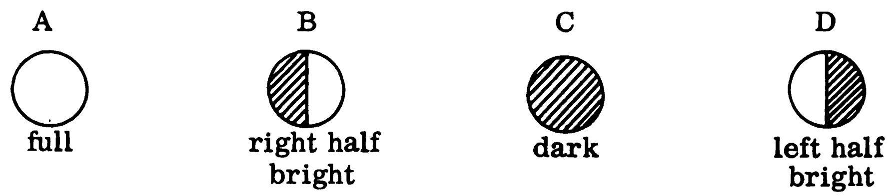

Figure A4 -- Answer choices for item 3

Item 4 set-up: Show the sun-moon in a position that would produce a last crescent (as viewed in Figure A5). This time mark the moon's position with an "X" so students do not actually see the phase and explain that the "X" represents the moon.

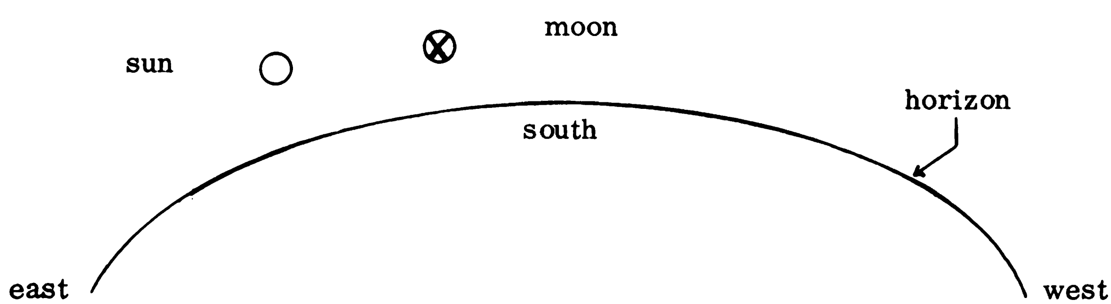

Figure A5 -- Set-up for items 4 and 5

Item 4: "What would the moon appear to be like as seen in the sky and as observed from here on earth?" Answer choices are shown in Figure A6.

Figure A6 -- Answer choices for item 4

Item 5 set-up: Use the same set up as in item 4.

Item 5: "If you could observe this same situation from the sun and look toward the moon, how would the moon appear to you?" See Figure A7.

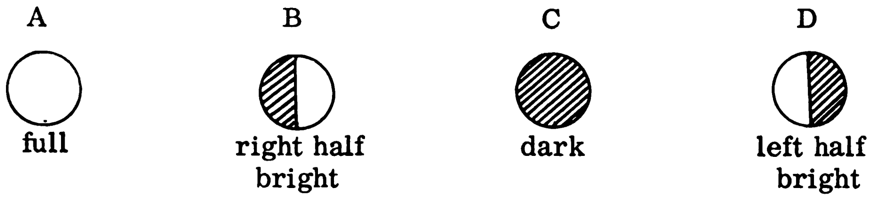

Figure A7 -- Answer choices for item 5

III. Concept - Recognizing the positions of the sun at different seasons.

Background for items 6-8: An explanation will be given for the reasons of why the sun is "in" different zodiacal constellations during the year (revolution of earth around sun). To do this the instructor will show the sun on the ecliptic and run the annual motion. It will be pointed out that the sun's apparent motion is an illusion caused by the earth's own revolution around the sun. Zodiacal figures will be shown as this is done.

Item 6 set-up: Project four slides on the cove depicting Gemini, Sagittarius, Virgo, and Pisces. An attendant in the center of the room will hold a Trippensee "planetarium"* (orrery) in view of the students. See Figure A8.

*The Trippensee Planetarium is a hand held model of the sun and earth. The earth is attached to the sun by means of a connecting arm that enables the earth to revolve around the sun.

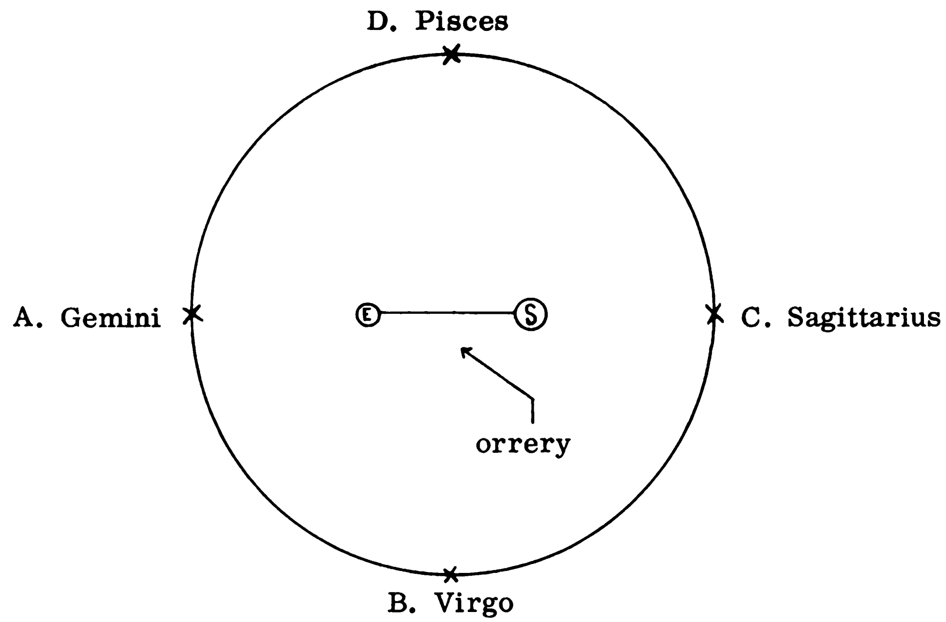

Figure A8 -- Set-up for item 6 (as seen from above the chamber)

Item 6: "You are standing on the earth, here (point). In which of the zodiacal pictures that you see around the room does the sun seem to be in?"

Item 7 set-up: Switch the orientation of the orrery 180^{o} as shown in Figure A9.

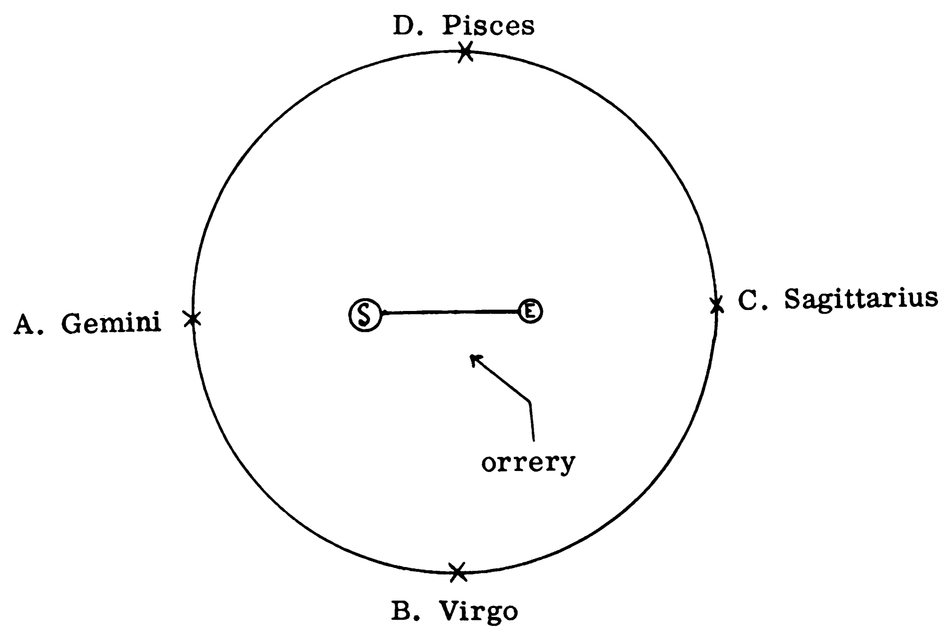

Figure A9 -- Set-up for item 7 (as seen from above the chamber)

Item 7: "You are standing on the earth, here (attendant points to earth globe). When you look towards the sun you can't actually see any stars because of the glare of the sun. Which of these four constellations would best be seen at night because it is in the opposite direction of the sun?"

Item 8 set-up: Place the Trippensee in the position shown in Figure A10.

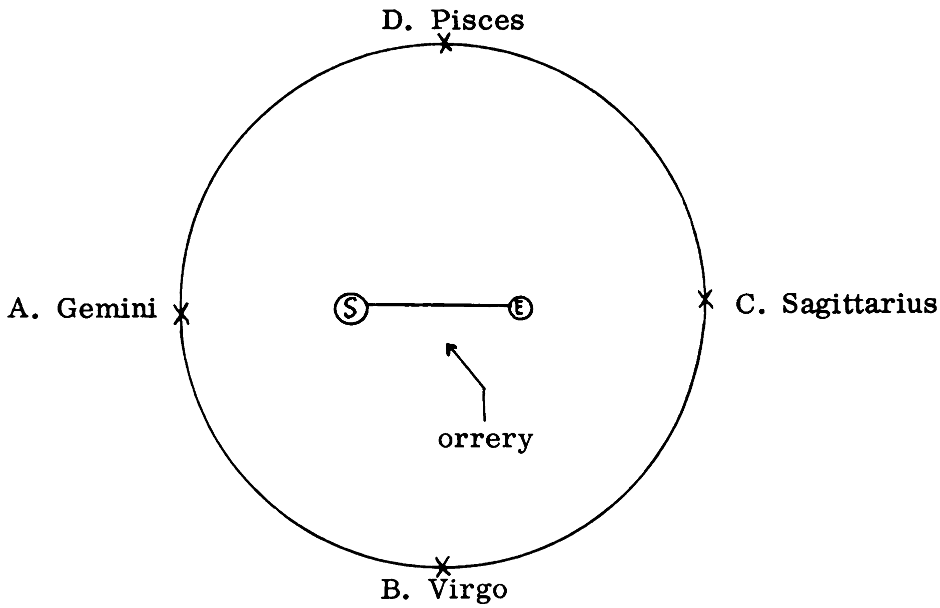

Figure A10 -- Set-up for item 8 (as seen from above the chamber)

Item 8: "Now imagine for a moment that you could stand on the sun and face toward the earth. What constellation would be in the opposite direction or, in other words, in back of you?"

IV. Concept - Recognizing apparent star motions due to the earth's diurnal motion.

Background for items 9-14: The lecturer will briefly explain why the sun, moon, stars, and planets all seem to be at various positions during the night and day. Because the earth spins on its axis one way, the sky seems to rotate the opposite way causing the heavenly objects to rise in the east and set in the west.

To explain these concepts the lecturer will use the daily motion of the sky prior to sunset letting dusk to occur, and letting the stars become visible. The words rise and set will be explained and used.

Item 9-14 set-up: Rotating earth device is projected against a background of stars and is placed in a stationary position as shown in Figure A11.

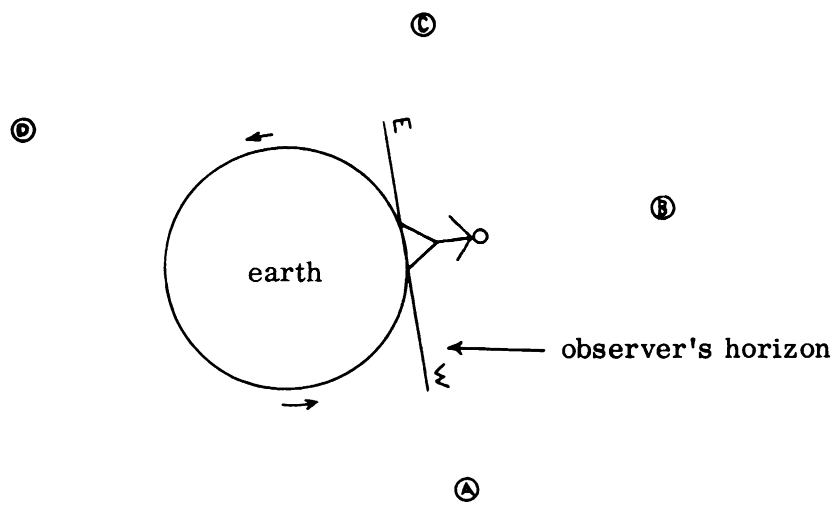

Figure A11 -- Rotating earth device used for items 9-14

After an explanation of the device, it will slowly rotate 360^{o} to show direction of rotation. It will then be stopped at a point similar to the original picture as shown in Figure A11.

Item 9: "To observer standing on the earth, which star has just risen?"

Item 10: "Which star is just about to set?"

Item 11: "Which star is the next to rise?"

Item 12: "Which star is overhead of the observer?"

Item 13: "Which star will be the next to be seen overhead of the observer?"

Item 14: "To the observer, which star is the closest to being in the opposite direction of A?"

V. Concept - Utilizing the Geocentric Earth Projector* to give the student a view of the sky motions as viewed from inside the earth, he will then transfer his viewpoint to a new reference point outside the earth.

Background for item 15: An explanation will be given for the geocentric viewpoint. A projection of the sun's image will be placed near the equator and the student will be told that from his present viewpoint inside the earth, he would see the sun at this place. See Figure A12.

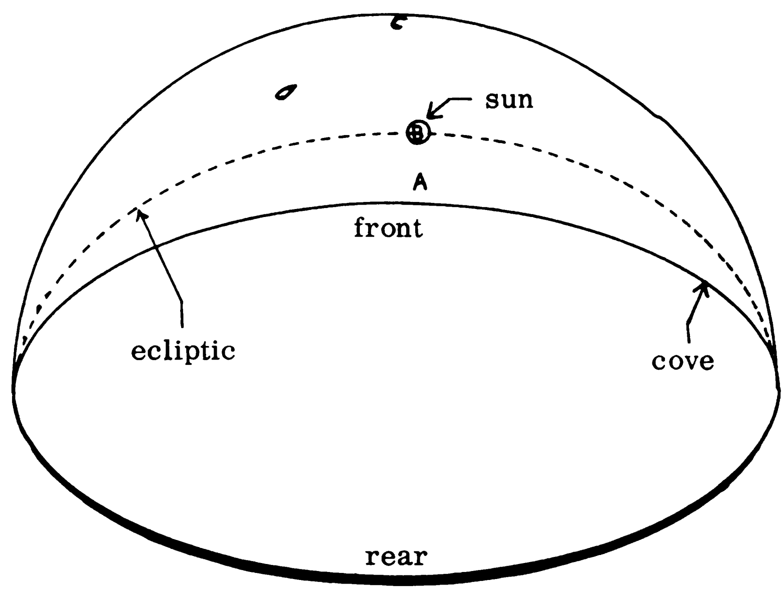

Figure A12 -- Set-up for item 15 (as seen from above and rear of chamber)

Item 15: "If this is where the sun appears on a certain day of the year, (point to the sun) where would you have to be on the earth to see the sun directly overhead?" (The answer choices are A, B, C, D, one of which is directly in the spot where the image of the sun is placed.)

*The Geocentric Earth Projector projects the continents on the dome so that the continents appear reversed in orientation, giving the observer the impression that he is at the center of the earth looking out at the surface.

<u>Background for items 16-19:</u> Using the Geocentric Earth Projector, the students will be placed at a vantage point in the center of a transparent earth. The students will observe a figure of a man standing on a satellite above the surface of the earth and facing them. (See Figure A13.) The directions relative to this man are clearly marked, i.e., his right, left and "up". For the next four items, this man on a satellite will move across the sky above the surface of the earth. There is an "X" marked on the surface of the earth. As the orientation and motion of the man are changed for the next few items, he apparently would see the "X" move in certain directions in relation to himself. To the man on the moving satellite the "X" would appear to move up, down, right or left.

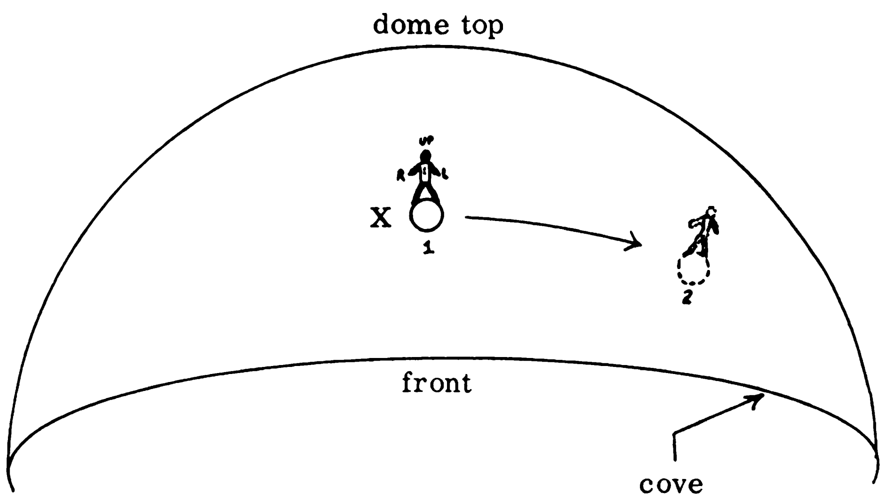

Figure A13 -- Set-up for item 16 (as seen from rear of chamber)

<u>Item 16 set-up</u>: Explain that the satellite is going to move and that the student is to imagine that he is the person standing on the satellite. The student sees an "X" marked on the surface of the earth. The

satellite and man are then mobilized, and the student, playing the role of the person on the satellite, is asked how the "X" would appear to move to him. The answer choices are then projected (see Figure A14) and time is given for the student to select his answer.

<u>Item 16:</u> "Imagine that you are a person standing in this position (point to to the man standing on the satellite). You are facing the earth. If you could see this point on the earth, marked with an "X", how would it appear to move to you if we let the satellite move? (Move the satellite to position 2 as in Figure A 13.)

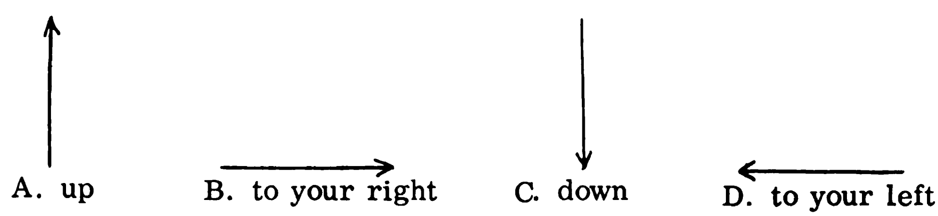

Figure A14 -- Answer choices for items 16-19

<u>Item 17 set-up</u>: The procedure for this item is the same as it item 16. The one exception is that the man is oriented as shown in Figure A15.

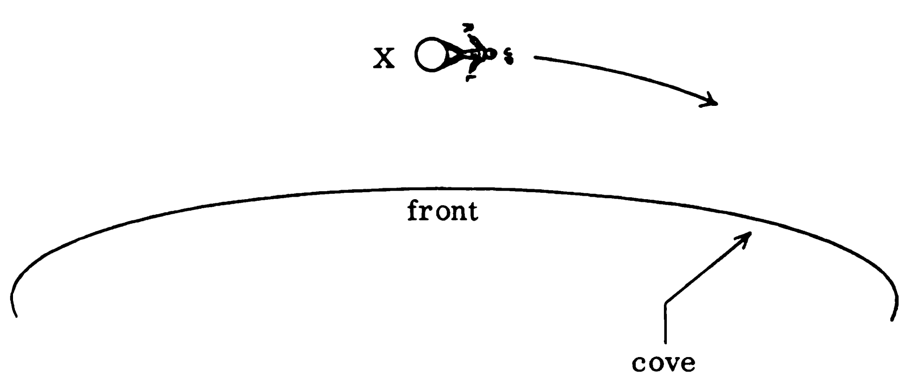

Figure A15 -- Set-up for item 17 (as seen from rear of chamber)

<u>Item 17:</u> "Again imagine yourself to be this person standing on the satellite, here, (point) watching this "X". How does the "X" appear to move? (Answer choices are the same as in Figure A14.)

<u>Item 18 set-up</u>: The man on the satellite is oriented in such a way as to appear upside-down relative to the student. (See Figure A16.)

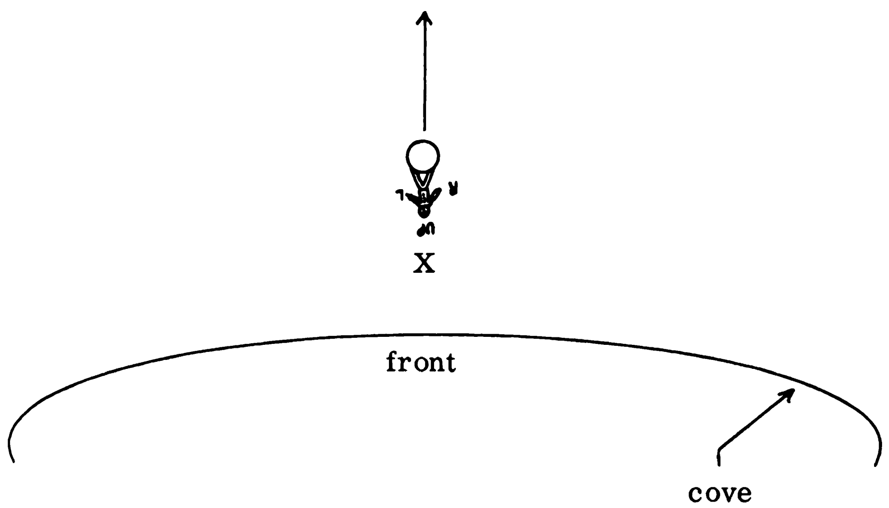

Figure A16 -- Set-up for item 18 (as seen from rear of chamber)

The "X" marked on the surface appears to be in front of the man on the satellite. The students are told to imagine that they are the man on the satellite and as the satellite moves they are to select the direction in which the "X" would seem to move. The motion of the satellite will be in a direction that is verticle to the floor of the planetarium chamber.

<u>Item 18:</u> "How does the "X" appear to move to you as you are standing on this moving satellite?" (Answer choices are the same as in Figure A14.)

Item 19 set-up: The man on the satellite is oriented as shown in Figure A17 and will move as indicated by the arrow.

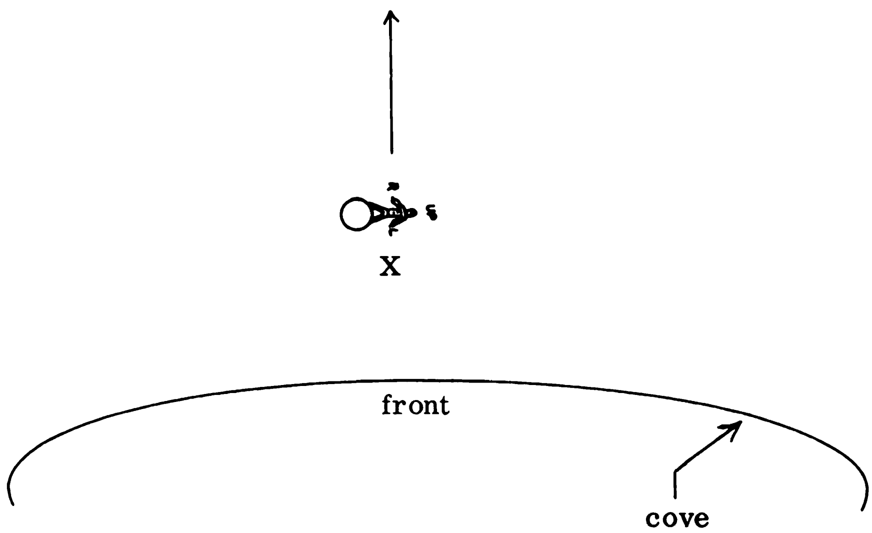

Figure A17 -- Set-up for item 19 (as seen from rear of chamber)

The students are given the same information as in previous items. The motion is started and the answer choices are again visible to the students. (Same as in Figure A14.)

Item 19: "How does the "X" appear to move as you are standing on this satellite."

VI. Concept - The students will determine whether a roll, pitch, or yaw has been performed by a command module in which they are occupants.

Background for items 20-22: Explain roll, pitch, and yaw using a model airplane to perform the various motions. Next, darken the theater and when the stars are visible, project the nose cone of a command module on the cove (see Figure A18). This will be the student's frame of reference.

The lecturer will then project another craft, the Saturn III stage, at 90^{o} to the left of the nose cone. The idea will be to link together the two crafts as in a space rendezvous. The III stage rocket is an image that is moved simultaneously with the stars.

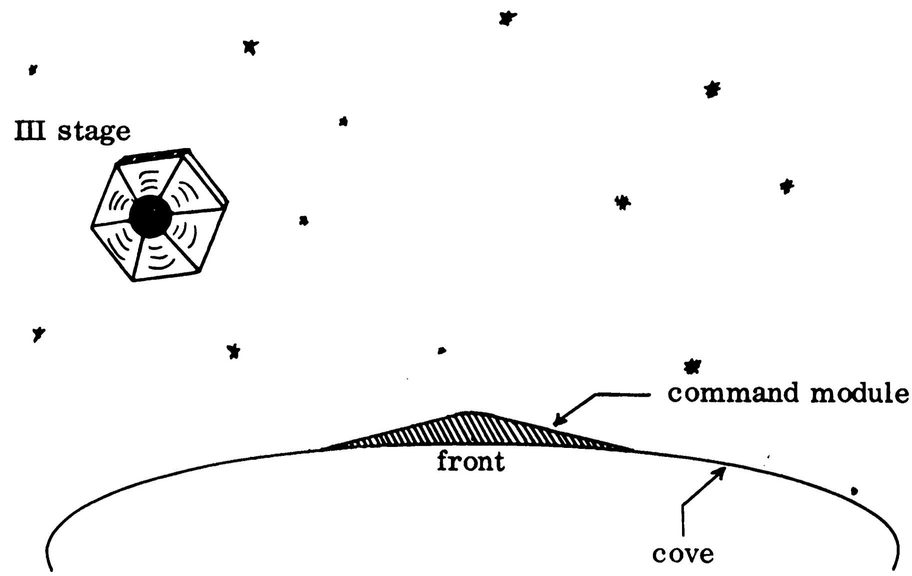

Figure A18 -- Set-up for items 20-22 (as seen from rear of chamber)

Item 20 set-up: Perform a "yaw left".

Item 20: "What motion are we doing?"

A. Pitch up B. Pitch down C. Clockwise roll

D. Yaw left E. Yaw right

Item 21 set-up: Perform a "pitch up".

Item 21: "What motion are we doing?"

A. Pitch up B. Pitch down C. Counterclockwise roll

D. Yaw left E. Yaw right

Item 22 set-up: Perform a "yaw right".

Item 22: "Which movement are we now doing?"

A. Pitch up B. Pitch down C. Clockwise roll

D. Counterclockwise roll E. Yaw right

VII. Concept - Zoom effects. The student will try to determine which of four objects is moving.

Background for items 23 and 24: In each case the student will be given a set of conditions but will have to figure out reference points in order to judge which object has apparently done the moving.

Item 23 set-up: The student is in the command module and sees the three objects in front of him. These are labeled A, B and D. (C is the command module). See Figure A19.

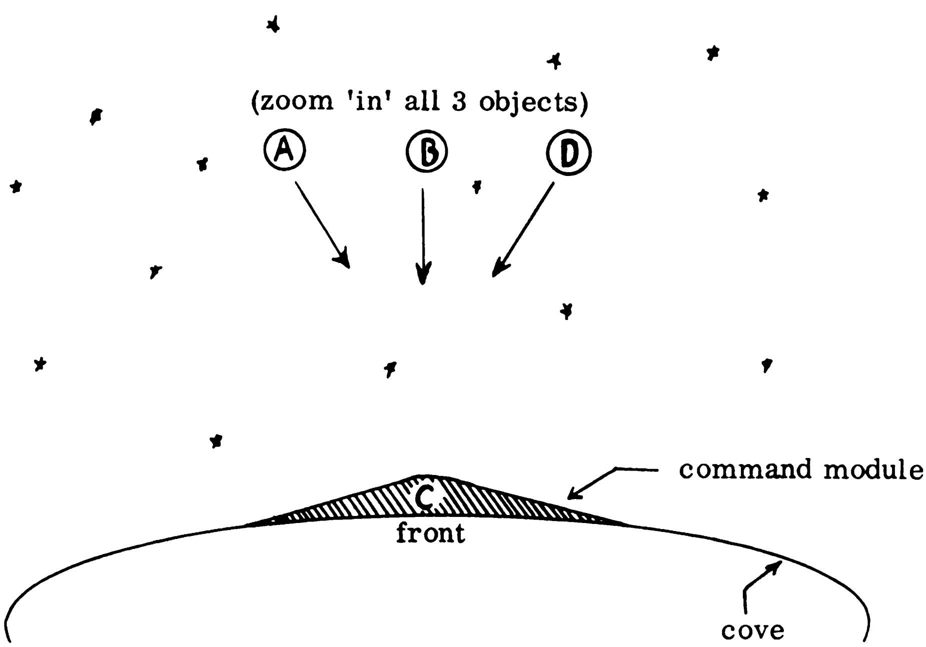

Figure A19 -- Set-up for item 23 (as seen from rear of chamber)

Item 23: "If I told you that only one of the four objects is actually moving, which one would you select?" (A, B, C, or D)

Item 24 set-up: See Figure A20.

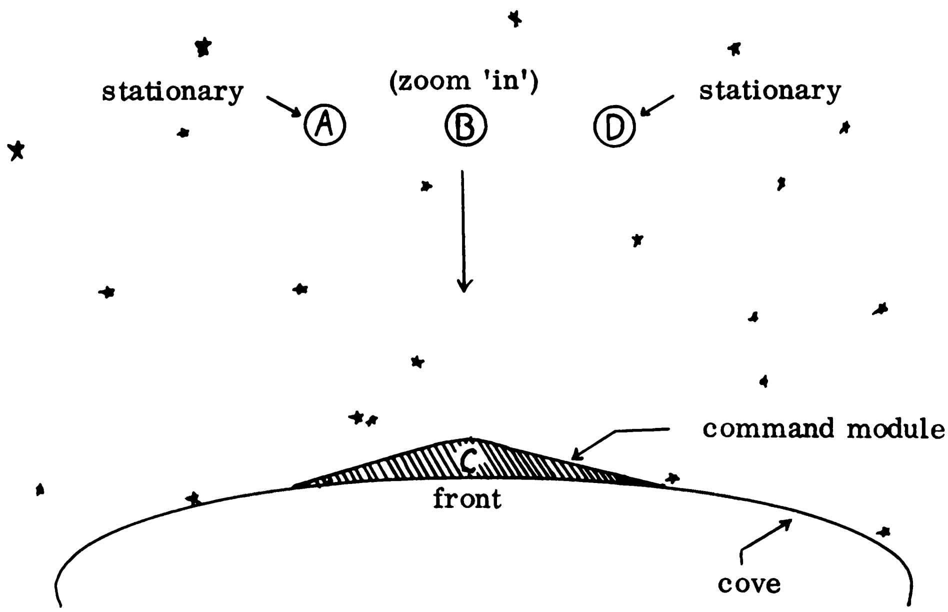

Figure A20 -- Set-up for item 24 (as seen from rear of chamber)

Item 24: "Again we have a similar set-up as before. The three objects are at the same distance away from the command module. Only one of the four objects is going to move. (Start the zoom.) Which object is moving?" (A, B, C, D)

VIII. Concept - By looking at planetary orbit diagrams the student will be asked to mentally place himself on a certain planet and predict how the other planets move relative to himself.

Background for items 25-30: A brief lesson on planetary motion is presented to the students. The concepts contained in the lesson are of planetary position, planetary motions, and the resultant apparent motions due to the combined effects of the previous factors. The Spitz orrery is used to depict differential planetary motion. This device consists of small projectors that move dots (planets) in such a way as to represent relative orbital velocity of the planets. The effect of using the Spitz orrery is one of an observer watching the planets in motion as seen from the North Ecliptic Pole. As this device is used, the students are shown that the inner planets move faster than the outer planets. Also, it is pointed out that, depending on the observer's location, he will see the planets apparently move in different ways. An analogy of a circular highway with different lanes for different speeds is given. In this analogy it is pointed out that if the observer were in the race car called Earth, faster cars on the inner track would seem to pass him and appear to be going forward against a background of stars. Forward is defined as the direction his car is headed at that moment. As his Earth car passes a slower moving car on an outer track, e. g., Mars, the Mars car would appear to be "backing up" against the background of stars. However, it is also pointed out that if the cars are on the opposite side of the track (on the far side of the sun), they would appear to be going backwards to an observer in an Earth car.

The student is then asked to apply this knowledge to a picture of the planet positions at a particular moment in time. For simplicity, only the Sun, Venus, Earth and Mars will be represented (see Figure A21).

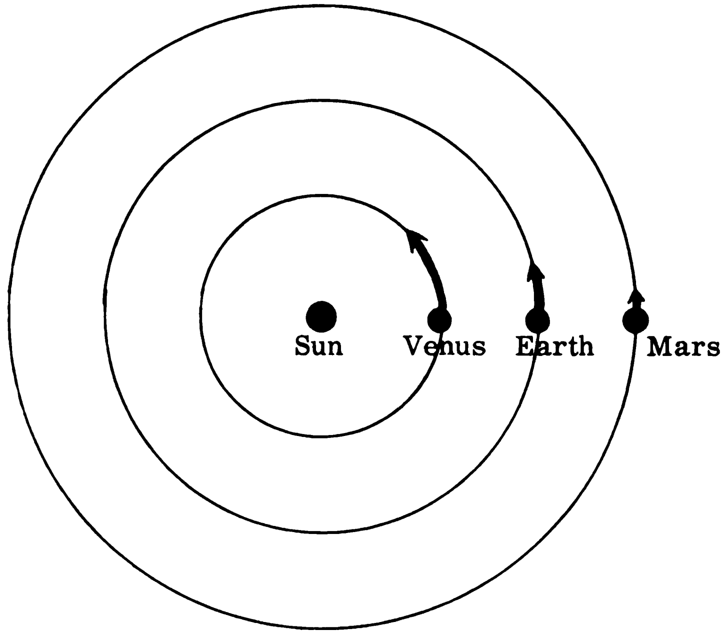

Figure A21 -- Orbit diagram for item 25

The arrow lengths are explained to be reminders to the students that the inner planets move faster than the outer planets. The orbits and the planet dots are also color coded, e.g., Mars always appears red. The student is again given definitions of forward and backward and then presented a situation as seen from Earth. Planet images with direction arrows are shown in the sky as seen from Earth.

Item 25 set-up: Project a slide depicting the planet positions as seen in Figure A21. Explain the drawing once again and that the students will be observers placed on the Earth standing at the center of the Earth dot image and facing in the direction that the Earth is moving. (Although it is not stated, the observer standing at this position would have his body vertical to the plane of the ecliptic.) The student is then asked to identify how Mars and Venus would appear to be moving. At this point the student is told that he will now be taken down to the Earth and will look into the sky. The orbit diagram is removed from view and the observer sees images of Mars on his right side (see Figure A22). Forward and backward arrow indicators are identified and defined. Thus, the student will be asked how Venus and Mars appear to move in the sky against a background of stars. Four choices of answers will be projected one at a time. Finally, a composite of all four answer choices is presented simultaneously as in Figure A22, and the student is asked to study the orbit diagram once more (projected again) and to make a choice. After a brief pause, the question is then formally restated and projected on the dome.

<u>Item 25:</u> "You are on the Earth, here, (point) and facing in this direction (point in the direction in which Earth is moving). How would Mars and Venus appear to be moving?"

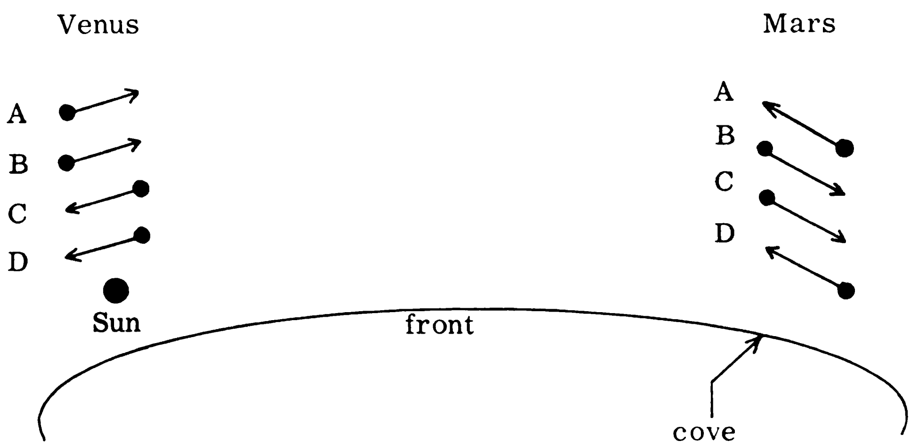

Figure A22 -- Composite answer choices for items 25 and 26

Item 26 set-up: The procedure of explaining an orbit diagram is the same as in the item 25 set-up. The diagram presented to the students is seen in Figure A23. Again the student will be observing Mars and Venus from his position of the Earth (point to the location on the Earth dot). The answer choices are the same as in Figure A22.

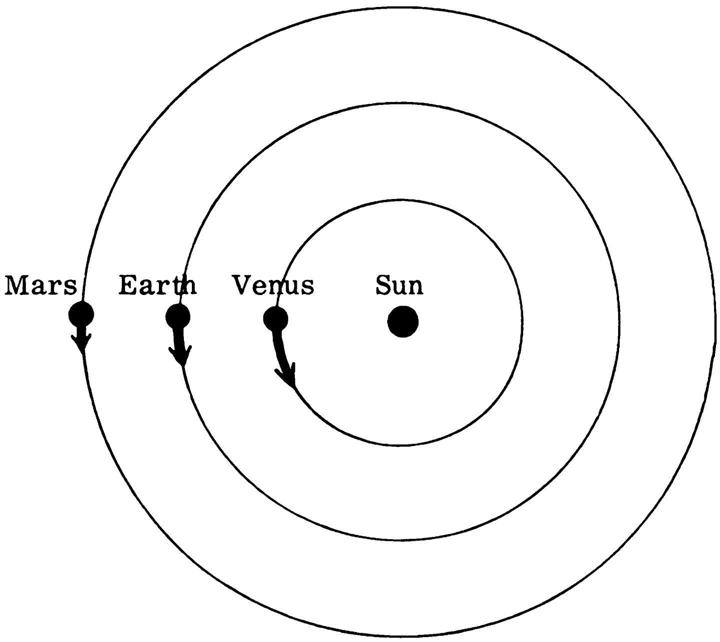

Figure A23 -- Orbit diagram for item 26

Item 26: "You are on the Earth, here, (point) and heading in this direction (indicate the direction in which the Earth is moving). How would Mars and Venus appear to move?"

Item 27 set-up: Use the same procedure as in the item 25 set-up. The orbit diagram that is used for item 27 is seen in Figure A24. The composite answer choices are presented in Figure A25.

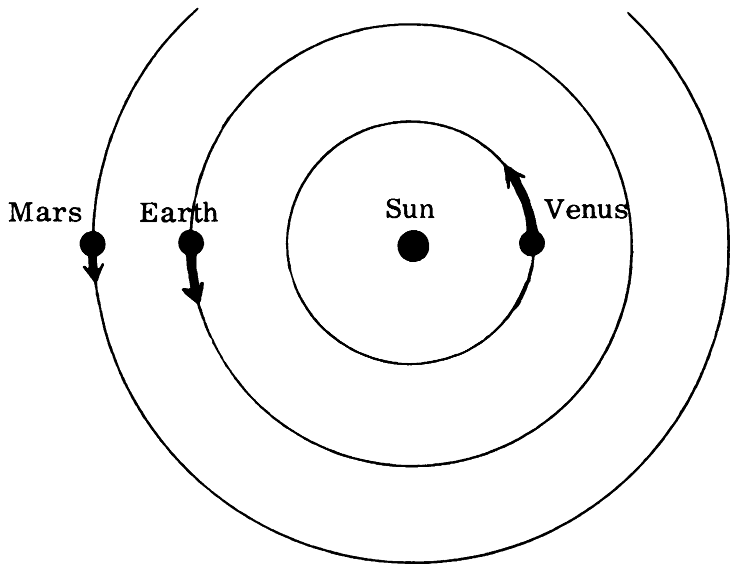

Figure A24 -- Orbit diagram for item 27

Item 27: "You are on the Earth, here, (point) and heading in this direction (point to the direction in which the Earth is moving). How would Mars and Venus appear to move?"

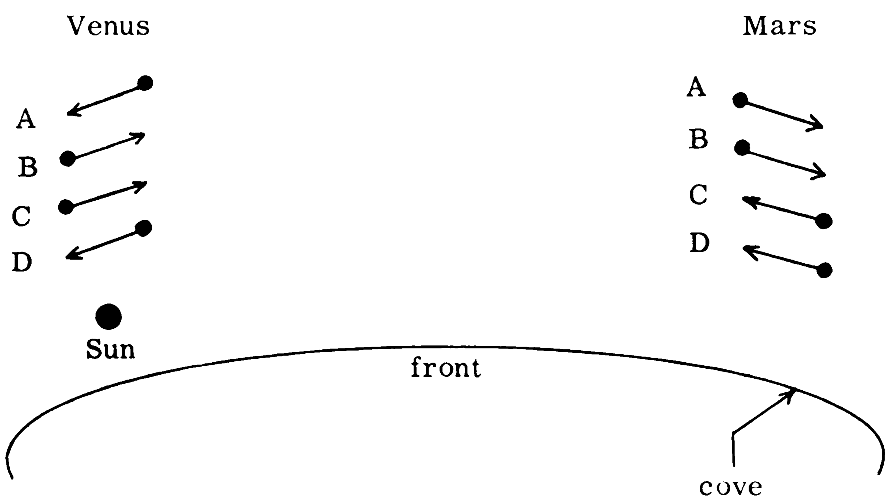

Figure A25 -- Composite answer choices for items 27 and 28

Item 28 set-up: Use the same procedure as in the item 25 set-up. The The orbit diagram that is used for item 28 is seen in Figure A26. The composite answer choices are the same as the preceding item and are presented in Figure A25.

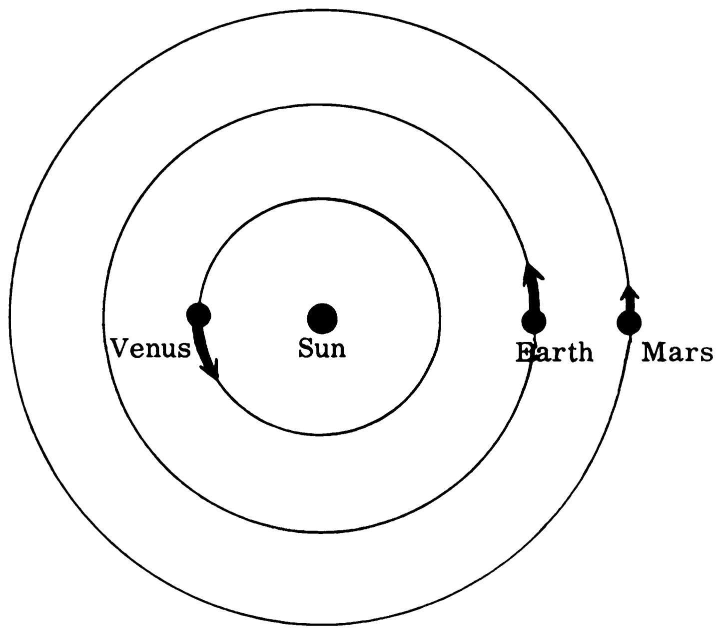

Figure A26 -- Orbit diagram for item 28

Item 28: "You are on the Earth, here, (point) and heading in this direction (point to the direction in which the Earth is moving). How would Mars and Venus appear to move?"

Item 29 set-up: Use the same procedure as in the item 25 set-up. The orbit diagram that is used in item 29 is shown in Figure A27. The composite answer choices are presented in Figure A28.

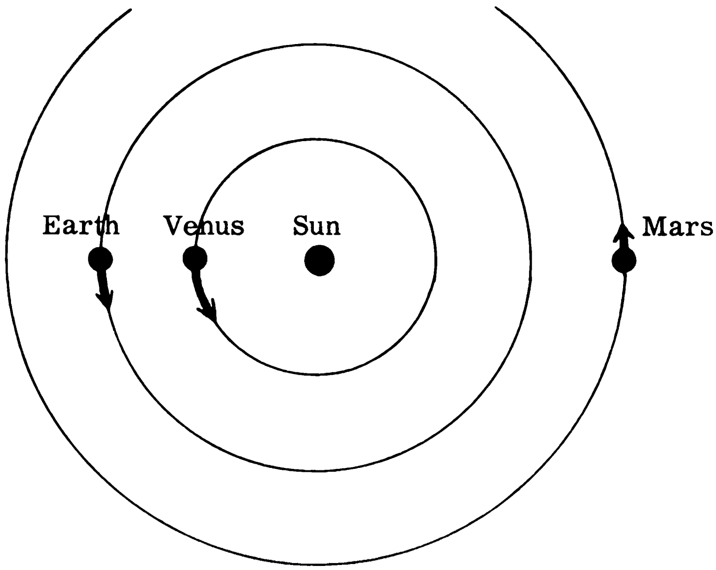

Figure A27 -- Orbit diagram for items 29 and 30

Item 29: "You are on the Earth, here, (point) and heading in this direction (point to the direction in which the Earth is moving). How would Mars and Venus appear to move?"

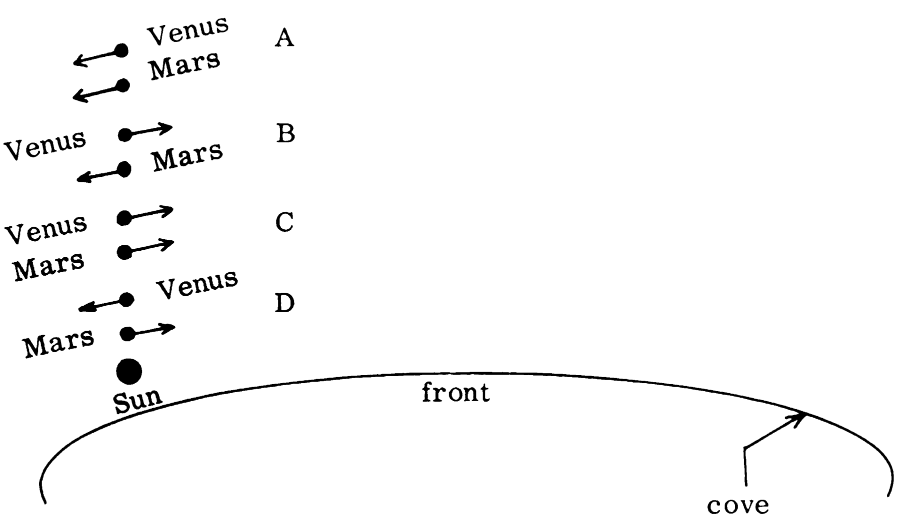

Figure A28 -- Composite answer choices for item 29

Item 30 set-up: Use the same procedure as in the item 25 set-up. The orbit diagram that is used for item 30 is the same as in the previous item (number 29). However, the students are told that they will be observing Earth and Venus from a position on Mars, not on Earth. Therefore, the composite answer choices will reflect positions of Venus and Earth (see Figure A29).

Item 30: "This time, you are standing on Mars, here, (point) and heading in this direction (point to the direction in which Mars is moving). How would Venus and the Earth appear to move?"

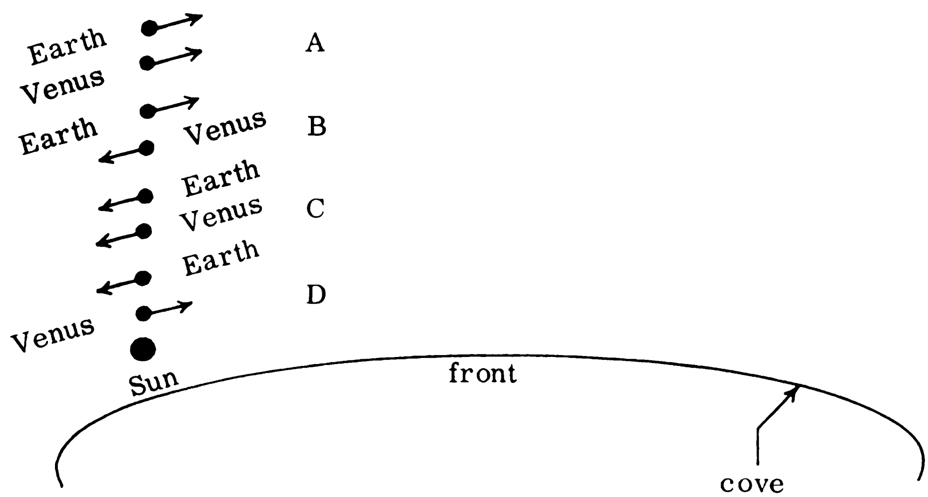

Figure A29 -- Composite answer choices for item 30

ANSWER KEY

1. C	16. B
2. C	17. C
3. D	18. A
4. A	19. D
5. A	20. D
6. C	21. A
7. C	22. E
8. A	23. C
9. C	24. B
10. A	25. B
11. D	26. B
12. B	27. A
13. C	28. A
14. C	29. B
15. B	30. C

Figure A30 -- Answer key to the 30 item examination

APPENDIX B

FREQUENCY DISTRIBUTIONS

TABLE B1

Computer Printout of Frequency Distribution on Trial Version of the Examination

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 9900 AUGUST 1970

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
23	1	1	97	74.2
20	1	2	93	67.3
16	2	4	86	58.1
15	4	8	73	55.8
14	2	10	60	53.5
13	2	12	52	51.2
12	1	13	45	48.9
11	2	15	39	46.6
10	2	17	30	44.3
9	2	19	21	42.0
8	1	20	15	39.7
7	2	22	8	37.3
4	1	23	2	30.4

MEAN 12.47
STANDARD DEVIATION 4.34
VARIANCE 18.90
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B2

Computer Printout of Frequency Distribution on Pretest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 4000 MARCH 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
29	1	1	99	89.2
25	1	2	99	79.6
24	3	5	98	77.2
23	1	6	98	74.8
22	4	10	97	72.4
21	6	16	96	70.0
20	7	23	94	67.6
19	8	31	91	65.2
18	13	44	88	62.8
17	12	56	84	60.4
16	17	73	80	58.0
15	22	95	74	55.6
14	28	123	67	53.2
13	39	162	57	50.8
12	26	188	47	48.4
11	38	226	37	46.0
10	27	253	27	43.6
9	23	276	20	41.2
8	25	301	13	38.8
7	18	319	6	36.4
6	8	327	2	34.0
5	2	329	1	31.6
4	3	332	0	29.2

MEAN 12.64
STANDARD DEVIATION 4.17
VARIANCE 17.43
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B3

Computer Printout of Frequency Distribution on Posttest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 3000 MARCH 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
28	6	6	99	72.7
27	1	7	98	70.5
26	9	16	96	68.3
25	12	28	93	66.1
24	10	38	90	63.9
23	15	53	86	61.7
22	8	61	82	59.5
21	27	88	77	57.3
20	28	116	69	55.0
19	32	148	60	52.8
18	24	172	51	50.6
17	23	195	44	48.4
16	25	220	37	46.2
15	24	244	29	44.0
14	24	268	22	41.8
13	20	288	16	39.6
12	16	304	10	37.3
11	11	315	6	35.1
10	7	322	3	32.9
9	3	325	2	30.7
8	4	329	1	28.5
7	1	330	0	26.3
6	1	331	0	24.1

MEAN 17.70
STANDARD DEVIATION 4.52
VARIANCE 20.48
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B4

Computer Printout of Frequency Distribution of SCIS Students on Pretest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 9501 APRIL 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
25	1	1	99	81.6
24	2	3	98	79.2
23	1	4	98	76.7
22	2	6	97	74.2
21	1	7	96	71.8
20	2	9	95	69.3
19	5	14	93	66.8
18	5	19	91	64.4
17	6	25	88	61.9
16	12	37	83	59.5
15	13	50	76	57.0
14	13	63	69	54.5
13	16	79	62	52.1
12	14	93	54	49.6
11	23	116	44	47.1
10	19	135	33	44.7
9	16	151	23	42.2
8	17	168	15	39.8
7	13	181	7	37.3
6	4	185	2	34.8
5	1	186	1	32.4
4	2	188	0	29.9

MEAN 12.14
STANDARD DEVIATION 4.06
VARIANCE 16.56
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B5

Computer Printout of Frequency Distribution of Non-SCIS Students on Pretest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 9503 APRIL 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
29	1	1	99	87.3
24	1	2	98	75.4
22	2	4	97	70.6
21	5	9	95	68.2
20	5	14	91	65.8
19	3	17	89	63.5
18	8	25	85	61.1
17	6	31	80	58.7
16	5	36	76	56.3
15	9	45	71	53.9
14	15	60	63	51.5
13	22	82	50	49.1
12	13	95	38	46.8
11	16	111	27	44.4
10	8	119	19	42.0
9	6	125	14	39.6
8	7	132	10	37.2
7	6	138	5	34.8
6	4	142	2	32.4
4	1	143	0	27.7

MEAN 13.34
STANDARD DEVIATION 4.19
VARIANCE 17.61
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B6

Computer Printout of Frequency Distribution of SCIS Students on Posttest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS.

30 ITEMS ON TEST 9502 APRIL 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
28	2	2	99	72.0
27	1	3	98	69.6
26	8	11	96	67.2
25	11	22	91	64.7
24	9	31	85	62.3
23	11	42	80	59.9
22	3	45	76	57.5
21	18	63	71	55.1
20	18	81	61	52.6
19	24	105	50	50.2
18	14	119	40	47.8
17	14	133	32	45.4
16	11	144	26	43.0
15	11	155	20	40.5
14	16	171	13	38.1
13	9	180	6	35.7
12	4	184	3	33.3
11	1	185	1	30.8
10	2	187	1	28.4
6	1	188	0	18.7

MEAN 18.89
STANDARD DEVIATION 4.13
VARIANCE 17.06
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

TABLE B7

Computer Printout of Frequency Distribution of Non-SCIS Students on Posttest

EVALUATION SERVICES
RAW SCORE DISTRIBUTIONS

30 ITEMS ON TEST 9504 APRIL 1971

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE
28	3	3	98	76.1
27	1	4	97	73.9
26	1	5	96	71.7
25	1	6	96	69.5
24	1	7	95	67.3
23	4	11	93	65.1
22	5	16	90	62.9
21	9	25	85	60.7
20	10	35	79	58.5
19	8	43	72	56.3
18	10	53	66	54.1
17	9	62	59	51.9
16	14	76	51	49.7
15	13	89	42	47.5
14	8	97	34	45.3
13	11	108	28	43.1
12	12	120	20	40.9
11	10	130	12	38.7
10	5	135	7	36.5
9	3	138	4	34.3
8	4	142	2	32.1
7	1	143	0	29.9

MEAN 16.12
STANDARD DEVIATION 4.54
VARIANCE 20.62
STANDARD SCORE HAS MEAN OF 50 AND STANDARD DEVIATION OF 10

APPENDIX C

ADDRESSES OF SCHOOLS PARTICIPATING IN THE STUDY

APPENDIX C

ADDRESSES OF SCHOOLS PARTICIPATING IN THE STUDY

East Lansing Public Schools

1. Bailey Elementary Schools
   300 Bailey Street
   East Lansing, Michigan 48823

2. Central Elementary School
   325 W. Grand River
   East Lansing, Michigan 48823

DeWitt Public Schools

1. Fuerstenau School
   205 Washington Avenue
   DeWitt, Michigan 48820

Grand Ledge Public Schools

1. Delta Center School
   305 S. Canal Road
   Grand Ledge, Michigan 48827

2. Delta Mills School
   Delta River Road
   Lansing, Michigan 48827

3. Hayes School
   Nixon Road
   Grand Ledge, Michigan 48827