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AN EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF MANIPULATIVE USE IN PLANETARIUM ASTRONOMY LESSONS FOR FIFTH AND EIGHTH GRADE STUDENTS

Wayne State University

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AN EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF
MANIPULATIVE USE IN PLANETARIUM ASTRONOMY
LESSONS FOR FIFTH AND EIGHTH
GRADE STUDENTS

by
JAMES D. EDOFF
DISSERTATION

Submitted to the Graduate School
of Wayne State University,
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Approved by:

[Signatures]
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The planetarium is a sophisticated facility designed to duplicate and project the motions of the moon, planets, sun and stars so that complicated, long-sequenced celestial events may be readily observed, studied, and understood. With its invention in the 1920's the planetarium came into the domain of large cities and museums. The few facilities that were built in the 1930's, '40's, and '50's were generally regarded as objects of curiosity by visiting tourists. However, the 1957 launching of the first artificial satellite by the Soviet Union shocked America out of its complacency. By accepting the space challenge, the United States had to accept the responsibility of educating its people to the space environment and in the process found its educational program wholly inadequate to meet the challenge. "It was this dilemma that brought the modern American planetarium--and more specifically again the small planetarium--into its own " (Ary 1974, p. 12). The concern of the President and Congress led to the NDEA matching funds and Title III grants being used to construct hundreds of new, small planetariums throughout the country. Their development and acceptance into the educational community has been a remarkable occurrence with over 1,100 facilities built to date. As evidenced by Gall (1978), most are associated with
educational institutions and are visited by an estimated 12 million students each year (Friedman 1976).

Smith (1966) noted that planetariums "have been heralded as marvelous aids for teaching astronomical concepts but this praise is mainly based on subjective opinion" (p. 4). There has been relatively little research conducted to substantiate if they actually are a valuable asset in the teaching of astronomy. "The few research studies available in the area emphasize the current state of confusion and the need for this kind of evaluation research" (Smith 1974, p. 76).

Educators have questioned if the facility is actually superior to the classroom in teaching many astronomical concepts Tuttle (1966), Smith (1966), Rosemergy (1967), Soroka (1968), Wright (1968), Ridky (1974), Reed (1975), Ortell (1977). However, this position has met with much criticism, even by one of the researchers (Soroka 1974, p. 122): "What we do not need are more complex comparative studies of teaching techniques contrasting planetarium instruction to various experimental and control (classroom) groups." Further confusion has resulted because many studies which compared classroom teaching with planetarium teaching have reached conflicting conclusions.

In the studies of the past few years, strongly divergent results have appeared with some favorable, and some highly unfavorable, conclusions. When one finds that competent observers advocate strongly divergent points of view, it seems likely that both have observed something valid about the situation and
that both represent a part of the truth. (Sunal 1976, p. 348)

However such research has demonstrated a dearth of practical knowledge as to how a planetarium lesson should be presented. The rapid increase in the number of planetariums has resulted in hundreds of educators being placed in charge of coordinating and operating facilities without having any practical training or inservice education. "While the theory of our primary subject, astronomy, is well preserved in print, the techniques of planetarium operation are yet to be adequately documented" (Tate 1977, p. 7). The problem arises that little is known about teaching techniques and procedures that would or would not be effective. "Further research is needed in order to provide those who present planetarium lectures or teach astronomy concepts in the classroom with an understanding of the effectiveness of various methods of instruction" (Smith 1976, p. 10). Thus, there is a need for research into the types and effectiveness of planetarium techniques. Such specific recommendations concerning further planetarium research have been made by planetarium educators. Reed (1974) noted: "The research articles continue to show a need for a conceptual framework within which to develop purposeful instructional strategies" (p. 129). Bisard (1979) recommended that "planetariums need to foster more evaluation with research which is well designed to verify the best techniques for facilitating learning that are available in the planetarium" (p. 9). Bishop (1980) concluded: "Planetarium studies which explore the effectiveness of
particular methods, based on sound learning theory, with realistic and distinctive control methods (are) needed" (p. 5).

Research by Ridky (1974), Reed (1975), and others has shown that planetarium lessons are most effective when they utilize successful classroom techniques. More recent studies, Fletcher (1977), Mallon (1980), and Bishop (1980), have been concerned with student involvement and participation during the planetarium presentations. Such concern for active pupil participation follows the recommendations of early educational writers such as Maria Montessori and John Dewey. Developmental psychologists such as J. Piaget (1964), J. Suchman (1960), and J. Bruner (1965) have also advocated that direct manipulation of concrete objects is important in the development of learning in children.

Statement of Problem

The resultant problem of the study was to conduct an experimental comparison among fifth and eighth grade students employing a planetarium unit of study which included direct manipulation and one which excluded direct manipulation of an instructional object. The unit included three major topics with students making three instructional visits to the planetarium. Criterion measures were student performance on three immediate topic post-tests, a delayed unit post-test, and pre-post measurements of attitude. The variables of previous experience, manipulative opportunity, grade, and gender were examined.

The purpose of this study was to investigate the
following question: In an educational planetarium are fifth and eighth grade lessons incorporating student manipulation of a concept object or lessons without concept model manipulation the most effective method for increased achievement and attitude change?

Measurement of achievement included the ability to answer questions which required recall of information or application of knowledge of observation of positions. The measurement of attitude was suggested because of research by Ridky (1974), Ortell (1977), and others which has indicated that planetarium teaching may be in the affective domain.

"It can be concluded that the effectiveness of the planetarium appears not to lie in facilitating content achievement but rather in effecting attitudinal change" (Ridky 1974, p. 93). A "mystique effect" eluded to by many planetarium operators and investigated by Ridky (1975) and Bishop (1980) suggested analysis of the variable of previous planetarium experience affecting student concept attainment. Grade and gender were also studied as possible influences. The following six questions represent the research basis for measuring the effectiveness of manipulative use in planetarium lessons:

1. Is retention, as shown through unit post-test results, different for students using a manipulative than for those not using a manipulative?

2. Does the use or non-use of a manipulative within a planetarium unit of study effect a student's attitude toward astronomy education?

3. Does previous planetarium experience effect the
immediate post-test scores of students using or not using the manipulative?

4. Is the manipulative more effective for one of the three types of lessons?

5. Does grade level or sex influence the effectiveness of manipulative use?

6. Is the ability to correctly answer recall, application, or observation questions effected by manipulative use?

Assumptions

Students honestly attempted to answer the test items correctly.

Seating position in the planetarium chamber did not significantly alter a student's perspective of the presented material.

Three planetarium visits were sufficient to effect an attitude change.

Controls

All students experienced an identical time allotment and content presentation within the planetarium chamber.

The same visuals were used during experimental and control lessons.

The investigator presented all material.

Test items were read to students to lessen reading ability differences.

Limitations

Internal Validity

Small differences within treatments existed because the lessons were not recorded and student responses varied from
group to group.

Differences in the total school environment, including school programs, may have affected student receptivity.

**External Validity**

The population of this investigation included only fifth and eighth grade students from one school district and caution must be exercised in generalizing the results to other student populations of proportionally different socioeconomic levels.

**Operational Terms**

**Planetarium** - a simulation mechanism that shows the movements of the celestial bodies as they appear to an observer on earth. The planetarium chamber consists of a dome with an inner white surface serving as a projection surface for many small projectors that are placed at the center of the sphere. The positions and motions of these projectors are inter-connected by driving gears in such a manner that the images of the celestial bodies are depicted as they are seen in the natural, clear sky. The instrument can be manipulated to show the appearance of the sky at any time from any place on earth (adapted from Reed 1973, p. 553). A Spitz instrument model A-4 was used in this study. The facility's dome diameter was 30 feet with a seating capacity of seventy individuals.

**Application questions** - those test questions which require the student to apply the facts presented during a planetarium lesson to a unique but related situation.

**Manipulative** - a three dimensional object for student handling and movement. It is inferred that the manipulative
permits a student to examine an illustrated position from different perspectives. A clear, plastic, hemisphere dome and a glass marking pencil were used by each student in the experimental group of this study.

Observation questions - those test questions which require the student to correctly identify an answer by choosing one of the choices pointed out in the planetarium sky.

Previous planetarium experience - exposure to any series of educational presentations in a school planetarium within a prior three-year period.

Recall questions - those test questions which require the selection of answers which were directly presented during the planetarium lesson.

Topic post-test - a paper-and-pencil test covering topical information and given immediately after the lesson presentation before students leave the planetarium.

Unit post-test - a paper-and-pencil test including all the topics presented during the three planetarium sessions. This test is given in a classroom three weeks after the last planetarium visit.
CHAPTER II
REVIEW OF RELATED RESEARCH

Planetariums take science out of the realm of the abstract, bringing it clearly and enjoyably to life. Astronomy and space science become relevant especially with the planetarium's ability to simulate most celestial phenomena ... the planetarium is a powerful motivator. (Morris 1972, p. 55)

This statement is typical of the claims that educators have made about the value of a planetarium facility. However, most attitudes are based on intuitive feelings rather than on research findings. Planetarium research efforts have been reported in the last three decades. Most studies in the 1960's and early 1970's on this topic simply reported survey findings about the managerial aspects of the planetarium such as perceived goals, topics most often presented, and director's qualifications.

Research in the mid-to-late 1970's shifted to a validating process of demonstrating the worth of planetariums to astronomy education. Most recently studies have sought to identify the various factors of instruction which can facilitate and improve learning within the planetarium chamber. The following review of research contains three sections which discuss these descriptive, comparative, and evaluative studies, and a fourth section which summarizes literature related to the research variables of this experimental study.
Descriptive Planetarium Research

Descriptive surveys attempted to present the status of procedures at various stages of planetarium development. Chamberlain's (1962) pioneering study reported information from ten major planetarium facilities in the United States. In addition to giving a summary of the general physical features of the buildings, projection theaters, and exhibit spaces, this survey reviewed the history, development, and characteristics of the various projection devices. Through an analysis of the practices and variations in practices concerning the popular lecture format, the author concluded that the planetarium reaches its greatest potential when it is administered by professionally-trained staff members who are oriented to both astronomy and education. The value of Chamberlain's (1962) study rests in its ability to be used as a guide for those constructing a planetarium facility and/or curriculum. By illustrating many of the problems within planetarium productions, the researcher provided suggestions for avoiding them. Chamberlain's only concern, however, was the operation of the planetarium from an administrative perspective; he did not explore the relationship of the planetarium to education. It remained for Korey to explore this aspect of the planetarium domain.

Korey (1963) tabulated questionnaires from 191 responding institutions in an attempt to measure the contribution of planetariums to elementary education. Her many findings identified the topics presented most often to elementary school classes, and the activities involving these children,
and the frequency of visitations. Such negative aspects as the lack of adequate operating funds and lack of any definite procedures to evaluate class visits, led Korey to conclude that the educational potentialities of planetariums had not been fully realized. Seven years after this study, Warneking's comments demonstrated that Korey's derived opinion was still appropriate. "We really have little objective evaluation to assure us that the programs are effective or to guide us in getting the greatest possible learning value from the planetarium and the programs presented in it" (Warneking 1970, p. 14).

Moore (1965) was concerned about the impact of the planetarium on an older group of subjects. However, what began as an attempt to analyze the effectiveness of planetarium training in adult science education, was actually a personality survey of those who attended planetarium programs. The planetarium experience mainly became a method of dividing the adult population of the Mott Adult Education Program into two groups. Moore's findings did include, however, an indication that multiple exposure to planetarium programs made highly significant differences in adults' ability to recognize space terms.

Downing (1971) also investigated adult education in the planetarium, however, he was most concerned with the identification of adult learning processes. Unfortunately, over one-third of the 145 planetarium staff that completed his questionnaire had no method of adult program evaluation. Two of the adult learning principles—one relating to problem
centered learning, and the other relating to participation in planning—were not found to be successfully utilized by planetarium staff. However, this study did introduce the concern that research was necessary to identify planetarium teaching techniques which would create a conducive climate for learning and concept retention. Similarly, Kobel (1967) sought to develop programs and acquire data necessary for the operation of a planetarium located in a public school system. Suggestions for the development and operation of school planetarium programs were made, along with techniques for presenting those programs to elementary and secondary school students.

In order to determine the practices and procedures in the use of planetariums and observatories among secondary schools, McDonald (1965) gathered data from 78 schools and summarized the mandated and recommended positions of state offices of education toward the installation and utilization of planetariums. He discovered that only five states had minimum standards of instruction or certification requirements in science for planetarium teachers. The highest rate of planetarium use was in relation to the concepts of motion and celestial geometry. Unfortunately, this information was purely descriptive, not prescriptive, and the conclusions only allowed planetarium personnel to ascertain if they were similar to the norms of operation. This research philosophy was strongly criticized by T. Smith (1974) when he noted, "it appears that the attitude of the period was that if most everyone else conducted certain aspects of the planetarium in
a specific manner, then the method must be correct" (p. 1965).

The survey results from 260 planetariums were more thoughtfully analyzed by Dean (1971) as he developed practical guidelines for the selection of planetarium instruments. Like Chamberlain (1962), Dean discusses the characteristics of various projection devices but more correctly considered the availability of personnel, pupils to be served, and style of teaching as impacting planetarium effectiveness.

Curtin (1967) was more concerned with the teaching techniques used in the planetarium, and his analysis of 38 tape recorded fourth and ninth grade planetarium programs gave data on astronomy content and types of questions asked by planetarium instructors. He found no content differences between elementary school and junior high school programs, and also noted that a program length of 40 minutes was typical. In all but seven of the lectures, planetarium instructors asked questions of their audiences. In categorizing these questions according to Bloom's Taxonomy, it was learned that all but nine of 413 questions were in the knowledge class. Only seven questions were classified as translation, one as extrapolation, and one as analysis of relationships. Here again, we find an example where planetarium lessons were not realizing maximum educational potential.

These nine descriptive studies not only provided information about planetarium design, operation, and management, but also introduced questions about the value of planetariums in the teaching of astronomical concepts. Such a concern may have motivated the eleven researchers, who are
reviewed in the following section, to investigate comparisons between the effectiveness of planetariums and of classrooms in presenting astronomical information

**Comparative Planetarium Research**

This section reviews those studies which compare the planetarium experience to the traditional classroom experience. In general, the major design of such comparative studies was to find variations among two groups on acquisition of one or more astronomical concepts. T. Smith (1974) correctly noted that it was unfortunate that most comparative studies did not isolate a particular factor as the critical variable. The studies, therefore, concluded either in favor or against the planetarium without providing information "as to which of the multitude of factors operating in the planetarium have assisted or retarded the learning process with respect to some set of behavioral objectives" (p. 24).

One of the first planetarium classroom research studies was completed by Tuttle (1966) in which astronomy units were taught concurrently to two sixth grade classes which were matched by I.Q., chronological age, and reading score. While one class was taught only in the planetarium and the other only in the classroom, pre-tests and post-tests were used to determine gains in two and three dimensional spatial relations tests from the Multiple Aptitude Test Battery. The results, all in favor of the planetarium instructed group, indicated significant improvement in both two and three dimension spatial relations and improvement in retention of content. However, since a small sample was used (N=64), Tuttle (1966, 1968).
designed a second experiment involving 400 sixth grade students to evaluate the same factors plus the value of using models and visual aids in the classroom. In this study, Tuttle (1968) found no significant difference in astronomy achievement or difference in improvement of spatial ability. There was much concern about the different conclusions reached in each of the studies. Tuttle attributed the use of visual methods and the variations in teaching between participating teachers to the removal of significance between the two groups.

During the same period of time, B. Smith (1966) was investigating the effectiveness of a planetarium lecture-demonstration with a classroom lecture-demonstration for sixth grade groups in terms of achievement of selected astronomical concepts. The experimental group, consisting of twelve intact classes, experienced one forty minute planetarium presentation on selected concepts and the control group, also twelve classes, has the same concepts presented in one classroom lesson. Smith taught both groups and evaluated the learning immediately after the lecture-demonstration by his multiple choice test. His null hypothesis of no difference was rejected, since sixth grade students experiencing the classroom lecture-demonstration achieved significantly higher than those experiencing the planetarium presentation on the same selected astronomical concept. Smith suggested that the higher achievement by the control group may have resulted from the more familiar learning situation existing in the classroom, and he recommended more research on this at the
Sixth grade students were also the subjects of the research by Rosemergy (1967) in which three teaching arrangements were used to measure the effectiveness of the planetarium in teaching selected astronomical phenomena. In each, the children received five 45-minute periods of instruction. One group received four periods of classroom instruction followed by one period of instruction in the planetarium. Another group received the first and the last periods of study in the planetarium. The control group had all five lessons in the classroom. These three arrangements were to reflect "the general usage of planetariums in elementary school science instruction" (Smith 1974, p. 27). Nineteen concepts leading to understanding of the two phenomena of sky motions and phases of the moon were identified and measured within a forty item multiple choice examination. Each of the three teaching arrangements were found to be effective in increasing the understanding of astronomical phenomena, but there was no significant difference found among the three arrangements.

A similar study by Soroka (1967) reached the opposite conclusion by finding the planetarium more effective than the classroom in contributing to the understanding and comprehension of basic astronomical and geographical concepts. His research involved 202 eighth grade students divided into two matched treatment groups. One group was taught a six week unit, which included directions, coordinate systems, constellations, seasons, and lunar and planetary motions, in
the classroom while the other group received instruction on the same topics in both the classroom and planetarium. Soroka's results may be considered suspect because he did not make validity or reliability assessments of his tests nor did he indicate the number or frequency of planetarium visits.

This concept of a variable planetarium presentation schedule was also used by Wright (1968) when she studied the effectiveness of teaching an astronomy unit when it is supplemented by (a) a planetarium program, (b) a planetarium program, preparation by the teacher, and a follow-up exercise, (c) a planetarium program, preparation by the planetarium lecturer, and a follow-up exercise. Students from 59 intact classes were randomly assigned by class into four treatment groups. Group one was tested before attending the planetarium; group two attended the planetarium before being tested; group three had teacher preparation, planetarium, and follow-up exercise before being tested; and group four had planetarium lecturer preparation, planetarium and follow-up exercise before being tested. The testing instrument of eighty questions included seventy-five true-false items from Barnard's Astronomy Achievement Test.

Wright (1968) found a statistically significant difference in achievement. The students who attended the planetarium program achieved larger gain scores than those who did not attend. The preparation and follow-up activity did not improve scores over the planetarium presentation alone, and the individual who prepared the students had no significant effect on scores. Wright's study, like Soroka's, appears very
supportive of the planetarium as a valuable teaching aid, but this conclusion is obscured by the experimental design. That is, it appears that groups two, three, and four actually had an additional period of instruction when they attended the planetarium and the achievement increase could have been due to increased time on task.

Ridky (1973) was also interested in astronomy achievement as a function of a variable planetarium presentation schedule. In his investigation, three groups of eighth grade students and three groups of college students were examined. The primary question asked if the planetarium is an effective instructional device for teaching selected astronomy topics when contrasted to or combined with inquiry activities used in the nationally developed science curricula. Junior high students with combined lessons of classroom activity and planetarium presentation (group III) demonstrated in post teaching a significant content achievement over the pure planetarium (II) and the pure classroom activity (I) groups. There was very little difference between junior high groups I and II, and no interaction effect between treatment and retention for college groups.

This study made a significant contribution to understanding the value of the planetarium because it clearly demonstrated that the facility can be educationally effective if it is used in combination with classroom activities. Until this study, an equal number of research projects had shown the advantage of the planetarium over the classroom, Tuttle (1966), Soroka (1967), Wright (1968) as had shown the opposite,
Smith (1966), Rosemergy (1967), Tuttle (1968). Ridky accounted for this discrepancy of early results by noting that the planetarium lesson or classroom activities should not be viewed as isolated events. One can only speculate why the college groups (I, II, III) didn't have results paralleling the junior high subjects. Though the author gives no indication, one could surmise that academic activities for twelve year olds might not have a similar impact on college age students. Bishop (1980) suggested that "junior high students do not conceptualize as readily as college students, and they require more concrete experience for learning; the planetarium may provide (this)" (p. 31).

Two secondary result findings of this study may eventually be considered the major contribution of Ridky's research to understanding the effectiveness of a planetarium lesson: A pilot study assessed if an orientation to the planetarium facility would improve student post-test achievement scores. Clearly a "mystique effect" was noted and a basic orientation to the room significantly improved test results. This gives direction to any future research studies because the "mystique effect" is an important variable to consider when researching a planetarium's instructional effectiveness. In addition, a questionnaire given to the subjects of this study had demonstrated that the effectiveness of the planetarium appears not to lie in facilitating content achievement as much as effecting attitudinal change. It was concluded that it would be of greater benefit to develop planetarium experiences that deal primarily in the affective
domain.

Though criticism could be directed toward the rather small subject number in the study (approximately 25 per group), the investigation is of value because it made researchers aware that a multiple planetarium/classroom balance, a "mystique effect", and an attitudinal impact, were three important variables to consider in future research.

A follow-up study by Reed (1973) is more sophisticated, though parallel, to Ridky's investigation: A larger group of college students was studied and activities which had been proven effective in the college classroom were used both in isolation from and combination with the planetarium. More specifically, the research problem asked if the planetarium when used in combination with a celestial globe and chalkboard was a more effective mode in improving student achievement than the globe and chalkboard alone.

Though valid testing and clear results did not support the existence of a significant difference between the two learning situations, they did contribute much to an understanding of conditions for planetarium effectiveness. An excellent pilot study had shown that the planetarium alone was less effective than the celestial globe and chalkboard within a classroom setting. This allowed validation of two implications: The planetarium, in order to be used effectively, should be used as a simulation device along with a classroom teaching-learning situation. Also, those aspects of teaching and learning that have been identified as effective and desirable in the normal classroom situation
should be applied to the planetarium situation.

In contrast to the Ridky (1973) study, Reed (1973) had shown no difference in the attainment of affective behavioral objectives. Though the affective domain results were limited to a small amount of data as compared to the cognitive measure.

Supporters of planetariums in education might consider the Ridky and Reed studies as non-supportive for including a planetarium in science curricula. However, they should be careful not to quickly support the results of Ortell's investigation (1977). Though the data analysis of this study indicated that the performance of planetarium instruction was consistently higher than that of regular classroom instruction, the subjects and data gathering techniques used leave doubt as to validity or findings. Basically, college students from one community college with a planetarium were compared to college students from another community college without a planetarium for academic performance in the areas of mean grade point averages, sex, and age grouping. As a "control" only students within one of three total academic standings (3.0 higher, 2.0-2.9, less than 2.0) were compared to each other; however, it was assumed that this sub-grouping reflected academic ability. No attempt was made to relate the curricula of the two schools; thus, it is possible that a grade point average from each does not reflect similar academic ability. Success in the courses was measured by midterm and final grades.

A greater fault in this study is the lack of a
comparison between the topics and techniques used within the classroom and planetarium settings. Was it more difficult topics, poor teaching, or less exposure which caused the differences in achievement? Unless this is known, neither method of instruction may be indicated as superior to the other. Finally the researcher had to admit "because the students in the population of this study selected to enroll or not to enroll in planetarium instruction, it cannot be concluded definitely that planetarium instruction itself was the cause of consistent and significantly higher academic performance of planetarium students" (p. 118).

The studies by Ridky (1973), Reed (1973), and Ortell (1977) did have the obvious comparative features of involving college students in a study of the effectiveness of a planetarium versus a classroom in academic achievement. One shared feature of the Ridky and Ortell studies actually demonstrated a weakness in research planning. That is, neither study identified which aspects of planetarium instruction were most influential in student academic performance. At least Reed's notion, that successful classroom techniques be applied to planetarium lessons, provided a basis for improving academic performance in a planetarium lesson.

Even though Reed made a basic attempt to narrow the approaches used in both the classroom and planetarium, none of these comparative studies had a single factor isolated as the critical variable. Thus, the comparative studies concluded either in favor of or against the planetarium, but
never provided information as to which of the multitude of factors operating in the planetarium have assisted or retarded the learning process as measured by an achievement test.

From the studies reviewed several recommendations can be made and some of the following implications may suggest further research:

1. A single planetarium visit may not be an effective learning experience since the student may need to become familiarized to the new type of learning situation to effectively learn.

2. An astronomy course should not exclusively use the planetarium.

3. A planetarium should be incorporated into a class activity schedule. It should not be used solely as a celestial demonstration chamber.

4. The effectiveness of a planetarium can be best measured if a single factor within a presentation is used as the variable for the study.

5. The value of the planetarium may be in the affective domain. The cognitive concepts, that the planetarium simulates, may be just as easily understood after classroom presentations.

The two final studies in this section of the literature review were concerned with such an affective measurement. Sunal (1973) found that, when compared to other time periods, increased performance in higher order cognitive and affective goals occurred when the planetarium visit took place during the last half of a classroom astronomy unit. His study of 986
second grade students included one group with classroom instruction, one group with planetarium and classroom instruction, and one group with no instruction at all. Like others, Sunal found both the classroom and the classroom-planetarium methods effective, but realized no significant statistical differences between the two presentation modes.

The primary purpose of Burnetts's research (1976) was to ascertain if a new earth-space science program utilizing a planetarium had a significant effect on the attitudes of fourth, seventh, and eighth grade students toward the study of astronomy. At the end of the 1974 school year students completing a conventional science course without a planetarium experience were tested for attitude toward astronomy with an interest survey. At the end of the 1975 school year, students at the same grade level who had received instruction which included one or more planetarium units, were tested. Analysis of results of fourth graders in 1975 demonstrated a significant improvement in attitude on half of the test items, while analysis of the junior high school interest survey showed a positive and significant change on six out of seven test items. This researcher and others (Bishop 1980), however, doubt that the planetarium can be considered the primary motivator of the study since it was used for less than one percent of the instructional time.

The comparative study format used to assess the effectiveness of planetarium as an instructional tool has received much criticism. Etheridge (1974) stated it most
strongly:

These studies are virtually all in one category of research: media – media comparisons, most of them are hardly worth the time spent on them ... The planetarium field is currently on the horns of a dilemma, most of the extant research is not generalized. Most of the contentions about the planetarium are unsupported. (p. 49)

Sunal (1976) noted that varying results have appeared and "when one finds that competent observers advocate strongly divergent points of view, it seems likely that both have observed something valid about the situation and that both represent a part of the truth" (p. 348). The way out of the dilemma is to conduct carefully controlled experiments on variables within the planetarium. Bishop (1980) concludes:

Therefore, within-planetarium studies--studies which are concerned with specific planetarium variables--should provide more generalizable guidelines for planetarium education. However, details of some of the planetarium-classroom comparisons should give direction to the construction of well-designed within-planetarium investigations. The finding that classroom methods are equally and sometimes more effective than planetarium methods indicates that planetarium methods which incorporate some of the features of classroom teachings should be developed and tested against traditional planetarium methods. (p. 35)

This approach represents the most recent trend of evaluative
research within the planetarium and studies incorporating this methodology will be presented in the next section of the literature review.

Within Planetarium Research

The philosophy of the following studies did not include an involvement with between-media research, but rather was interested in those instructional features in a planetarium which would best improve achievement or attitude. Such research articles have helped to establish a conceptual framework within which purposeful instructional strategies could be developed.

One of the first within-planetarium research efforts was made by T. Smith (1974) because he felt that "research is needed in order to provide those who present planetarium lectures or teach astronomy concepts in the classroom with an understanding of the effectiveness of various methods of instruction" (p. 76). The study was concerned with the effect of two teaching methods on the recognition of constellation figures with the null hypothesis declaring that the superimposing of graphical mythological constellation figures on constellation star fields during the teaching of these constellations would not effect the mean performance of the two groups in recognizing the star field when the figures were not present. The third and fourth grade subjects were tested by both pre- and post- paper-and-pencil tests in the classroom and a planetarium test which required students to view constellations on the dome and correctly identify them on the same paper-and-pencil test answer sheet.
After the treatments, both groups greatly increased their mean scores on the classroom post-test and the planetarium test. The null hypothesis could not be rejected when a comparison of group means failed to show significance. Thus, with respect to the particular population of subjects, the use of visual illustrations neither helped nor hindered the subject's ability to recognize star fields on star charts or in the planetarium sky.

In an attempt to measure the effectiveness of two teaching styles in the planetarium, taped versus live, Mallon (1974) used 103 second grade students who had been randomly assigned to one of two groups. Group one received a taped planetarium program on constellations, while group two received an identical, but "live" version of the program. Questioning was not permitted in either situation and both groups were post-tested in the planetarium immediately following their treatment before any instruction could take place. A t-test was used on the post-test scores and the results indicated a significant difference between the groups with the "live" treatment group advancing five times more than the students who received the identical but taped program.

Presentation methods in the planetarium were also compared by Etheridge (1976) when he studied the achievement differences between a group having experienced a taped program in which the planetarium instrument simulated the sky and a group having experienced the same taped program in which projected slides representing the celestial sphere replaced the planetarium images. Two college classes were used for
each group and two 30-minute lessons, sun/seasons and moon/motions, were immediately followed by a post test. Though the analysis of results included complex interactions with spatial and verbal abilities, the basic conclusion realized no difference in content learning between the two groups.

The research by Giles (1981) compared the effects of advance organizers and clustering as mediators of learning in lessons presented at a planetarium. A nonrandomized pre-post test design with thirty-six intact high school classes was used with the planetarium teacher presenting all of the treatments to all of the students. Though the experimental and control groups were also divided by ability track levels, the basic design included a control treatment without the benefit of the learning mediators, clustering, and advance organizers, that were presented in various combinations to the experimental group. The results noted that the treatment group receiving both clustering and advance organizers in the instruction performed significantly higher on the post-test than any other treatment group; however, the clustering treatment and advance organizer treatment each produced significantly higher performance than the control treatment. This investigation produced data which indicated the multiple use of mediators of learning can significantly improve the learning outcome of planetarium presentations.

The final five studies of this section all share a common concern for the effectiveness of student involvement in the presentation mode of planetarium lessons.

Friedman (1974) reported an informal study at the
Lawrence Hall of Science on the receptivity of planetarium audiences to a discovery approach to learning. The Holt Planetarium staff had developed five separate 50-minute "participatory" programs which were presented to the general public and to single unit school groups. Within these shows, the members of the audience would verbally respond to questions and/or complete a collection of data. This approach was contrasted to the lecture-type format. Evaluation was based on visitor response cards, and the staff felt that these programs were just as attractive to visitors as non-interactive programs and that the amount actually learned was significantly greater for the interactive show.

A more vigorous study of this direct/indirect approach was completed by Cottrill (1976) to determine achievement differences of fourth grade students taught by these approaches in planetarium instruction. Nine randomly chosen sections received planetarium teaching described as indirect with teacher lectures, discussion, teacher questions, student responses, and teacher praise. Another nine sections received direct instruction which only included teacher lecture. Three topic sessions were presented to each group and the tape recordings made of all the lessons were analyzed by the Flanders Interaction Analysis System to determine the degree of direct and indirect teaching. The post-test results were significantly higher than pre-test results for all eighteen classes, but insignificant F-values were found for each of the three test instruments when direct was compared with indirect. The hypothesis that the classes taught by the
indirect approach would perform better on the post-tests was not supported by the data and there was no significant difference in achievement between the groups.

Fletcher (1977) also found no significant difference in achievement between a participatory and traditional planetarium unit of study, however, his research did find significant effects with instructor variations. The study involved eight planetarium teachers who were given a traditional program script, a participatory program script, and all the materials needed to present both programs to randomly selected eighth and ninth grade earth science classes. Both planetarium programs presented the same concepts involving apparent daily motion of the sun, moon, and stars and similar questioning methods. This latter fact made Mallon (1980) declare that Fletcher did not examine a "'Participatory Oriented Planetarium' program and a traditional 'Star Show' planetarium program, but rather two versions of a P.O.P. program, one requiring physical activities and one requiring cerebral activities" (p. 31).

The testing instrument included twenty multiple choice items with eight items related to application of the astronomical concept and twelve items related to rote memory. Overall results indicated that the important factor which affects student achievement was not whether a traditional or participatory program was used, not whether the program was presented for the first or second time, and not when the students were measured for achievement, but rather the instructor who presents the program.
This result which indicated that the personality of the planetarium teacher is the major factor in predicting the success of a lesson in a planetarium was sharply criticized by Giles (1981). He noted that studies which have reported planetarium learning to be dependent on characteristics of the teacher should be questioned in light of the information gathered by his study. Giles' investigation determined that one teacher utilizing different mediators of learning can bring about significantly different learning outcomes.

Because he did not believe that the Fletcher (1977) study actually made a valid comparison, Mallon (1980) investigated the relative effectiveness of a "Participatory Oriented Planetarium" (P.O.P.) program and a traditional "Star Show" planetarium program in increasing understanding of concepts and attitudes toward astronomy. The major study, which involved 324 third grade students in Pennsylvania, was complemented by four smaller studies at widely separated regions in the United States. The instructional programs were chosen from existing scripts about Spring constellations. The traditional star show was tape recorded and the participatory program was presented live to allow audience involvement. Testing included the researcher's paper-and-pencil content test and a Likert-style science opinionnaire modified from Fisher (1973). As a general conclusion, Mallon (1980) noted that the Participatory Oriented Planetarium program, utilizing an activity based format and extensive verbal interaction, is clearly the more effective utilization of a small planetarium facility for teaching constellation study and improving
students' attitudes about astronomy" (pp. 77-78). The strength of his data certainly supports such a finding, but one must reflect on Mallon's earlier study (1974) which found the "live" treatment group advancing five times more than the group having a tape recorded program. Why then would he include this variable in his own major study (1980) by having the traditional program on tape and the participatory presented live? Again, as with Fletcher (1977), the actual value of the results must be doubted.

Even the carefully controlled and interpreted research by Bishop (1980) failed to demonstrate a statistically significant difference between traditional and participatory instructional methods. Bishop developed a participatory planetarium unit which included a series of eight lessons incorporating the Karplus Learning Cycle (based on work of Piaget) with student model manipulation and student drawing and compared it to a traditional planetarium unit with student note-taking. Achievement in each of four astronomy concept areas - the celestial sphere and earth rotation, the seasons, lunar phases and planet positions and motions - was measured by immediate lesson post-tests, by an immediate unit post-test, and by a delayed unit post-test. Twenty-nine research hypotheses were evaluated to measure the effects of treatment, initial spatial ability, gender, and known model manipulation experience.

Both the traditional and participatory groups performed better on an immediate post-test than did the no-treatment control group, but there was no significant difference between
groups exposed to the two instructional methods. A delayed post-test did reveal, though, that the students exposed to the participatory approach retained significantly more of what they had learned than did students exposed to the traditional approach. Spatial ability, gender, and previous model experience were found to be important variables effecting performance.

The within-planetarium research reviewed in this section often failed to reach conclusive results about the value of the experimental conditions. Smith (1974) and Etheridge (1976) could not substantiate improved visual methods; Mallon (1974) and Giles (1981) did demonstrate that live presentations using mediators of learning could significantly improve learning; and only Mallon (1980), and Friedman (1974) (not Cottrill (1976), Fletcher (1977), or Bishop (1980)) could conclude in favor of participatory lessons over the traditional lecture method in improving content achievement.

These studies are of value to this research, however, since they helped to isolate the variables which should either be controlled or explored within a manipulative study. To avoid the approach conflict of traditional versus participatory, this study presented lessons to both the experimental and control group which had the participatory format of utilizing an activity (drawing on manipulative versus physical pointing) and extensive verbal interaction. The teacher effect of Fletcher (1977) and Giles (1981) was controlled by the researcher presenting the entire unit of instruction. The
variables of grade, gender, attitude, and previous planetarium experience were considered as part of result analysis.

The concluding section of this literature review briefly outlines some of the articles which have contributed to understanding the research variables of manipulative use, gender, previous experience, instrumentation, and attitude.

**Variables in Research**

**Manipulatives**

One of the strongest impressions to emerge from reading the literature on formal operations is the vast difference between adolescents in intellectual achievement and ability. Certainly these differences must be taken into account if instruction is to bring about learning. "The high level of interest, even preoccupation, with the idea of Piagetian stages and the performance of certain tasks has obscured the overall thrust of Piaget's work and led to a notion that we have to wait until an adolescent becomes 'formal operational' and then begin certain kinds of instruction" (Soroka 1974, p. 116). Instead, we should be devising instructional methods and promoting attitudes that will help increase a student's performance skills. Piaget (1963) pointed out that the passage through the stages of development can be accelerated by physical or social experiences. This may "indicate that individualized activities for each child, in some planetarium programs, are desirable" (Bishop 1976, p. 6). Piaget's theory of cognitive development suggests that all students must pass through a stage in which they need concrete experiences during
learning activities in order for the learning to have meaning for them (Sonntag 1979). Piaget noted:

Action is only instructive when it involves the concrete and spontaneous participation of the child himself, with all the tentative gropings and apparent waste of time that such involvement implies. It is absolutely necessary that learners have at their disposal concrete material experiences (and not merely pictures) and that they form their own hypotheses and verify them themselves through their own active manipulations. (Jackson 1979, p. 77)

In an attempt to verify this point of view, Bishop reported two of her own minor studies as part of the literature review in her dissertation (1980). Forty-eight second grade students were randomly assigned to five groups in a study which found that the groups which had received both model manipulation and drawing experience performed significantly better on a test about constellations. In a similar manner, those sixth grade students who studied moon phases by using manipulatives and an exploration activity, tested much better than those control students who had experienced neither method. When compared to slides and transparencies, "three dimensional models which are manipulated by students ... prove superior" (Bishop 1980, p. 78). Previously mentioned studies by Smith (1966), Pitluga (1968), and Reed (1970), have also indicated the value of student model manipulation in learning astronomical concepts.

There has been very little research done to prove the
value of manipulatives. A few studies in math and science have found positive results: Wallace (1974) determined the effectiveness of mathematics instruction based on the use of manipulative materials in grades 4, 5, and 6. She demonstrated that the mean performance of students in the manipulative group was greater than of controls on both achievement and manipulative tests. Talley (1973) found that college students who used model construction and manipulation in a chemistry class performed significantly better than students who had received only class lecture. MacBeth (1974) designed an investigation to test the importance of a manipulative experience in Science - A Process Approach in the attainment of science skills for kindergarten and third grade students. He learned that "the influence of direct first-hand manipulative experiences in the development of process skills may well be more important for the early primary grade child than for older children" (MacBeth 1974, p. 50). In a literature review, Friedman (1978) concluded that, after first grade, an instructional strategy in teaching mathematics which gives pre-eminence to the use of manipulative materials was unwarranted. Because of its potential value but limited understanding, a manipulative variable was chosen for the research.

**Gender**

The sex of the pupil was a research variable in this study because research has yielded conflicting results on its effect upon attitude and concept attainment.

The Rosemergy (1967) study, which evaluated the
effectiveness of planetariums as teaching devices for sixth grade children, found that boys had significantly greater understanding than girls of phases of the moon and apparent turning of the sky before formal instruction on these topics. Fuller (1979) studied third grade children in research on science concept formation and retention. The research, which involved the topic of life cycles, failed to prove that the student's gender influenced the ability to acquire or retain the science concept of life cycles. DeLocke (1966), however, found variations between males and females in his experiment which used creative exercises, traditional exercises, and no exercises in space science education for elementary students. In the experimental groups there was a significant difference between male and female pupils in fluency, favoring females. In all groups, space science achievement favored the males.

Comparisons of adult and sixth grade students on an outer space science test were made by Dennis (1962). The results of the study did show favorable performances by both groups with one-eighth of the student group scoring higher on achievement tests than the average adult. Statistically significant differences between boys and girls were found with boys scoring higher than girls on the test of outer space science concepts. Shrigley (1972) was concerned with achievement and attitude of sixth graders and discovered a sex difference in attitude with the males rating much higher. The results of the science achievement test indicated no sex difference in concept attainment. The female students had a significantly lower attitude rating than the males, at the
same time they did not have a lower mean score on achievement. This could "imply that either attitude does not affect science achievement or that girls' scores on science attitude scores are affected by culture" (p. 792). Bishop (1980) reported that "it is widely accepted among science educators that astronomy is perceived as a primarily masculine subject" (p. 92) and that the "perceived masculinity hypotheses' should be considered" (p. 93).

Previous Experience

Presentations and writings by Ridky (1975), Davis (1978), Akey (1973), and others have indicated the necessity of a planetarium orientation session or sessions before a meaningful lesson can be taught. If this "mystique effect" does exist, it will be an important variable to consider in planetarium research.

Ridky (1975) demonstrated that forty percent of the variance of post-test scores of his eighth grade students was attributed to an orientation session. The orientation session helped the best achieving group and presented the purpose of the domed ceiling, the function of the major components of the projection equipment, and the purpose of the lighting system. This gain was also confirmed by Bisard (1979) in his research on the effects of four introductory formats (written, personal, slide, and null) to a planetarium program. He noted that "planetariums should utilize subject matter introductions in their public presentations to maximize learning" (p. 9). This has also been observed when a single supplemental planetarium lesson follows classroom introduction (Sunal 1976).
Instrumentation

Some researchers claimed the varied results in studies on the effectiveness of the planetarium were due to the type of test instrument used to evaluate achievement. Dean (1972) objected to the common use of planer, two dimensional, paper-and-pencil tests. He thought a true test of observational astronomy learning would have to be conducted using the real sky. His research included the individual testing of each student orally and under the real sky to measure planetarium effectiveness, but did not demonstrate that paper-and-pencil testing was an improper means of evaluation. The question of which method is superior remained unanswered. T. Smith (1976), therefore, tested third and fourth grade students to find out if a paper-and-pencil test can be used in place of the planetarium sky to evaluate a student's learning of constellations. The experimental group was given a paper-and-pencil instrument which consisted of a multiple choice answer sheet and a series of constellation star fields. The control group used the same answer sheet, but stars on the planetarium dome replaced the drawings on the paper-and-pencil tests. The correlations between the instruments allowed Smith to conclude the validity of paper-and-pencil testing.

Hayward (1976) developed such a paper-and-pencil test that used an observational format in the planetarium as a reasonable substitute for the real sky to evaluate the attainment of instructional objectives related to selected concepts on the annual motions of the sun, moon, and planets. The thirty-four item instrument was effectively field tested
with 471 sixth grade students to again confirm the validity of such an evaluative tool. Warneking (1970) had pointed out, though, that a subject will do better on any evaluating instrument which more clearly reflects the mode of instruction than one that does not. Many students, while well experienced with the paper-and-pencil method of testing, often have never been tested in a planetarium. When one considers this familiarity factor in conjunction with the unfamiliarity of the planetarium environment, it would be reasonable to expect scores to differ, but studies by Soroka (1967), Tuttle (1967), Wright (1976), Rosemergy (1968), Reed (1970), T. Smith (1972, 1976), and Hayward (1976) have shown no significant difference between planetarium and classroom paper-and-pencil testing formats.

Attitudes

Since the value of the planetarium in changing student attitudes toward space science education has been questioned by several researchers and has met with conflicting results, affective measurement was included as a variable in this research project.

Ridky (1973), as previously discussed, thought that the effectiveness of the planetarium did not lie in facilitating content achievement as much as effecting attitudinal change. Wentzel (1974) claimed that "the planetarium influences people at the emotional level rather than the cognitive level" (p. 4). Burnette's (1976) two-year study of the planetarium's ability to change attitudes found differences between grade levels. In the fourth grade component of this research, the findings
of improvement in attitude toward earth-space science were inconclusive. Seventh and eighth grade students, however, did show a positive and significant change in attitude. Griffin's analysis (1978) of eighth grade students found that two exposures to planetarium lessons as a review activity actually caused a significant decline in the attitude toward astronomy among high-achieving students. But two exposures to planetarium lessons did not significantly improve students' attitudes toward astronomy at any achievement level.

This latter result of Griffin had been verified by Reed (1973) with no difference in the attainment of affective behavioral objectives among college students. Other researchers such as Bishop (1980) and Mallon (1980) had expressed similar findings. The most critical of any attempt to alter attitudes was T. Smith (1974) when he noted that too many individuals justify star show extravaganzas on the grounds that the affective domain generated by the use of elaborate auxiliary media promoted education. His 1974 study concluded on page 81 by stating that:

Education or the transmittal of information can occur in a setting where little emphasis is placed on the affective domain and thus it seems that the effort required to produce this domain may be greatly reduced without affecting the cognitive domain.

SUMMARY

The review of literature in this chapter included descriptive studies by Chamberlain (1962), Korey (1963), Moore (1965), McDonald (1966), Kobel (1967), Curtin (1967), Warneking
(1970), Downing (1971), and Dean (1971) which provided information about planetarium design, operation, and management. The questions this research raised about the value of planetariums in the teaching of astronomical concepts were addressed in the section on comparative planetarium research. In general, the major design of such comparative studies was to find variations among groups on acquisition of astronomical concepts or attitudinal changes. There were researchers who found that the classroom was as effective or more effective than the planetarium; they included Tuttle (1968), B. Smith (1966), Rosemergy (1967), Ridky (1973), Reed (1973), and Sunal (1973). Those who provided results in favor of the planetarium were Tuttle (1966), Soroka (1967), Wright (1968), Ortell (1977), and Burnette (1976). Such media-media comparisons received much criticism because they failed to identify those aspects of planetarium instruction which contributed to a relative increase or decrease in the learning of astronomical information.

Cottrell (1976), Fletcher (1977), and Bishop (1980) could not support the advantages of interactive planetarium lessons.

The concluding section, which presented variables in research, gave directive to this present study by showing the advantages of manipulative use in instructional programs, and by illustrating the many contradictory opinions about the impact of gender, previous experience, instrumentation, and attitude on the learning of space science information. The following chapter includes these factors in an experimental design which attempts to access the value of using a manipulative in planetarium instruction.
CHAPTER III
PROCEDURES

Restatement of the Problem

The following study made an experimental comparison with fifth and eighth grade students to measure the effectiveness of direct manipulation of an instructional object during astronomy unit presentations in the planetarium. Students were evaluated on their ability to correctly answer recall, application, and observation questions at the conclusion of each visitation. This series of three planetarium lessons on features of the celestial sphere and time, seasonal changes, and lunar movement and phases was presented to each student sample by grade and group. Retention of material was measured by a post unit test which was administered three weeks following the last planetarium lesson. Also, this investigation attempted to assess and compare the students' attitudes toward astronomy and the planetarium both prior to, and after the three planetarium experiences. The variables of previous planetarium experience, grade level, and gender were considered in the evaluation.

Description of Population

The population studied was the entire fifth and eighth grade student body (N=542) of the three elementary schools and one middle school of Fitzgerald Public Schools in Warren, Michigan. This community in Macomb County borders on the northern limits of the City of Detroit and is representative of a suburb of a large metropolitan area. Students reside in
single-family, condominium, and apartment structures which are interspersed among retail stores and factories. Socio-economically, students range from middle class to upper lower class and intellectually, contribute to a mean IQ score of 103. The population within the district is fairly stable; only nine percent of the students studied had never been exposed to the planetarium lessons which had been presented to all fourth and fifth graders since this representative group was of school age.

In order to assure a true experimental condition, random selection within a grade, within a building was made to assign approximately thirty-eight percent of the students to the experimental group which used the manipulative during the planetarium lessons and approximately forty-three percent of the students to the control group which experienced an identical unit of study but did not use the manipulative during the planetarium lessons, and nineteen percent to the group which did not experience any planetarium lessons. Assignment of student, group, building, and approach was purely random with utilization of a table of random numbers (Rand 1955). Due to absenteeism and attrition, not all students were included in every stage of evaluation but Table 1 gives an overview of population classification. Students were not always brought to the planetarium by teachers who were their main academic instructors. This variation could be attributed to random student grouping, teacher availability, and scheduling times. Such a variable was not considered important since this investigator presented the entire unit of
### TABLE 1

**POPULATION SAMPLE STATISTICS**

**BY GRADE**

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>8</th>
<th>5 &amp; 8 Combined</th>
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</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td>45% (N=139)</td>
<td>52% (121)</td>
<td>48% (260)</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>55% (169)</td>
<td>45% (113)</td>
<td>52% (282)</td>
</tr>
<tr>
<td><strong>Proportion</strong></td>
<td>56.8% (308)</td>
<td>43.2% (274)</td>
<td>100% (542)</td>
</tr>
<tr>
<td><strong>Using manipulative</strong></td>
<td>39% (120)</td>
<td>37% (87)</td>
<td>38.2% (207)</td>
</tr>
<tr>
<td><strong>Not using manipulative</strong></td>
<td>46% (142)</td>
<td>39% (92)</td>
<td>43.2% (234)</td>
</tr>
<tr>
<td><strong>Having no unit</strong></td>
<td>15% (46)</td>
<td>23% (55)</td>
<td>18.6% (101)</td>
</tr>
<tr>
<td><strong>Prior planetarium experience</strong></td>
<td>96% (244)</td>
<td>83% (149)</td>
<td>90.8% (393)</td>
</tr>
<tr>
<td><strong>No prior planetarium experience</strong></td>
<td>4% (10)</td>
<td>17% (30)</td>
<td>9.2% (40)</td>
</tr>
</tbody>
</table>
study to each of the students and the accompanying teacher performed a chaperone function.

**Experimental Design**

A post-test only, control-group, true experimental design as described by Campbell and Stanley (1963, p. 25) was used to evaluate student ability to answer recall, application, and observation questions immediately after each of the three lessons (topic post-tests) and to measure retention of material after three weeks (unit post-test). A modification of this design included the administering of the unit post-test to a third group of students who had not experienced any of the planetarium lessons in the experimental unit of study. The only pre- and post- measurement in this study involved the repeated use of the assessment form (astronomy opinionnaire) evaluating student attitude toward astronomy and the planetarium both prior to, and after, the three planetarium experiences.

The reason that the stronger test-retest experimental design was not a viable alternative, was suggested by Bishop (1980): "Students (not previously exposed to the material) would perform very poorly on a pre-test and that the poor performance would have a negative effect on students' perceived ability to master the concepts" (p. 123). Such a poor performance was evidenced by the no unit control group's lack of success on the unit post-test. Symbolically, the experimental design follows:
R = randomization
A\textsuperscript{1} = pre attitudinal opinionnaire
L\textsubscript{1} = lesson on features of celestial sphere and time
L\textsubscript{2} = lesson on seasons
L\textsubscript{3} = lesson on lunar movement and phases
X\textsubscript{1,2,3} = manipulative use for topics
O\textsubscript{1,2,3} = topic post-tests (at end of lesson)
A\textsubscript{2} = post attitudinal opinionnaire
O\textsubscript{4} = unit post-test (three weeks after completion of unit)

Example one is referenced as the experimental group, number two is the non-manipulative control group, and number three is the no-unit control group.

**Instructional Program**

As stated previously, both the experimental and non-manipulative control groups experienced planetarium lessons which were identical except for the omission of the opportunity for student model manipulation by the control group. To assure an equivalent time on task, the control students had to physically affirm understanding by pointing out described features or locations while the experimental students would outline identical features on plastic hemispheres with a marking pencil. Since the presentation was not tape recorded, chaperoning teachers served as observers and evaluators to assure that the planetarium instructor's teaching did not
exhibit a bias in enthusiasm or content toward the experimental teaching method.

The unit's three topics and the time elements involved, were representative of those frequently taught to elementary and middle school students in a planetarium. Bishop (1980), Wright (1968), Korey (1963) and others have validated that features of the celestial sphere and time, seasonal changes, and lunar movement and phases are appropriate and common elements of presentation.

The following outlines of the three planetarium lessons are the result of a six month pilot study which identified appropriate audio visual materials, questions, and sequencing of presentations. It may be noted that all of the students were exposed to the same visuals, questions, time limits, and topics; the only variation is the experimental students' opportunity to mark on and examine the plastic hemisphere (the manipulative) or the control group students' physical affirmation of presented material.

**Topic One: The Celestial Sphere and Time**

**Time:** 50 minutes

**Materials:** Planetarium

- -- - 35mm slides

1) Question "What is the apparent shape of space?"
2) View of a person standing outside on a clear night
3) Bowl shaped image of space
4) Ball of stars with earth in center
5) Title "Celestial Sphere"
6) Man on earth with extended horizon
7) Bowl shape above man as in slide six but with an arrow pointing up and arrows pointing around horizon

8) Eskimo and Hawaiian standing in relative home positions on earth

9) Bowl shaped view for Eskimo with north star at zenith

10) Home view for Eskimo

11) Bowl shaped view for Hawaiian with north star on horizon

12) Home view for Hawaiian

13) Title "Sun, Moon, Mercury, Venus"

14) Title "Mars, Jupiter, Saturn"

15) Title "Tiw"

16) Title "Woden"

17) Title "Thor"

18) Title "Frigga"

--- Large magnetic letters, "N", "E", "S", "W"

--- Tape recorded music

--- For experimental lessons: one clear plastic hemisphere, one red china marker, and one paper towel per student

Planetarium set up:

--- Every other desk top in upright position (experimental groups have manipulative materials in neighboring, "arms-down" seats)

--- Lights on full (blue, yellow, white)

--- Sun positioned on eastern horizon, full moon
Lesson sequence:

1. Announce to entering students that they are to sit only in chairs with the desk tops in an upright position. The seat each student selects will be his/hers for all three planetarium lessons.

2. Welcome group by stating this is the first of three lessons in the planetarium, explaining rules of behavior, and discussing the parts of the planetarium projector and how they simulate a night sky.

   lights dim to blue

3. Answer any curiosity questions about the planetarium chamber.

   show slide 1

4. Carefully discuss, with student input, the three main words of "apparent", "shape", and "space" before seeking an answer to the question.

   show slide 2

5. "What shape could you expect if stars were seen to the right, to the left, in front, in back, and overhead?" (bowl shape)

   show slide 3

6. Inquire what students see in the room that has a similar shape. (dome ceiling for control group; dome ceiling and plastic hemispheres for the experimental group)

   show slides 4 and 5

7. For a whole earth view, note that the apparent shape is that of a ball and question how far away the imagined edge of space would be. (infinite)
8. "How much of the celestial sphere could this person see?" (half) Note the arrow pointing above the person's head is the zenith. Print "zenith" on chalk board. Control group students physically affirm the meaning of the word by pointing directly over their heads and pointing to the zenith for the planetarium projector. Experimental group students note the meaning of the word by placing a dot at the top of the plastic hemisphere.

9. Print "horizon" on chalk board and mention that it is the meeting of land and sky. Control group students physically affirm the meaning of the word by pointing directly in front and all about themselves; then they point out the room's horizon. Experimental group students print "horizon" around the rim of the plastic hemisphere.

10. Ask how much of the celestial sphere each person can see. (half) Have students orally agree or disagree on which stars would be visible for each person in the example.

11. Note that the north star at the zenith of the north pole is not a particularly bright or beautiful star. It is special because it is closest to the north celestial pole.
show slides 11 and 12

12. Inquire if the location of the north star on the horizon would allow easy viewing for the Hawaiian and explain how the theoretical "half-view" is lessened for us by buildings, trees, and lights.

lights up to yellow

place "N" on dome

13. Explain the need for everyone to know the cardinal point directions. Control group students point north; experimental group students print "N" on their plastic hemispheres.

place "S" on dome

14. Say "Opposite of north is?" (south). Control students point; experimental students mark on hemisphere. "Where is east?" All students point (half of the students usually point one way, the other half the opposite). Show a locating method by the phrase "We are looking north:"

place "E" on dome

place "W" on dome

15. Control group students are asked to point to the various directions many times as the cardinal points are called out. The experimental group students print the remaining "E" and "W" on their plastic hemispheres and hold up their work to see if it orients properly with the room.

16. Ask how the ancient people told time. (Answers vary) interject the fact that the sun is a star and inquire why it looks
and feels so different. (closer)

17. Tell some of the ancient beliefs about the sun and note that even though our knowledge is better, we still use the sun for our method of noting time.

18. Define meridian as an imaginary line going from north to zenith to south. The control group students physically affirm the meaning by arm drawing the line several times; the experimental group students mark the meridian on the plastic hemispheres.

19. Direct attention to the east and explain that the planetarium's sun is a disk of light.

20. Question what the sun appears to be doing (moving) and if that is really its motion. (no -- earth is turning)

21. After students can explain backward view of land masses (view from center), locate countries, states, and directions.

22. Note the west to east rotation of the earth makes the apparent movement of the sun from east to west. Ask for analogies. (answers vary)
meridian on  23. Show that the sun in the morning is before
lights ¼ blue the meridian and the ancient term was "ante
print "ante meridian" on the ancient term was "ante
board meridian" from which we get a.m. for
sun moves morning times.
until on meridian
print "midday" 24. Ask when it is no longer a.m. and note that
on board the sun is directly south, on the meridian,
sun moves at its highest point for the day. This is
past meridian midday.
print "post 25. "What do we call this?" (p.m.) "Yes, that's
meridian" on right and the words are post meridian."
board

26. The students are asked to respond "morning"
sun moves or "afternoon" to a series of times such as
past meridian 7 a.m. (morning) or 3 p.m. (afternoon).
print "post 27. The control group students must physically
meridian" on affirm understanding of the sun's position
board in telling time by pointing out its expected position on the dome for various
times given. The experimental group
students must mark the expected positions
on their plastic hemispheres.

28. Talk about the earth rotating so the sun is
out of sight. "What can be seen?" (stars, etc.) "Why?" (not so bright, etc.)
lights up 29. Allow student reaction. (some stars
blue full brighter than others, some colors, some
music on
slowly set sun
lights off
stars on
<table>
<thead>
<tr>
<th>Slide Numbers</th>
<th>Description</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 and 14</td>
<td>Show slides</td>
<td>&quot;These objects appeared in the sky to the ancients as very special objects so the days of the week were named after them. First day — sun's day; second day — moon's day.&quot;</td>
</tr>
<tr>
<td>15, 16, 17, 18</td>
<td>Show slides</td>
<td>&quot;The planets had names that were different from our English. Third day — tiw's day; fourth day — woden's day; fifth — thor's day; sixth — frigga's day. What planet was the last day named after?&quot; (Saturn)</td>
</tr>
<tr>
<td></td>
<td>Show full moon then phases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stars rotate to sunrise</td>
<td>&quot;As you will learn in our third lesson, the moon goes through a series of appearance changes called phases. This takes about thirty days so the ancients called that time cycle a moonth. What do we call it?&quot; (Month)</td>
</tr>
<tr>
<td></td>
<td>Lights up with sun</td>
<td>&quot;So, you see, we got our a.m./p.m. times, our days of the week, and our month from ancient times.&quot;</td>
</tr>
<tr>
<td></td>
<td>Board erased</td>
<td>&quot;We have no more time for the lesson, but I want to ask you a few questions about what you have learned today.&quot;</td>
</tr>
</tbody>
</table>
|             | Cardinal points down | A dittoed copy of topic post test number one is given to each student. The experimental group students must first completely clean off the plastic
hemispheres; the control group students must help erase the chalk board and remove the magnetic directional signs.

The test is orally administered, as per instructions, and collected when students leave the planetarium.

**Topic Two: Seasonal Changes**

**Time:** 50 minutes

**Materials:** Planetarium

- Magnetic fluorescent title cards
  - **Set #1:** A. Fall equinox, September 23
    - B. E
    - C. 48° E. Equator
  - **Set #2:** A. Winter Solstice, December 21
    - B. S E
    - C. 24° E. Tropic of Capricorn
  - **Set #3:** A. Vernal equinox, March 21
    - B. E
    - C. 48° E. Equator
  - **Set #4:** A. Summer solstice, June 21
    - B. N E
    - C. 72° E. Tropic of Cancer

- Large magnetic letters, "N", "E", "S", "W"
- Tape recorded music
- Flashlight

For experimental lessons: one clear plastic hemisphere, one red china marker, and one paper towel per student
Planetarium set up:
- Every other desk top in upright position (experimental groups have manipulative material in neighboring "arms down" seats)
- Lights on blue and yellow
- Sun positioned at 12\textsuperscript{h} 0\textsuperscript{m} right ascension and on the eastern horizon

Lesson sequence:

1. Welcome back the students and direct them to sit in their assigned chairs, which have the desk tops in an upright position.

2. Review the cardinal point directions in the planetarium chamber by using north as the reference point. The control group students physically affirm their knowledge of the directions by pointing to the proper location as a cardinal point is called out. The experimental group students print the directional letters on their plastic hemispheres and hold up their work to see if it orients properly with the room.

3. Ask where we could expect to find the rising sun (east) and why the sun appears to move upward in that direction. (rotation of earth)

4. "What time of day would it be if the sun was located here?" (Answers vary, but the important notation is that it is an a.m.)
time period.) "If 'a' stands for ante or before, what is it before?" (the meridian)

5. Students are reminded how the meridian line may be drawn from north to zenith to south. Control group students trace out this line by sweeping their arms in the proper direction. The experimental group students draw the ecliptic on their plastic hemispheres.

6. Students are shown that the numbers on the meridian line will allow us to measure how high an object is above the horizon when it is directly south. Control students point to 0°, 45°, and 90° in altitude. Experimental students print these numbers on their meridian lines.

7. "Where do you expect the sun to set?" (west) "Good, when the stars can be clearly seen, I want you to carefully notice how they appear to move in each direction." (east-up, west-down, south-arc, north-circle)

8. Note how we would not be able to see the sun and other stars at the same time on earth, but could from moon or other non-atmospheric locations.

"Because we revolve or go around the sun, this star appears to go 'backward' about
10. State that the ecliptic is the path of the sun and the dates along it will be useful in setting up the planetarium for today's lesson on seasons.

11. On the chalk board list the three main reasons for seasons as:
   a) tilt of earth's axis 23 1/2°
   b) revolution about sun
   c) direct and indirect solar rays

12. Explain the relative tilt of the earth's axis and show by walking around the demonstration table that the earth is tilted toward the sun for our summer, neither toward nor away for our fall and spring, and away for our winter.

13. Ask "If the light is shining right at the board, what kind of rays would the surface get?" (direct) "If it is held at an angle?" (indirect) "Which gives the most energy to a certain area?" (direct) "Which would we have for our summer?" (direct)

14. Print five columns on the chalk board with the labels: 1) name and date, 2) sunrise point, 3) midday altitude, 4) sunset point, 5) position over earth. Announce that we are going to gather the data to complete
place title set #1a

15. "The first season we will look at is the fall equinox. The word equinox sounds like what two words?" (equal night)

"Yes, on the first day of this season we have equal daylight and night hours. What is the date for the first day?"

(Sept. 23)

dim lights
ecliptic on
sun on

16. Note that the sun is on the proper date on the ecliptic and show the rising point.

move sun to meridian

17. "What is the midday altitude?" (48°)

move sun to setting

18. "Where is the sun setting?" (west)

turn on geocentric earth;
bring sun back to meridian slowly

gEOCENTRIC earth off;
place titles set #1b, c, d

20. Note the data gathered for this season.

Control group students trace out the movement of the sun by pointing to the proper sunrise, midday and sunset positions.

Experimental group students draw the arc path of the sun for first day of this season on their plastic hemispheres.

place title set #2a

21. Note that the first day of the next season is the winter solstice with the term sol coming from the word for sun as in solar system.

ecliptic on annual motion

22. "We are going to set the planetarium for..."
the first day of winter. On what ecliptic date should I place the sun?" (December 21)

move sun 23. "Where will the sun rise?" (students usually incorrectly state east) "No, look, the sun is coming up in what direction? (southeast)

sun to meridian 24. "What is the midday altitude?" (24°)

move sun to setting 25. "Where is the sun setting?" (southwest)

turn on geocentric earth 26. "The sun would be overhead if we were on the Tropic of?" (answers vary) "Remember you often wear a cap in winter."

bring sun back to meridian 26. (Capricorn is response)

slowly

Geocentric earth off 27. Note the data gathered for this season.

place titles set #2b,c,d 27. Control group students trace out the movement of the sun by pointing to the proper sunrise, midday, and sunset positions. Experimental group students draw the smaller arc path of the sun for the first day of winter on their plastic hemispheres.

place title set #3a 28. Note that the first day of the next season is the vernal equinox with a discussion of the terms vernal and quinox.

ecliptic on 29. "We will now set the planetarium for the first day of spring. On what ecliptic date should I place the sun?" (March 21)

annual motion of sun
move sun 30. "Where will the sun rise?" (confused, guessed answers) "Where do you see it?" (east)

sun to meridian 31. "What is the midday altitude?" (48°) "Where do you expect the sun to set?" (most answer directly west) "Right, and where would it be directly overhead?"

place titles set #3b,c,d 32. "Great, it is exactly the same as what other season?" (fall or autumn)

meridian off ecliptic on place title set #4a 33. Present the final season of the four, the summer solstice with the sun positioned at June 21 on the ecliptic.

annual motion of sun 34. "Many may be surprised to see the summer sun rising here." (northeast generally) "How high an altitude will it get?" (answers vary, if 90° is stated often, note that the sun is never at Warren's zenith) "This is its greatest altitude, what is it?" (72°)

sun to setting 35. "Where is the sun setting?" (generally northwest)

grocentric earth on sun back to meridian 36. "Now the sun would be overhead if you were on the Tropic of Cancer."

grocentric earth off; place title set #4b,c,d 37. Note the data gathered for this season. Control group students trace out the movement of the summer sun by pointing to
the proper sunrise, midday, and sunset positions. Experimental group students draw the arc path of the sun on their plastic hemispheres.

38. Ask for inferences as to why the altitude numbers varied and note that the relationship is accounted by the tilt of the earth.

39. A dittoed copy of topic test number two is given to each student after directional signs have been taken down, and the experimental group students have completely cleaned off the plastic hemispheres, or the control group students have helped remove titles. (This is done by instructor for experimental group)

40. The test is orally administered, as per instructions, and collected when students leave the planetarium.

**Topic Three:** Lunar Movement and Phases

**Time:** 50 minutes

**Materials:** Planetarium

--- 35 mm slides

1) Title "Pointing to the Zodiac"

2) Zodiac constellation outlines with sun on ecliptic line

3) North circumpolar constellation map

4) Boy pointing from Draco to Zodiac constellations
5) Same as number four with addition of "90°" to show angle of pointing
6) Zodiac constellation outlines
7) Blank - to simulate moon at new phase
8) Moon at waxing crescent phase
9) Moon at first quarter phase
10) Moon at full phase
11) Moon at waning crescent phase

- - Large magnetic letters, "N", "E", "S", "W"
- - Magnetic fluorescent moon cards showing phases:
  a) new, b) early waxing crescent, c) first quarter,
  d) waxing gibbous, e) full, f) waning gibbous,
  g) last quarter, and h) late waxing crescent.
- - Tape recorded music
- - Flashlight
- - Demonstration of lunar movement and sun illumination on chalk board with:
  1) Suspended large flashlight
  2) Small styrofoam ball on magnet to represent moon
  3) Large styrofoam ball on magnet to represent earth and an inserted pin to show viewer's position.

- - For experimental lessons: one clear plastic hemisphere, one china marker, and one paper towel per student.

Planetarium set up:
- - Every other desk top in upright position (experimental groups have manipulative material in neighboring, "arms-down" seats
- - Lights on blue and yellow
- - Sun at midday
- - Moon off, but at early waxing crescent phase and above the ecliptic
- - Lunar movement demonstration on chalk board with flashlight off and moon in new phase position

Lesson sequence:

1. Welcome students and direct them to sit in their assigned chairs, which have the desk tops in an upright position.

2. As in lesson two, review the cardinal point directions in the planetarium chamber by using north as the reference point. The control group students physically affirm their knowledge of the directions by pointing to the proper location as a cardinal point is called out. The experimental group students print the directional letters on their plastic hemispheres and hold up their work to see if it orients properly with the room.

3. "What time of day would it be if the sun is at this place in the sky?" (midday) "What pretend line that goes from north to zenith to south, would it be on?" (meridian)

4. Ask, "If we are going to talk about the moon today, why would we want to point to
the zodiac?" (answers vary but centralize on idea that moon would be located near these groups of stars).

5. State that the sun and its yearly path go through the zodiac constellations. Ask, "What is the name of the path of the sun which we learned in the last lesson?" (ecliptic)

6. Note that finding the zodiac constellations and the ecliptic line can be done with the help of another group of stars known as the north circumpolar constellations. Briefly discuss the names, location, and movement of these constellations.

7. "What north circumpolar constellation helps us point to the zodiac and the ecliptic line?" (Draco)

8. "Good, how much of an angle is made from Draco to the ecliptic line?" (90°) Have students hold arms at this angle and show how you can tilt your body and maintain the same angle. Practice with students standing.

9. "When the sun sets in the direction . . . (west) in what direction will you have to look for Draco?" (north) Help find Draco by using the "pointer stars" in the Big Dipper.
10. Have students stand and make the $90^\circ$ arc angle to point out the zodiac and ecliptic line.

11. Inquire, "Can you find Draco now?" (answers vary) Remind students how to find this north circumpolar constellation and finally point it out in the planetarium sky.

12. The control group students trace out the path of the sun by making a $90^\circ$ angle with their arms and point from Draco. The experimental group students hold up their plastic hemispheres and draw the position of the ecliptic line.

13. As students confirm the correctness of their ability to locate the ecliptic, note that the altitude of this line changes and ask, "When Draco is high in the sky, the ecliptic is...?" (low) "When Draco is low, the ecliptic is...?" (high)

14. Note, as with lesson two, we could not see the sun and stars at the same time from earth. "The sun will always be on the ecliptic because the ecliptic is the...?" (path of the sun)

15. "Here is the moon. Is it on the ecliptic?" (no)

16. Note that the moon changes position in the sky because it revolves around the earth.
continue
moon movement
toward east
until on
ecliptic

17. "When the moon crosses the ecliptic it is
at a point called the 'node'; this happens
twice an orbit about the earth."

18. Note that an eclipse of the sun or moon
could occur if the moon is at one of two
special phases while it is on the
ecliptic, while writing conditions of a
solar and lunar eclipse on the chalkboard.

with flashlight
on star ball,
simulate
solar eclipse

19. "Did you notice that the moon changes its
appearance as it revolves about the earth?"
(Yes) These changes are called the phases,
and I will help you learn about them with
the models of the sun, moon, and earth on
the chalkboard."

the following
uses the
chalkboard
demonstration: 20. "Ask, "what would this large flashlight
represent?" (Sun) "The small ball?"
(Moon) "The large ball?" (Earth)
"The pin on the earth ball?" (Answers
vary, mention it is our viewing point from
earth)

large
flashlight on

21. Illustrate how half of the moon is always
illuminated by the sun and reinforce how
shadows create the eclipses.

move "moon"
about "earth"
"moon" between "sun" and "earth"  

22. "Could we see any of the lighted part of the moon when it is in this position?"  
(no) Note how it would have to be on the ecliptic to cause a solar eclipse.

moon card "a" on board  

23. "We can't see the moon during this phase, but I will represent it by the darkened circle. The phase is called 'new'."  
Print word on chalkboard under card.

move "moon" about 30° from sun/earth line  

24. "Do you notice how we can now see some of the lighted surface of the moon?" (yes)  
"Would we see very much of the moon?" (no)

moon card "b" on board  

25. "It is lit on which side?" (right) This phase is called the 'early crescent'."  
Print words on chalkboard under card.

move "moon" to 90°  

26. "Now can we see more or less of the lighted surface?" (more)

moon card "c" on board  

27. Note that this has been incorrectly called a "half moon" by many people. Ask for suggestions why it is really the "first quarter" and mention that it is one quarter of its orbit about the earth.

move "moon" to about 150°  

28. "Can we see all of the lighted surface?" (no) "Most of it?" (yes)

moon card "d" on board  

29. "This is called a gibbous moon." Print words on chalkboard under card. "It is lit on the ...?" (right) "with a little missing part on the ...?" (left) Outline "missing" portion with chalk.
move "moon" to about 180°  30. "Since we can see all of the lighted surface you know the phase would be called what?" (full)

moon card "c" on board
move "moon" to about 240°

moon card "£" on board
move moon to 280°
moon card "g" on board
move "moon" to about 340°
moon card "h" on board

32. Most students will guess this to be a gibbous moon. Ask, "Would it appear the same as the other gibbous?" (no) "How would it be different?" (answers vary)
33. "What side is most lit now?" (left) Outline "missing" portion with chalk and write phase name under card.
34. "Could this be a first quarter?" (no) It must be a...?" (last quarter or third quarter)
35. Print name of phase under card and note illumination on left.
36. "What phase is this?" (crescent) "Great, is it early or late?" (late)
37. Print phase name under card and ask, "Is the sun showing from the right or left?" (left) If response is poor, use flashlight to demonstrate position of sun relative to side of moon we see as illuminated.
38. State, "Now I am going to show you some slides of the real moon. I want you to tell me the phase."
39. "What phase is this?" (students are often
confused because nothing is showing in front of the room) "This is the new phase— we can't see it!"

40. "Since this moon is just barely showing and is lit on the right, its phase must be...?" (early crescent)

41. Control group students are instructed to point to the position in the sky in which they would expect to find this phase. Experimental group students hold up their plastic hemispheres and draw the proper shape of the moon in the correct position. Both groups are given much help with this first attempt to locate positioning.

42. "This phase is....?" (first quarter) Students do the same activity as outlined in previous sequence statement. The correct position is shown.

43. "Could we see this in the sky when the sun was showing?" (confused answers) Explain that the sun and moon would be opposite. Therefore, "when the sun is setting, the full moon would be ...?" (rising); and "when the full moon is setting, the sun would be ...?" (rising)

44. "This phase is...?" (last quarter) Students do the same activity as outlined in sequence statement number 41 from this
lesson. The correct position is shown.

45. A dittoed copy of topic post-test number three is given to each student after directional signs have been taken down and the experimental group students have completely cleaned off the plastic hemispheres, or the control group students have helped remove moon cards and phase names from chalkboard. (This is done by instructor for experimental group.)

46. The test is orally administered, as per instructions, and collected when complete. The astronomy opinionnaire is then completed by each student (for the second time) and is collected when the students leave the planetarium.

**Instrumentation**

**Information Form**

A brief information form was completed by each subject prior to the first planetarium unit. This questionnaire (Appendix A) was used to maintain the filing method in all measurements of a particular student, to identify the control variables of grade, gender, and previous planetarium experience, and to ask corroborative information.

**Cognitive Tests**

Since there were no standard evaluative tools available to measure the content and approach of this study, a series of tests were developed by the researcher during a six month
pilot study which commenced a year prior to the data gathering of this experiment. For ease of test administration, grading, and analysis, a multiple choice format was chosen. Before using any field testing procedures, three tests of approximately equal length were constructed according to the guidelines of Gronlund (1976). This involved the formulation of clearly stated problems, the identification of plausible alternatives, and special efforts to remove irrelevant clues to the answers.

The academic instruments were verified for clarity and content by a panel of ten individuals which included a planetarium instructor, a science teacher, fifth and eighth grade teachers, and selected good and poor students who had recently completed the related coursework. Each reviewer was asked to do the following for each test item: a) answer the item and give reason for choice; b) estimate the difficulty of an item (easy, average, hard); c) provide suggestions for changes in the item; and d) state the apparent type of question (recall, application, observation). In addition, the educators had to match the questions with the appropriate section of the lesson's script. Through analysis of the panelists' responses, sources of error were identified and corrected, difficulty levels were balanced, a few words were changed, and question type and content validity were assured.

The celestial sphere and time topic post-test contained seventeen items with eight questions (47%) requiring recall of presented information, six questions (35%) requiring application of presented facts to a unique but related situation,
and three questions (18%) requiring observation of an item projected on the dome. The seasons topic post-test also contained seventeen items, but seven (41%) were recall, seven (41%) were application, and three (18%) were observational. The third topic post-test on lunar motion and phases had sixteen items, with nine (56%) recall, four (25%) application, and three (19%) observational. The variation between the number of recall and application questions was due to the differing amount of factual information presented during a lesson.

Because of the expense and difficulty of scheduling buses to bring students to the planetarium, it was decided that the delayed unit post-test would be administered in the classroom three weeks after the last planetarium session. This necessitated omitting the observation questions, but the test did include the identical remaining questions from the three topic post-tests. None of the astronomy information was reviewed during the three weeks following the lesson on lunar motion and phases.

As noted in the lesson outlines, each test item and answer choice was read to the students by the instructor and a ten second response time was given for students to circle their answer on the test paper. This was done as a control for reading skill variations among the subjects, but the tests were within the grade level equivalence of readability as measured by a computer analysis using the Bormuth index and Dale Long List (Irving 1979, p. 10). Test one had a readability index of 56.7 with 91.7% of words on Dale Long
List with a grade equivalence of 5.2. Test two had 48.2, 97.5%, and 3.2 respectively, while test three measured to be 53.7, 94.5%, 4.5.

Test reliability was measured by the two methods of test-retest and split-half as outlined by Bartz (1976, pp. 330-335). The results shown in Table 2 report the Pearson for the correlation of two administrations of each topic post-test to twenty students and the Spearman-Brown coefficient for a split-half question analysis of thirty random sets of post-tests.

Copies of the three topic post-tests and the delayed unit post-test are found in Appendix B.

**Attitude Measurement**

To measure student attitude toward astronomy and the planetarium, an existing instrument was used exactly as suggested by Mallon (1980). The Likert style opinionnaire was first presented in an article by Fisher (1973) and had a reported test-retest reliability score of .793 and a split-half score of .833.

The wording on the opinionnaire was slightly modified to better relate it to this study. The following alterations were made:

1. The word "astronomer" replaced the word "scientist".
2. "Planetarium" was inserted for "science classroom".
3. The word "science" was replaced in each appropriate question by the word "astronomy".
<table>
<thead>
<tr>
<th>Method</th>
<th>Test - Retest</th>
<th>Split - Half</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>.81</td>
<td>.796</td>
</tr>
<tr>
<td>Post-Tests</td>
<td>.79</td>
<td>.849</td>
</tr>
<tr>
<td>Unit Test</td>
<td></td>
<td>.641</td>
</tr>
<tr>
<td>Topic 2</td>
<td>.72</td>
<td>.752</td>
</tr>
<tr>
<td>Topic 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Topic 1** = Features of Celestial Sphere and Time

**Topic 2** = Seasonal Changes

**Topic 3** = Lunar Movement and Phases
This opinionnaire was read to and completed by students in the classroom, the day before they attended the first planetarium lesson. An identical form was again presented and read for student completion in the planetarium immediately after the third lesson. No students experienced difficulty responding to the post opinion evaluation, but most of the students, who had no previous planetarium experience before lesson one, found the pre-opinionnaire difficult to complete.

To tally the results each answer choice was weighted 5, 4, 3, 2, 1, with 5 assigned to the answer which, if chosen, would reflect a judgment favorable to the program. Thus, a score of 60 demonstrated a mean, "no opinion" attitude; a higher score represented a more positive opinion about the study of astronomy and the planetarium.

A copy of the astronomy opinionnaire appears in Appendix C of this report.

Statistical Analysis

The data analyzed in this study was gathered from the previously mentioned information form, cognitive tests, and attitude measurement so that the following six research questions could be answered:

1. Is retention, as shown through unit post-test results, different for students using a manipulative than for those not using a manipulative?

2. Does the use or non-use of a manipulative within a planetarium unit of study effect a student's attitude toward astronomy education?

3. Does previous planetarium experience effect the
Immediate post-test scores of students using or not using the manipulative?

4. Is the manipulative more effective for one of the three types of lessons?

5. Does grade level or sex influence the effectiveness of manipulative use?

6. Is the ability to correctly answer recall, application, or observation questions effected by manipulative use?

In order to answer these questions statistically and measure the significance of any variations, Dayton (1970) noted that "an appropriate null hypothesis must be set up and an appropriate term placed in the structural model for a score in the design" (p. 95). Thus the following null hypotheses were generated:

\( H_{01} \) There is no significant difference between the delayed unit post-test scores of students using the manipulative and those not using the manipulative.

\( H_{02} \) Students who have experienced the planetarium lessons using the manipulative have an attitude toward astronomy education which is not significantly different from that of students not using the manipulative in excess of the unique variance due to pre- or post-treatment measurement.

\( H_{03} \) There is no significant difference between the initial topic post-test scores of students having had previous planetarium experience and those of students having had no previous planetarium experience in excess of the unique variance due to
use or non-use of the manipulative.

**H_0.4** There is no significant difference between the immediate topic post-test results of students using the manipulative and those not using the manipulative in any of the lessons in excess of the unique variance due to grade and gender.

**H_0.5** The topic post-test scores of students using the manipulative do not significantly vary among grade level and gender groups.

**H_0.6** There is no significant difference between the results on the immediate topic recall, application, or observation questions of students using the manipulative and those not using the manipulative.

In order to address these six null hypotheses and gather information related to the corresponding research questions, various statistical tests were utilized. Analysis of the data was assisted by the Michigan Terminal Computer System at Wayne State University, Detroit, Michigan, with the program SPSS (Statistical Package for the Social Studies).

Specifically, null hypothesis one, which was concerned with the effect of using a manipulative on the retention scores of the delayed post unit test, was examined by a one-way analysis of variance (ANOVA) and contrasts employing the Scheffe method. Null hypothesis two, involving student attitudes toward the planetarium and astronomy education, was studied by a two one-way ANOVA's with treatment and pre-, post-attitudes as the independent variables or factors, and by chi-square analysis of the frequency of attitude change.
null hypothesis three, concerned with the "mystique effect" from no previous planetarium visitations, was inspected by a two-factor ANOVA with the immediate post-topic test score of the lesson on the celestial sphere and time as the criterion variable and by multiple classification analysis. Null hypothesis four, on the effectiveness of the manipulative for the three lessons, and null hypothesis five, concerning the variables of grade and gender, were both analyzed through three 2x2x2 ANOVA designs in which question scores from the post topic tests were the criterion variable, two of the dimensions were the classification variables of grade level and sex, and another dimension was the major treatment variable of manipulative and non-manipulative. Null hypothesis six, on questions type and manipulative effectiveness, was examined by a 2x3 analysis of variance with repeated measures and a one-way analysis of variance. The level of significance to accept or reject any of these null hypotheses was alpha=.05 with α=.10 indicating a trend suggesting further confirmatory exploration.

So that the major analytical model of ANOVA would be considered correct, compliance with the following assumptions (Minium 1970, p. 404) was assured:

1. The sub-group populations were normally distributed.
2. Samples were drawn at random.
3. Selection of elements comprising any sub-group was independent of selection of elements of any other sub-group.
4. There was homogeneity of variance.
Though these assumptions appear restrictive, Glass (1970) illustrated the robustness of ANOVA by pointing out that certain violations of these assumptions have little effect on the results of the statistical analysis. As a precaution, however, the Scheffe method of multiple comparisons was chosen over the more general Turkey method for the one-factor ANOVA. This S-method is "regarded by mathematicians as superior to the T-method because of its generality and greater sensitivity when complex combinations of the sample means are being estimated" (Glass 1970, p. 395). Also, Jae-On Kim noted it is "stricter than the other tests and is exact, even for unequal group sizes" (Nie 1975, p. 428).

This chapter has presented the procedures used to make an experimental comparison with fifth and eighth grade students on the effectiveness of direct manipulation of an instructional object during astronomy unit presentations in the planetarium. The population description, experimental design, instructional program, instrumentation, and statistical analysis sections were included to give background and support for the next chapter on analysis of data.
CHAPTER IV
ANALYSIS OF DATA

Introduction

The purpose of this investigation was to make an experimental comparison with fifth and eighth grade students between planetarium units of study which included and excluded direct manipulation of an instructional object. Each of three major topics of celestial sphere and time, seasonal changes, and lunar motion and phases, was presented during an instructional visit to the planetarium. The variables of previous experience, manipulative opportunity, grade, and gender were examined with the criterion variables being student performance on three immediate topic post-tests, delayed unit post-test, and pre-post measurements of attitude.

Six basic questions represented the research basis for measuring the effectiveness of manipulative use in planetarium lessons.

1. Is retention, as shown through unit post-test results, different for students using a manipulative than for those not using a manipulative?

2. Does the use or non-use of a manipulative within a planetarium unit of study effect a student's attitude toward astronomy education?

3. Does previous planetarium experience effect the immediate post-test scores of students using or not using the manipulative?
4. Is the manipulative more effective for one of the three types of lessons?

5. Does grade level or student gender influence the effectiveness of manipulative use?

6. Is the ability to correctly answer recall, application, or observation questions effected by manipulative use?

These questions were answered and their resultant null hypotheses were examined through an analysis of data which was gathered from 542 students of Fitzgerald Public Schools in Warren, Michigan.

**Measurement of Knowledge Retention**

In order to investigate the impact of manipulative use on learning and retaining the material presented during the planetarium lessons, two modes of analysis were used: One method examined the delayed unit post-test scores within the three varying exposures to material and the other method noted the difference between the total of the three immediate post-tests and the delayed unit post-test.

Null hypothesis one, which stated that there is no significant difference between the delayed unit post-test scores of students using the manipulative and those not using the manipulative, was rejected on the basis of the one-way analysis of variance summarized in Table 3. For this statistical procedure, comparisons were made from test scores of students within each of the three groups which were identified as follows: Group 1--those using the manipulative during the lessons, Group 2-- those not using the manipulative
TABLE 3

A ONE-WAY ANALYSIS OF VARIANCE OF DELAYED UNIT POST-TEST SCORES ON THE THREE TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>9513.02</td>
<td>4756.51</td>
<td>136.02*</td>
</tr>
<tr>
<td>Within groups</td>
<td>508</td>
<td>17763.95</td>
<td>34.97</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>510</td>
<td>27276.97</td>
<td>53.66</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
during the lessons, and Group 3--those not experiencing the planetarium unit of instruction, with a probability of less than .001, it was concluded that a significant difference on this criterion variable existed between the groups. As might be expected, the mean score of group three was considerably lower than either of the two treatment groups experiencing the planetarium lessons. To assure that the low performance of this control group was not the only contributor to the overall significance, further analysis was completed. A contrast study, as shown in Table 4, not only indicated a statistically significant difference between group three and each of the other two groups, but also, validated that the groups which experienced the lessons in the planetarium had differences in material retention. Examination of the means indicated the delayed unit post-test performance of the students who used the manipulative to be superior to that of the students who did not use the manipulative.

If just the two groups who experienced the unit of study are considered, the knowledge retention may be also seen as a difference between the measurements of learned information immediately after the planetarium lessons and the measurement of information retained three weeks after the last planetarium exposure. A summary of results of a one-way analysis of variance of this difference for the two treatment groups is shown in Table 5. Inspection of the means demonstrated that both groups did not retain all the initial knowledge. However, group one with a mean of 4.8 less correct on the delayed unit test had a greater retention of knowledge than group two
**TABLE 4**

A CONTRAST ANALYSIS OF DELAYED UNIT POST-TEST SCORES BETWEEN THE THREE TREATMENT GROUPS

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Number</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (using manipulative)</td>
<td>194</td>
<td>28.37</td>
</tr>
<tr>
<td>2 (not using manipulative)</td>
<td>216</td>
<td>27.00</td>
</tr>
<tr>
<td>3 (having no unit)</td>
<td>101</td>
<td>16.92</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Contrast Groups</th>
<th>Value</th>
<th>S. Error</th>
<th>T Value</th>
<th>T Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 vs 2</td>
<td>1.37</td>
<td>0.58</td>
<td>2.34</td>
<td>0.020</td>
</tr>
<tr>
<td>1 vs 3</td>
<td>11.45</td>
<td>0.73</td>
<td>15.77</td>
<td>0.001</td>
</tr>
<tr>
<td>2 vs 3</td>
<td>10.08</td>
<td>0.71</td>
<td>14.14</td>
<td>0.001</td>
</tr>
</tbody>
</table>
TABLE 5


<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>54.07</td>
<td>54.07</td>
<td>4.32*</td>
</tr>
<tr>
<td>Within groups</td>
<td>255</td>
<td>3188.68</td>
<td>12.50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>256</td>
<td>3242.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p<.04
which had a mean of 5.8 less correct on the delayed unit test. This difference in retention is found to be statistically significant with a probability of less than .04.

On the basis of the analysis of variance procedures and the contrast analysis, the data is supportive of retention being different for students using a manipulative than for students not using a manipulative. Also, the inclusion of student object manipulation during a planetarium unit of instruction will improve a student's retention of learned information.

**Measurement of Attitudes**

The data gathered to measure student attitudes toward astronomy education included the presentation of the same Likert-scale opinionnaire prior to the planetarium unit of instruction and immediately following the third planetarium lesson. This allowed analysis of the effect of the use of a manipulative on attitude and attitudinal changes.

Null hypothesis two, which stated that students who have experienced the planetarium lessons using the manipulative have an attitude toward astronomy education which is not significantly different from that of students not using the manipulative in excess of the unique variance due to pre- or post-treatment measurement, was retained on the basis of the one-way analysis of variance summarized in Table 6. For this statistical procedure, the concluding opinionnaire scores of the two treatment groups were compared, and the difference was not found to be significant; the probability was greater than .83. The data for all subpopulation groups indicated a
TABLE 6

A ONE-WAY ANALYSIS OF VARIANCE OF THE CONCLUDING OPINIONNAIRE SCORES OF THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>3.62</td>
<td>3.62</td>
<td>0.04</td>
</tr>
<tr>
<td>Within groups</td>
<td>398</td>
<td>34111.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>399</td>
<td>34114.68</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non-Significant, F, p > .83
positive attitude toward astronomy education. The deviation from the grand mean of 77.85 was only 0.12 for the students using the manipulative and -0.11 for the students not using the manipulative. This slightly more positive indication for manipulative usage would not allow null hypothesis rejection.

Further analysis of the impact of teaching method of attitude included an investigation of the difference between the initial and final opinionnaire for the two treatment groups. A summary of the one-way analysis of variance for this difference is shown in Table 7, and it also indicates retention of null hypothesis two. The probability of .12 is just beyond the alpha of .10 which had been accepted as indicating a trend; further confirmatory exploration is not warranted. However, the data supports 64% of the students improving their attitudes with the non-manipulative group demonstrating the greater frequency of increase in attitude (53% of group 2 as opposed to 47% of group 1). Chi-square analysis of the frequency of increase or decrease in attitude for each of the variables of treatment, grade, gender or pre-experience, indicated significance for only the fifth grade variation. The observed frequency of non-manipulative students increasing their attitude was much greater than expected.

On the basis of the analysis of variance procedures, the data is not supportive of manipulative use as a variable effecting a student's attitude toward astronomy education. The mean scores on the opinionnaire before and after the planetarium unit of instruction indicated a positive attitude.
TABLE 7

A ONE-WAY ANALYSIS OF VARIANCE OF THE ATTITUDE CHANGE BETWEEN THE PRE- AND POST-OPINIONNAIRE SCORES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>582.25</td>
<td>582.25</td>
<td>2.49</td>
</tr>
<tr>
<td>Within groups</td>
<td>439</td>
<td>102480.00</td>
<td>233.44</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>440</td>
<td>103062.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non-Significant F, p > .12
Measurement of Preexposure Impact

The literature introduced the idea of a "mystique effect" as being an initial sense of awe experienced during the very first attendance of a planetarium lesson. Investigating the impact of such a condition, was one of the objectives of this study.

Null hypothesis three, which stated that there is no significant difference between the initial topic post-test scores of students having had previous planetarium experience in excess of the unique variance due to use or non-use of the manipulative, was rejected on the basis of the 2x2 factorial analysis of variance which is summarized in Table 8. For this statistical procedure, the immediate post-test scores on the topic of the celestial sphere and time were examined within treatment and exposure groups. Of the main effects, only the preexperience could be considered as having a significant impact on the test scores (alpha<.05); the group differentiation was not significant. Interaction of group and experience was not supported.

Table 9 presents the data which shows the impact of preexperience exposure. Students who had lessons in a planetarium within three years of this study performed significantly better on the initial post-test. The deviation of .83 from the grand mean of 14.26 was even more pronounced when it was adjusted for grade level and equaled 1.43. Such grade level impact will be discussed in a later section of this chapter, but it should be noted that the impact of preexperience was still statistically significant; the group having planetarium
TABLE 8

A 2x2 FACTORIAL ANALYSIS OF VARIANCE OF THE INITIAL TOPIC POST-TEST SCORES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT AND THEIR PREEXPERIENCE EXPOSURE

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
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<td>22.32</td>
<td>11.16</td>
<td>1.99</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>0.52</td>
<td>0.52</td>
<td>.09</td>
</tr>
<tr>
<td>Preexperience</td>
<td>1</td>
<td>21.84</td>
<td>21.84</td>
<td>3.91*</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td>8.36</td>
<td>8.36</td>
<td>1.50</td>
</tr>
<tr>
<td>Group by preexperience</td>
<td>1</td>
<td>8.36</td>
<td>8.36</td>
<td>1.50</td>
</tr>
<tr>
<td>Residual</td>
<td>410</td>
<td>2290.08</td>
<td>5.59</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>413</td>
<td>2320.76</td>
<td>5.62</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .05
TABLE 9

A MULTIPLE CLASSIFICATION ANALYSIS OF THE INITIAL UNIT POST-TEST SCORES WITHIN THE TWO GROUPS WHICH EXPERIENCED THE UNIT AND THEIR PREEXPERIENCE EXPOSURE

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Unadjusted Deviation</th>
<th>Eta</th>
<th>Adjusted for Grade Level Deviation</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using manipulative</td>
<td>197</td>
<td>0.04</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Not using manipulative</td>
<td>217</td>
<td>-0.03</td>
<td>-0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preexperience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>379</td>
<td>0.07</td>
<td>0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>35</td>
<td>-0.76</td>
<td>-1.31</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>Grand mean =</td>
<td>14.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple R² =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.14</td>
</tr>
<tr>
<td>Multiple R =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.38</td>
</tr>
</tbody>
</table>
attendance scored higher on the achievement test. Previous planetarium experience does effect the immediate post-test scores of students using or not using the manipulative.

**Measurement of Manipulative Effectiveness on Varying Topics**

A different topic was presented within each of the three planetarium visitations. Topic one discussed location points, celestial sphere, and time; topic two examined the seasonal changes in the sun's position; topic three presented information about lunar motion and phases. One goal of this study was to identify which lesson topic was best taught by use of concept object manipulation.

Null hypothesis four, which stated that there is no significant difference between the immediate topic post-test results of students using the manipulative and those not using the manipulative in any of the lessons, was rejected on the basis of a repeated measures 2x3 analysis of variance which is summarized in Table 10. For this statistical procedure, the scores of the three topic post-tests were the repeated measures in a comparison between the two groups which experienced the unit of instruction. Acceptable levels of significance were indicated for variation between the topic test scores, variation among the groups, and interaction of groups and tests.

Each of the three topic test scores contributed to the overall significance of the statistical variation. This is apparent from an inspection of means in which the first topic test on the celestial sphere had an entire population average
TABLE 10

A REPEATED MEASURES 2x3 ANALYSIS OF VARIANCE BETWEEN THE TWO TREATMENT GROUPS WITHIN THE TEST SCORES FOR EACH OF THE THREE POST-TOPIC TESTS

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>1</td>
<td>56.22</td>
<td>56.22</td>
<td>3.98*</td>
</tr>
<tr>
<td>Within groups</td>
<td>377</td>
<td>5330.56</td>
<td>14.14</td>
<td></td>
</tr>
<tr>
<td>Topic Tests</td>
<td>2</td>
<td>4400.14</td>
<td>2200.07</td>
<td>533.06**</td>
</tr>
<tr>
<td>Interaction (Group/Tests)</td>
<td>2</td>
<td>50.92</td>
<td>25.46</td>
<td></td>
</tr>
<tr>
<td>Within Tests</td>
<td>754</td>
<td>3111.94</td>
<td>4.13</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .05
** Significant F, p < .003
of 14.34 or 84% correct; the second topic test on seasonal
cchanges had 12.44 or 73% correct; the third topic test on
lunar phases had 9.63 or 61% correct. The identification of
the reasons for the decline in scores is beyond the scope of
this investigation, but it should be noted that the latter two
topics require mastery of projective concepts.

To identify the source of variation between the groups
with differing treatment methods, three 2x2x2 analyses of
multiple variance were made for topic post-test scores within
grade, gender, and group, Tables 11, 13, and 15, and
the corresponding multiple classifications were calculated, Tables
12, 14, and 16. This procedure indicated no significant
difference for treatment on topic one ($\alpha=.58$); students who
used and students who did not use the manipulative achieved
equally well on the celestial sphere test. A trend indicating
a possible variation greater than chance was identified for
the scores on the topic two test ($\alpha=.06$); the students who used
the manipulative scored 5% higher than those who did not use
the manipulative. The main contribution to the overall
significance of the group presentation method was the variation
between the test scores for the lunar phase lesson ($\alpha=.001$);
the students who used the manipulative had a mean score .47
points above the grand mean of 9.62, and the students who did
not use the manipulative had a mean score .42 points below the
grand mean. This variation as shown in Table 16 indicates a
mean gain of 9% by the group experiencing object manipulation
over the group not experiencing object manipulation.
TABLE 11

A 2X2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF CELESTIAL SPHERE AND TIME FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT BY GENDER, GRADE LEVEL, AND GROUP

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>9.95</td>
<td>9.95</td>
<td>2.11</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>206.71</td>
<td>206.71</td>
<td>43.94*</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>1.02</td>
<td>1.02</td>
<td>0.22</td>
</tr>
<tr>
<td>Two-way interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Grade</td>
<td>1</td>
<td>1.67</td>
<td>1.67</td>
<td>0.25</td>
</tr>
<tr>
<td>Gender Group</td>
<td>1</td>
<td>.58</td>
<td>.58</td>
<td>0.12</td>
</tr>
<tr>
<td>Grade Group</td>
<td>1</td>
<td>3.66</td>
<td>3.66</td>
<td>0.78</td>
</tr>
<tr>
<td>Three-way interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Grade Group</td>
<td>1</td>
<td>.02</td>
<td>.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Residual</td>
<td>371</td>
<td>1745.14</td>
<td>33.50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>1979.60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
### TABLE 12

**A MULTIPLE CLASSIFICATION ANALYSIS OF THE POST-TEST SCORES ON THE TOPIC OF CELESTIAL SPHERE AND TIME BY GENDER, GRADE LEVEL, AND GROUP**

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Unadjusted Deviation</th>
<th>Eta</th>
<th>Adjusted For Independents Deviation</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>182</td>
<td>0.25</td>
<td></td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>197</td>
<td>-0.23</td>
<td></td>
<td>0.10</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>223</td>
<td>-0.63</td>
<td></td>
<td>-0.62</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>156</td>
<td>0.91</td>
<td></td>
<td>.89</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using Manipulative</td>
<td>179</td>
<td>-0.07</td>
<td></td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Not using Manipulative</td>
<td>200</td>
<td>0.06</td>
<td></td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Grand mean \( \bar{X} = 14.45 \)**

**Multiple \( R = 0.12 \)**

**Multiple \( R = 0.34 \)**
TABLE 13

A 2X2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF SEASONAL CHANGES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT BY GENDER, GRADE LEVEL, AND GROUP

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>3</td>
<td>337.23</td>
<td>112.41</td>
<td>12.85</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.73</td>
<td>0.73</td>
<td>0.08</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>305.58</td>
<td>305.58</td>
<td>34.92*</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>32.02</td>
<td>32.02</td>
<td>3.66</td>
</tr>
<tr>
<td>Two-way interactions</td>
<td>3</td>
<td>179.28</td>
<td>59.76</td>
<td>6.83</td>
</tr>
<tr>
<td>Gender Grade</td>
<td>1</td>
<td>11.46</td>
<td>11.46</td>
<td>1.31</td>
</tr>
<tr>
<td>Gender Group</td>
<td>1</td>
<td>0.02</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Gender Group</td>
<td>1</td>
<td>163.02</td>
<td>163.02</td>
<td>18.63</td>
</tr>
<tr>
<td>Three-way interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Grade Group</td>
<td>1</td>
<td>47.68</td>
<td>47.68</td>
<td>5.45</td>
</tr>
<tr>
<td>Residual</td>
<td>371</td>
<td>3246.38</td>
<td>8.75</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>3810.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
TABLE 14

A MULTIPLE CLASSIFICATION ANALYSIS OF THE POST-TEST SCORES ON THE TOPIC OF SEASONAL CHANGES BY GENDER, GRADE LEVEL, AND GROUP

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Unadjusted Deviation</th>
<th>Eta</th>
<th>Adjusted for Independents Deviation</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>182</td>
<td>0.04</td>
<td>-0.05</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Female</td>
<td>197</td>
<td>-0.03</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>223</td>
<td>-0.75</td>
<td>-0.75</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Eighth</td>
<td>156</td>
<td>1.07</td>
<td>1.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using Manipulative</td>
<td>179</td>
<td>0.30</td>
<td>0.31</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Not using manipulative</td>
<td>200</td>
<td>-0.27</td>
<td>-0.28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grand mean\(^2\) = 12.48
Multiple R\(^2\) = 0.09
Multiple = 0.30
TABLE 15

A 2X2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF LUNAR PHASES AND MOTION FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT BY GENDER, GRADE LEVEL, AND GROUP

<table>
<thead>
<tr>
<th>Source Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>26.66</td>
<td>26.66</td>
<td>4.14</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>165.17</td>
<td>165.17</td>
<td>25.65*</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>73.47</td>
<td>73.47</td>
<td>11.41*</td>
</tr>
<tr>
<td>Two-way interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Grade</td>
<td>1</td>
<td>47.00</td>
<td>47.00</td>
<td>7.30</td>
</tr>
<tr>
<td>Gender Group</td>
<td>1</td>
<td>10.55</td>
<td>10.55</td>
<td>1.64</td>
</tr>
<tr>
<td>Grade Group</td>
<td>1</td>
<td>44.68</td>
<td>44.68</td>
<td>6.94</td>
</tr>
<tr>
<td>Three-way interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Grade Group</td>
<td>1</td>
<td>3.89</td>
<td>3.89</td>
<td>0.61</td>
</tr>
<tr>
<td>Residual</td>
<td>371</td>
<td>2389.14</td>
<td>6.44</td>
<td>8.21</td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>2759.25</td>
<td>7.30</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Unadjusted Deviation</th>
<th>Eta</th>
<th>Adjusted for Independents Deviation</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>182</td>
<td>-0.22</td>
<td></td>
<td>-0.28</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>197</td>
<td>0.21</td>
<td></td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>223</td>
<td>-0.53</td>
<td></td>
<td>-0.55</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>156</td>
<td>.76</td>
<td></td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using manipulative</td>
<td>179</td>
<td>0.47</td>
<td></td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>Not using manipulative</td>
<td>200</td>
<td>-0.42</td>
<td></td>
<td>-0.42</td>
<td></td>
</tr>
<tr>
<td><strong>Grand mean</strong></td>
<td></td>
<td>9.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Multiple R</strong></td>
<td></td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Multiple R</strong></td>
<td></td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The interaction between group and topic is significant and evidenced by decline in scores by both groups as the unit progressed and a greater mean score by the manipulative group over the non-manipulative group on each of the three topic tests.

On the basis of the repeated measures 2x3 analysis of variance, the three 2x2x2 multiple variance studies, the classification analysis, and the levels of significance, the data is supportive of the use of a manipulative object as being more effective for one of the three types of lessons.

**Measurement of the Influence of Grade Level and Gender**

This experimental study included students from the fifth and eighth grade levels to analyse the effects of these groupings on the effectiveness of manipulative use for each of the topics within the unit of study.

Null hypothesis five, which stated that the topic post-test scores of students using the manipulative do not significantly vary among grade level and gender groups, was rejected for grade only because of the statistically significant differences among the mean scores of the grade levels for all three tests. Tables 17, 18, and 19 summarize the results of 2x2 factorial analysis of variance procedures which examined the post-test scores for the celestial sphere, seasonal changes, and lunar phases, respectively.
TABLE 17

A 2x2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF CELESTIAL SPHERE AND TIME FOR THE TREATMENT GROUP USING THE MANIPULATIVE BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>2</td>
<td>133.78</td>
<td>66.89</td>
<td>13.04</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>2.72</td>
<td>2.72</td>
<td>0.53</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>127.68</td>
<td>127.68</td>
<td>24.89*</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by Grade</td>
<td>1</td>
<td>.70</td>
<td>.70</td>
<td>0.14</td>
</tr>
<tr>
<td>Residual</td>
<td>175</td>
<td>897.68</td>
<td>5.13</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>178</td>
<td>1032.15</td>
<td>5.80</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p<.001
TABLE 18

A 2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF SEASONAL CHANGES FOR THE TREATMENT GROUP USING THE MANIPULATIVE BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Source of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.23</td>
<td>0.23</td>
<td>0.03</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>458.38</td>
<td>458.38</td>
<td>61.75*</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by Grade</td>
<td>1</td>
<td>53.88</td>
<td>53.88</td>
<td>7.26**</td>
</tr>
<tr>
<td>Residual</td>
<td>175</td>
<td>1299.09</td>
<td>7.42</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>178</td>
<td>1812.48</td>
<td>10.18</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
** Significant F, p < .009
TABLE 19

A 2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF LUNAR PHASES AND MOTION FOR THE TREATMENT GROUP USING THE MANIPULATIVE BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>2</td>
<td>194.70</td>
<td>97.35</td>
<td>14.93</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>1.13</td>
<td>1.13</td>
<td>0.17</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>194.70</td>
<td>194.70</td>
<td>29.86*</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by Grade</td>
<td>1</td>
<td>10.78</td>
<td>10.78</td>
<td>1.65</td>
</tr>
<tr>
<td>Residual</td>
<td>175</td>
<td>1141.08</td>
<td>6.52</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>178</td>
<td>1346.55</td>
<td>7.57</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
These scores were the dependent variables used to investigate the impact of the gender and grade level variables for those students who studied the planetarium unit while performing concept object manipulations. Each table shows a statistically significant difference for grade level by topic, but not a statistically difference for gender and a significant gender-by-grade interaction only for the topic on seasonal changes.

The multiple classification analysis summary shown in Table 20 indicates that the eighth grade students had a higher achievement rating than the fifth grade students on each of the topic post-tests. The greatest variation was found for the topic on seasonal changes with a deviation range of 3.26 (26%) between the grade levels; topic three on moon phases was next with a 2.11 (21%) and the lesson on the celestial sphere was least with a 1.74 (12%).

An analysis of variance using the same independent variables for those students who did not have the opportunity to manipulate a concept model, Tables 21, 22, and 23, provided a statistically significant difference only between the grade levels for topic one and indicated no other significant variation for gender on topics one and two or for grade level on topics two and three. The deviation range of 1.36 from a grand mean of 14.50 resulted in a variance of grade level (9%) which was less than that for the same groups using the manipulative.
### TABLE 20

A MULTIPLE CLASSIFICATION ANALYSIS SUMMARY OF THE THREE UNIT POST-TEST SCORES FOR THE TREATMENT GROUP USING THE MANIPULATIVE BY GRADE LEVEL

<table>
<thead>
<tr>
<th>Topic</th>
<th>Variable of Grade</th>
<th>N</th>
<th>Unadjusted Deviation</th>
<th>Adjusted for Gender Deviation</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celestial Sphere</td>
<td>Mean = 14.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>106</td>
<td>-0.71</td>
<td>0.36</td>
<td>-0.71</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>73</td>
<td>1.03</td>
<td>0.35</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Seasonal Changes</td>
<td>Mean = 12.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>106</td>
<td>-1.33</td>
<td>0.50</td>
<td>-1.33</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>73</td>
<td>1.93</td>
<td>0.50</td>
<td>1.93</td>
<td></td>
</tr>
<tr>
<td>Lunar Phases</td>
<td>Mean = 10.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>106</td>
<td>-0.86</td>
<td>0.38</td>
<td>-0.87</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>73</td>
<td>1.25</td>
<td>0.38</td>
<td>1.26</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 21

A 2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF CELESTIAL SPHERE AND TIME FOR THE TREATMENT GROUP NOT USING THE MANIPULATIVE BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>2</td>
<td>98.03</td>
<td>49.01</td>
<td>11.34</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>8.08</td>
<td>8.08</td>
<td>1.87</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>82.34</td>
<td>82.34</td>
<td>19.04*</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by Grade</td>
<td>1</td>
<td>0.49</td>
<td>0.49</td>
<td>0.11</td>
</tr>
<tr>
<td>Residual</td>
<td>196</td>
<td>847.47</td>
<td>4.32</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>945.98</td>
<td>4.75</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .001
### TABLE 22

A 2x2 FACTORIAL ANALYSIS OF VARIANCE OF THE POST-TEST SCORES ON THE TOPIC OF SEASONAL CHANGES FOR THE TREATMENT GROUP NOT USING THE MANIPULATIVE BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td>2</td>
<td>14.62</td>
<td>7.31</td>
<td>0.74</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>0.08</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>14.59</td>
<td>14.59</td>
<td>1.47</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by grade</td>
<td>1</td>
<td>5.25</td>
<td>5.25</td>
<td>0.53</td>
</tr>
<tr>
<td>Residual</td>
<td>196</td>
<td>1947.28</td>
<td>9.94</td>
<td>0.53</td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>1967.16</td>
<td>9.89</td>
<td></td>
</tr>
</tbody>
</table>

Non-Significant F
TABLE 23

A 2X2 FACTORIAL ANALYSIS OF VARIANCE OF THE
POST-TEST SCORES ON THE TOPIC OF LUNAR
PHASES AND MOTION FOR THE TREATMENT
GROUP NOT USING THE MANIPULATIVE
BY GENDER AND GRADE LEVEL

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>34.35</td>
<td>34.35</td>
<td>5.39*</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>21.23</td>
<td>21.23</td>
<td>3.33</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender by grade</td>
<td>1</td>
<td>40.12</td>
<td>40.12</td>
<td>6.30*</td>
</tr>
<tr>
<td>Residual</td>
<td>196</td>
<td>1248.06</td>
<td>6.37</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>1337.98</td>
<td>6.72</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .02
For topic one on the celestial sphere, it may be argued that grade level has an effect on the post-test score regardless of treatment condition, but the effect of grade level for topic two on seasonal changes and topic three on lunar phases was unique to the groups manipulating an object during the instructional period. Therefore, grade level, but not gender, does influence the effectiveness of manipulative usage.

**Measurement of Ability to Answer**

**Three Question Types**

Each topic post-test contained three types of questions which were used to measure a student's gained knowledge. Recall questions sought answers which were directly stated during the planetarium presentations; application questions required the students to apply presented facts to unique, but related, situations; observation questions had answer choices pointed out in the planetarium sky. This study investigated the ability of students from both treatment groups to answer the question types.

Null hypothesis six, which stated that there is no significant difference between the results on the immediate topic recall, application, or observation questions of students using the manipulative and those not using the manipulative, was rejected due to the results of a repeated measures 2x3 analysis of variance which is summarized in Table 24. For this statistical procedure, the score totals of each question type were the repeated measures of a comparison between the two groups which experienced the unit of instruction.
### TABLE 24

A 2X3 ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON QUESTION TYPE

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>1</td>
<td>1026.51</td>
<td>1026.51</td>
<td>1.68</td>
</tr>
<tr>
<td>Within groups</td>
<td>377</td>
<td>231077.00</td>
<td>612.94</td>
<td></td>
</tr>
<tr>
<td>Question types</td>
<td>2</td>
<td>60934.25</td>
<td>30467.13</td>
<td>184.60**</td>
</tr>
<tr>
<td>Interaction (Group/Question)</td>
<td>2</td>
<td>1506.18</td>
<td>753.09</td>
<td>4.56*</td>
</tr>
<tr>
<td>Within questions</td>
<td>754</td>
<td>124446.00</td>
<td>165.05</td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .01
** Significant F, p < .001
The interaction between group and question type was found to be statistically significant at the .01 level, also the variation in ability to answer question types was found to be significant.

The interaction between group and question type is evidenced by a decline in the total percent correct from the recall to application to observation questions and by the lower mean scores of the non-manipulative group over the manipulative group. These means are shown in Table 25. As apparent from inspection of the treatment means, the main contribution to the overall significance of variance in question type answering was the deviation in the recall group; the other two question types were comparable in results. This was confirmed through a one-way analysis of variance of each of the question type scores for the two treatment groups. A summary of the results appears in Tables 26, 27, and 28, which indicate a very low probability that the variation in recall scores would be by chance. Thus, the ability to correctly answer recall questions appears to be effected by manipulative use.
TABLE 25

A DESCRIPTION OF THE SUBPOPULATION FOR THE PERCENT CORRECT OF THE QUESTION TYPES WITHIN THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT INSTRUCTION

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recall</td>
<td>14825.00</td>
<td>80.10</td>
<td>12.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group 1</td>
<td>15533.33</td>
<td>77.67</td>
<td>13.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group 1</td>
<td>12358.82</td>
<td>69.04</td>
<td>16.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td>13711.76</td>
<td>68.56</td>
<td>15.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>11199.99</td>
<td>62.57</td>
<td>26.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>12433.33</td>
<td>62.17</td>
<td>19.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>12433.33</td>
<td>62.17</td>
<td>19.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Group 1 (N = 179) Using Manipulative

Group 2 (N = 200) Not Using Manipulative
TABLE 26

A ONE-WAY ANALYSIS OF VARIANCE OF THE RECALL QUESTION SCORES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>2509.83</td>
<td>2509.83</td>
<td>15.12*</td>
</tr>
<tr>
<td>Within groups</td>
<td>377</td>
<td>62592.70</td>
<td>166.03</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>65102.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant F, p < .0001
### TABLE 27

**A ONE-WAY ANALYSIS OF VARIANCE OF THE APPLICATION QUESTION SCORES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>22.19</td>
<td>22.19</td>
<td>0.09*</td>
</tr>
<tr>
<td>Within groups</td>
<td>377</td>
<td>94735.08</td>
<td>251.29</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>94757.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Non-significant F, p > .77
TABLE 28

A ONE-WAY ANALYSIS OF VARIANCE OF THE OBSERVATION QUESTION SCORES FOR THE TWO TREATMENT GROUPS EXPERIENCING THE UNIT

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>0.29</td>
<td>0.29</td>
<td>0.00*</td>
</tr>
<tr>
<td>Within groups</td>
<td>377</td>
<td>198334.38</td>
<td>526.09</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>378</td>
<td>198334.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Non-significant F, p > .98
Summary of Findings

Experimental comparisons with fifth and eighth grade students were made between a planetarium unit of study which included concept model manipulation and an identical planetarium unit of study which excluded use of the manipulative. Measurements of knowledge retention, attitudes, preexperience impact, effectiveness on varying topics, influence of grade level and gender, and ability to answer question types, were investigated through analysis of variance procedures.

The data was supportive of difference in knowledge retention for students who used a manipulative and for students who did not use a manipulative during the planetarium lessons. The inclusion of student object manipulation improved the student's retention of learned material.

Both treatment groups exhibited a positive attitude toward astronomy education prior to and following the planetarium unit of instruction. There was no significant effect of the manipulative experience on the changing or final student attitudes.

A "mystique effect" was evidenced by examining the initial topic post-test scores of students who have and who have not had prior planetarium experiences. Students who have had planetarium lessons within three years of the first lesson of the unit, scored higher on the achievement test.

Three different topics were taught during the unit of instruction. The use of the manipulative improved the mean score of those students tested for knowledge of information from the topic of lunar phases and motions.
While gender does not appear to effect the value of concept model manipulation, grade level greatly alters the scores. Those students in fifth grade did not perform as well as eighth graders on any of the topic post-tests.

Of the three types of questions included on the post-topic tests, the use of a manipulative can improve the ability to recall presented information.
CHAPTER V
SUMMARY AND DISCUSSIONS

Research

The planetarium, a sophisticated celestial projection facility, became popularized in the late 1950's when school districts in the United States accepted the responsibility of educating people about space environment and rocket travel. The rapid increase in the number of planetariums built for educational institutions has resulted in hundreds of educators being placed in charge of coordinating and operating facilities without having any practical training or inservice education.

There has been relatively little research conducted to substantiate the value of planetariums in teaching astronomy or to identify the teaching techniques or procedures used within the chamber that would be most effective. Most studies in the 1960's and early 1970's on these topics simply reported survey findings about the managerial aspects of the planetarium such as perceived goals, topics most often presented, and director's qualifications. Research in the mid-to-late 1970's shifted to a validating process of demonstrating the worth of planetariums to astronomy education. Most recently, studies have sought to identify the various factors of instruction which can facilitate and improve learning within the planetarium chamber.

In order to provide information and guidance to those who present planetarium lectures or teach astronomy topics in the
classroom, this study made an experimental comparison with fifth and eighth grade students to measure the effectiveness of direct manipulation of an instructional object during astronomy unit presentation in the planetarium. The purpose of the experiment was to investigate the following question:

In an educational planetarium are fifth and eighth grade lessons incorporating student manipulation of a concept object or lessons without concept model manipulation the most effective method for increased achievement and attitude change?

From this initial question, six questions were created as the basis for measuring the effectiveness of manipulative use in planetarium lessons:

1. Is retention, as shown through unit post-test results, different for students using a manipulative than for those not using a manipulative?

2. Does the use or non-use of a manipulative within a planetarium unit of study effect a student's attitude toward astronomy education?

3. Does previous planetarium experience effect the immediate post-test scores of students using or not using the manipulative?

4. Is the manipulative more effective for one of the three types of lessons?

5. Does grade level or student gender influence the effectiveness of manipulative use?

6. Is the ability to correctly answer recall, application, or observation questions effected by manipulative use?
The population studied was the entire fifth and eighth grade student body (N = 542) of the three elementary schools and one middle school of Fitzgerald Public Schools in Warren, Michigan. Students were randomly assigned to three groups for treatment variation. Group 1 experienced three lessons in the planetarium, which separately included the topics of the celestial sphere and time, seasonal changes, and lunar phases and motion. While attending a lesson, group 1 students outlined location points and objects on a plastic hemisphere with a marking pencil. Group 2 students were presented exactly the same lessons as group 1 students, but instead of using the manipulative, they physically affirmed understanding by pointing out described features or locations. Group 3 experienced none of the three topic lessons in the planetarium.

To measure the achievement of group 1 and group 2 students, four valid and reliable paper-and-pencil tests were designed. Three of the tests were administered immediately after the students completed a lesson in the planetarium (topic post-tests) and the fourth test (delayed unit post-test) was given three weeks after completion of the unit to measure retention of learned material. Group 3 students were only given the delayed unit post-test. Each topic post-test contained recall questions that sought answers which were directly stated during the planetarium presentations, application questions that required the students to apply presented facts to related situations, and observation questions that had answer choices pointed out in the planetarium sky.
To measure the attitude of group 1 and group 2 students, a twenty-item paper-and-pencil opinionnaire was given before and after the unit of instruction.

The data gathered from an information form, cognitive tests, and opinionnaires was analyzed through computerized analysis of variance procedures within the Statistical Package for the Social Studies (SPSS) program.

**Conclusions**

Based on the results of testing fifth and eighth grade students within the Fitzgerald Public School District, the following conclusions have been derived:

1. Null hypothesis one must be rejected. There is a significant difference between the delayed unit post-test scores of students using the manipulative and those not using the manipulative. The inclusion of student object manipulation during a planetarium unit of instruction will improve a student's retention of learned information.

2. Null hypothesis two must be retained. Students who have experienced the planetarium lessons using the manipulative have an attitude toward astronomy education which is not significantly different from that of students not using the manipulative in excess of the unique variance due to pre- or post-treatment measurement. Both groups of students had positive attitudes toward astronomy education before and after the
3. Null hypothesis three must be rejected. There is a significant difference between the initial topic post-test scores of students having had previous planetarium experience and those of students having had no previous planetarium experience. The "mystique effect" was evidenced. If students have had orientation to the planetarium chamber, they will learn more during a planetarium lesson.

4. Null hypothesis four must be rejected. There is a significant difference between the immediate topic post-test results of students using the manipulative and those not using the manipulative within the different lesson topics. The opportunity for concept object manipulation most improves a student's understanding of lunar phases and motion.

5. Null hypothesis five must be rejected. The topic post-test scores of students using the manipulative do significantly vary among grade level groups. Eighth grade students learned more than fifth grade students in each of the three lessons including concept model manipulation. The classification variable of student gender demonstrated no difference in learning ability.

6. Null hypothesis six must be rejected. There is significant difference between the results of recall, application, or observation questions of
students using the manipulative and those not using the manipulative. Students using a manipulative are better able to recall presented information than students who only physically affirm knowledge in the planetarium. Concept object manipulators demonstrate a slightly improved ability to apply presented knowledge and to observe astronomical locations.

7. Most generally, it may be concluded that planetarium instruction which included the opportunity for student drawing on a plastic hemisphere was clearly more effective in teaching about the celestial sphere and time, seasonal changes, and lunar phases and motion.

Discussion

Much of the earlier research involving planetariums attempted to validate the effectiveness of these educational facilities over classroom/lecture presentations. Even if the results had not been so contradictory, such studies would have given little assistance to individuals who seek to improve astronomy lessons. As T. Smith (1974) noted, research was needed to provide those who present planetarium lectures or teach astronomy concepts in the classroom with an understanding of the effectiveness of various methods of instruction. This study attempted to fulfill such a need by demonstrating the validity of using hands-on, concept model manipulation in astronomy lessons. The conclusions presented in the previous section are consistent with the ideas of Piaget (1964),
Suchman (1960), and Bruner (1965) who advocated the importance of direct manipulation of concrete objects in the development of learning in children. Even a recent planetarium study by Bishop (1980) had postulated that students having lessons in the planetarium require more concrete experience for knowledge attainment.

Unlike the study presented here, most of the recent within-planetarium research failed to reach conclusive results about the value of experimental conditions. Smith (1974) and Etheridge (1976) could not substantiate designs for improved visual presentations, and the results of Malloni (1980), Friedman (1974), in favor of participatory lessons over the traditional lecture method in improving content achievement, could not be validated by Cottrill (1976), Fletcher (1977), or Bishop (1980). These studies were valuable to this research, however, since they helped to isolate the variables which were either controlled or explored within this manipulative study.

As noted earlier, this study avoided the participatory versus traditional lesson controversy by presenting lessons to both the experimental and control groups which had the participatory format of utilizing an activity (drawing on the plastic hemisphere versus physical pointing) and extensive verbal interaction. The teacher effect reported by Fletcher (1977) and Giles (1981) was controlled by the researcher presenting the entire unit of instruction to all students. The variables of grade, gender, attitude, and previous planetarium experience were considered as part of the result analysis.
The results which concluded that the eighth grade students who used the manipulative demonstrated more learning than the fifth graders who used the manipulative, may have been predicted by many educators. One could argue that the older students were more experienced with paper-and-pencil tests or they were at a more "formal operational" stage of development. However, these suggestions would not explain the lack of differentiation for those students who did not have the opportunity to draw on the plastic hemisphere. Since the fifth grade manipulative group was still more successful in answering the test questions than the fifth grade non-manipulative group, it might be inferred that working with the concept model was slightly distracting to, but still effective for, the younger students.

The "perceived masculinity hypothesis" noted by Bishop (1980) was not evidenced by this study. Males and females demonstrated no significant variation in test scores for any of the three topics within the unit of instruction. This contradicts studies such as Rosemergy's (1967) which found that sixth grade boys had greater understanding than girls of phases of the moon, or DeRoche's (1966) space science achievement favoring the males. Even the attitude measurements of this study did not show a gender differentiation as did Shrigley (1972), who discovered a sex difference in attitude with males rating much higher.

This research cannot support the findings of Ridky (1973) which proposed that the effectiveness of the planetarium does not lie in facilitating content achievement as much as...
effecting attitudinal change. In general, all subgroups of students in this study started and concluded the unit of instruction with a positive attitude. The results presented are more similar to those of Griffin (1978), Reed (1973), and Bishop (1980).

The findings of this study are most in agreement with the many reports which indicate that there is an initial sense of awe experienced during the very first attendance of a planetarium lesson. This so called "mystique effect" lessened the achievement of the students who had no previous planetarium exposure. Supportive of such a need for pre-visit orientation are Akey (1973), Ridky (1975), Sunal (1976), Davis (1978), and Bisard (1979). Other studies have shown that even a very brief slide presentation, which explains the functioning of the planetarium machine, can improve student achievement.

Through consideration of and control for such variables as grade level, gender, attitude, and previous planetarium experience, this experimental study has demonstrated that lessons incorporating an opportunity for student model manipulation significantly improve student internalization and retention of presented material.

**Recommendations**

The data of this experimental study and its analysis indicate that lessons in an educational planetarium for fifth and eighth graders should incorporate student manipulation of a concept object for increased achievement. Though the opportunity to mark on a plastic hemisphere maintained greater retention of learned material, there have been limitations and
uncertainties in this research which suggest the following possibilities for future research:

1. Similar research studies should investigate the impact of manipulative usage on various age groups of students.

2. A study should be designed to seek reasons why there was grade differentiation in achievement among students using the manipulative and not for students who lacked the opportunity for concept model manipulation.

3. Topics other than celestial sphere and time, seasonal changes, and lunar phases and motion should be used to confirm the value of hands-on activities.

4. The sequence of topic presentation should be varied in a study to understand if it was the order or nature of the three topics which resulted in significant differences in information gain.

5. Classroom astronomy lessons which incorporate the use of a plastic hemisphere manipulative should be studied to test the validity of such a teaching methodology for increased achievement and attitude.

6. Various types and durations of orientation sessions should be investigated to identify the conditions necessary for the elimination of the first-visit "mystique effect".
APPENDIX A

INFORMATION FORM
Hi!

Mr. Edoff would like to know a little about you before you come to the planetarium. Please print in the spaces below:

Your Name: ___________________________ First Last

You are a (Check one) Boy Girl

How old are you? ________Years

On what date were you born? __________ Month __________ Day __________ Year

What grade are you in? (Circle one) 4 5 6 7 8

What is the name of your school? (Circle one)

Westview Schofield Mound Park Chatterton

What is the name of the teacher you have for science?

How do you feel about science classes? (Circle one)

like them very much like them don't know don't like them really don't like them

Have you had lessons in the planetarium before? ___Yes ___No

IF YOUR ANSWER WAS YES, PLEASE ANSWER EACH QUESTION BELOW:

How long since your last visit to the planetarium? (Circle one)

one month half year year more than a year

How many times have you visited the planetarium for lessons? (Circle one) 1 2 3 4 5 or more

You think the planetarium lessons were (Circle one)

very good good O.K. poor very poor

Write one thing you learned during your last planetarium visit:

________________________________________________________________________________________
TOPIC TEST 1

Name: (please print) ________________
First ____________________ Last ____________________

Grade: (circle one) 4 5 6 7 8
School: (circle one) Westview Schofield
Mound Park Chatterton

THIS IS A SHORT TEST ABOUT TODAY'S PLANETARIUM LESSON. AFTER EACH QUESTION IS READ, PLEASE CIRCLE THE BEST ANSWER FROM THE CHOICES GIVEN.

1. The point directly over your head is called the
   A. horizon   B. planetarium   C. zenith   D. nadir

2. The place where sky and land seem to meet is called the
   A. meridian   B. horizon   C. zenith   D. nadir

3. The words "ante meridian" stand for time in the
   A. morning   B. afternoon   C. evening   D. planetarium

4. The sun seems to rise up in the direction
   A. north   B. east   C. south   D. west

5. When the sun is at its highest point it is in this direction
   A. north   B. east   C. south   D. west

6. The sun seems to move across the sky because the earth
   A. revolves   B. doesn't move   C. rotates   D. rises

7. A pretend line in the sky which goes from north to overhead to south is the
   A. horizon   B. equator   C. ecliptic   D. meridian

8. Which of the following drawings is shaped like the way space looks to us?
   A. □   B. ∮   C. ○   D. ___
9. The pretend ball of stars going about the earth is called
   A. post  B. celestial  C. celestial  D. globe
   meridian  equator  sphere

10. If we are looking north, which arrow points toward west?
   A.  B.  C.  D.

   USE THIS DRAWING OF THE SKY FOR QUESTIONS 11 TO 13

11. Which number shows the place of the sun at 11 a.m.?
   A. 1  B. 2  C. 3  D. 4

12. Which number shows the place of the sun in early morning?
   A. 1  B. 2  C. 3  D. 4

13. Which number shows the place of the sun shortly after noon?
   A. 1  B. 2  C. 3  D. 4

14. In which direction does the earth spin?
   A. west to  B. north to  C. north to  D. west to
   north  south  east  east

   FOR THE LAST THREE QUESTIONS, PLACES WILL BE POINTED OUT
   IN THE PLANETARIUM.

15. The arrow is showing the
   A. zenith  B. equator  C. meridian  D. horizon

16. The arrow is drawing the
   A. zenith  B. equator  C. meridian  D. horizon

17. The arrow is pointing to the planetarium direction
   A. north  B. east  C. south  D. west
TOPIC TEST 2

Name: (please print) ___________________________ First ___________ Last ___________

Grade: (circle one) 4 5 6 7 8

School: (circle one) Westview Schofield
Mound Park Chatterton

THIS IS A SHORT TEST ABOUT TODAY'S PLANETARIUM LESSON. AFTER EACH QUESTION IS READ, PLEASE CIRCLE THE BEST ANSWER FROM THE CHOICES GIVEN.

18. A pretend line in the sky which is the "path of the sun"
   A. horizon B. ecliptic C. meridian D. equator

19. Stars appear to move upward in the direction
   A. north B. east C. west D. south

20. Stars appear to move in a circle pattern in the direction
   A. north B. east C. west D. south

21. The earth is tilted this many degrees
   A. 23½ B. 32½ C. 90 D. 45

22. If the earth did not rotate (spin), the sun would
   A. get bigger night and the north bright day
   B. not cause C. set in D. not be

23. Which of the following is not a reason for seasons?
   A. tilt of earth B. angle of sun light C. distance to sun D. revolution of earth

24. The sun appears to rise (go up) in this direction on the first day of spring
   A. north B. east C. south D. west

25. The sun appears to rise (go up) in this direction on the first day of winter
   A. north east B. south west C. south east D. west
26. The light we get from the sun in the **summer** has this kind of rays
   A. slow  B. indirect  C. dark  D. direct

27. On any day of the year the sun at midday is in the direction
   A. north  B. east  C. south  D. west

USE THIS DRAWING OF THE PATH OF THE SUN FOR DIFFERENT SEASONS FOR QUESTIONS 28 TO 30

28. Which letter shows the path of the sun on the first day of winter?
   A. a  B. b  C. c  D. d

29. Which letter shows the path of the sun on the first day of fall?
   A. a  B. b  C. c  D. d

30. Letter "c" shows the path of the sun for the first day of
   A. winter  B. summer  C. fall  D. spring

31. If the ecliptic line is high in the sky at midday, the season must be
   A. winter  B. summer  C. fall  D. spring

FOR THE LAST THREE QUESTIONS, PLACES WILL BE POINTED OUT IN THE PLANETARIUM.

32. The sun would appear to set (go down) here on the first day of
   A. winter  B. summer  C. fall  D. spring

33. The sun would appear to rise (come up) here on the first day of
   A. winter  B. summer  C. fall  D. spring

34. The sun would appear to set (go down) here on the first day of
   A. winter  B. summer  C. fall  D. spring
TOPIC TEST 3

Name: (please print) ___________________________ First | Last ___________________________

Grade: (circle one) 4 5 6 7 8

School: (circle one) Westview Schofield
Mound Park Chatterton

THIS IS A SHORT TEST ABOUT TODAY'S PLANETARIUM LESSON. AFTER EACH QUESTION IS READ, PLEASE CIRCLE THE BEST ANSWER FROM THE CHOICES GIVEN.

35. The north circumpolar constellation that helps us find the ecliptic is
   A. Ursa Major  B. Ursa Minor  C. Cephus  D. Draco

36. How many degrees is the ecliptic from that north circumpolar constellation?
   A. 9  B. 180  C. 90  D. 23 ½

37. A point where moon crosses the ecliptic is called a
   A. zenith  B. node  C. nadir  D. horizon

38. How many times in a month does the moon cross the ecliptic?
   A. 2  B. 3  C. 4  D. 0

39. An eclipse of the moon would take place if the moon is on the ecliptic and is in this position around the earth. (Pick one letter):

   \[ \text{Sun} \quad a \quad \text{Earth} \quad b \quad d \]

40. The moon changes how far it is from the earth. If it were at the greatest distance during its eclipse, the moon would be:
   A. all dark  B. part dark  C. bright  D. not moving

41. The moon revolves around the earth about once a
   A. season  B. month  C. year  D. day
42. The ecliptic line goes through these constellations
   A. Zodiac    B. North    C. South    D. Equator
   Circumpolar  Circumpolar

43. The moon appears to move "backward" (from E to W) this many degrees per day
   A. 1         B. 13       C. 23½     D. 90

USE THESE DRAWINGS OF PHASES OF THE MOON TO ANSWER QUESTIONS 44 TO 47

44. Which phase is an early crescent?
   A. a         B. b        C. c       D. d

45. Which phase is a last quarter?
   A. a         B. b        C. c       D. c

46. Which phase could you see just before the sun rises in the morning?
   A. a         B. b        C. c       D. d

47. Which phase would appear 90° to the left (←) of the sun?
   A. a         B. b        C. c       D. d

FOR THE LAST THREE QUESTIONS, PLACES WILL BE POINTED OUT IN THE PLANETARIUM.

48. If the sun is at midday and the moon appears here, the phase would be
   A. first      B. last     C. early    D. late crescent
   quarter     quarter       crescent

49. If the sun is at midday and the moon appears here, the phase would be
   A. first      B. last     C. early    D. late crescent
   quarter     quarter       crescent

50. If the sun is at midday and the moon appears here, the phase would be
   A. first      B. last     C. early    D. late crescent
   quarter     quarter       crescent
UNIT TEST

Name: (please print) ____________________________  First  ____________________________  Last  ____________________________

Grade: (circle one) 4  5  6  7  8
School: (circle one) Westview  Schofield
        Mound Park  Chatterton

THIS IS A RETEST ABOUT YOUR LAST THREE PLANETARIUM LESSONS.
AFTER EACH QUESTION IS READ, PLEASE CIRCLE THE BEST ANSWER
FROM THE CHOICES GIVEN.

1. The point directly over your head is called the
   A. horizon  B. planetarium  C. zenith  D. nadir

2. The place where sky and land seem to meet is called the
   A. meridian  B. horizon  C. zenith  D. nadir

3. The words "ante meridian" stand for time in the
   A. morning  B. afternoon  C. evening  D. planetarium

4. The sun seems to rise up in the direction
   A. north  B. east  C. south  D. west

5. When the sun is at its highest point it is in this direction
   A. north  B. east  C. south  D. west

6. The sun seems to move across the sky because the earth
   A. revolves  B. doesn't  C. rotates  D. rises
       work

7. A pretend line in the sky which goes from north to overhead
   to south is the
   A. horizon  B. equator  C. ecliptic  D. meridian

8. Which of the following drawings is shaped like the way
   space looks to us?
   A.  B.  C.  D. ———
UNIT TEST
Page Two

9. The pretend ball of stars going about the earth is called the
   A. post     B. celestial   C. celestial   D. globe
   meridian    equator      sphere

10. If you are looking north, which arrow points toward west?
    A. ←   B. ↓   C. ↑   D. →

USE THIS DRAWING OF THE SKY FOR QUESTIONS 11 TO 13

11. Which number shows the place of the sun at 11 a.m.?
    A. 1     B. 2     C. 3     D. 4

12. Which number shows the place of the sun in the early morning?
    A. 1     B. 2     C. 3     D. 4

13. Which number shows the place of the sun shortly after noon?
    A. 1     B. 2     C. 3     D. 4

14. In which direction does the earth spin?
    A. west to B. north to C. north to D. west to
       north south east east

THIS TEST WILL NOT USE NUMBERS 15, 16, 17

18. A pretend line in the sky which is the "path of the sun"
    A. horizon B. ecliptic C. meridian D. equator

19. Stars appear to move upward in the direction
    A. north   B. east    C. west    D. south

20. Stars appear to move in a circle pattern in the direction
    A. north   B. east    C. west    D. south
UNIT TEST
Page Three

21. The earth is tilted this many degrees
   A. 23½   B. 32½   C. 90   D. 45

22. If the earth did not rotate (spin), the sun would
   A. get   B. not cause   C. set in   D. not be bigger night and the north bright day

23. Which of the following is not a reason for seasons?
   A. tilt of earth   B. angle of sun   C. distance to sun   D. revolution of earth

24. The sun appears to rise (go up) in this direction on the first day of spring
   A. north   B. east   C. south   D. west

25. The sun appears to rise (go up) in this direction on the first day of winter
   A. north east   B. south west   C. south east   D. west

26. The light we get from the sun in the summer has this kind of rays
   A. slow   B. indirect   C. dark   D. direct

27. On any day of the year the sun at midday is in the direction
   A. north   B. east   C. south   D. west

USE THIS DRAWING OF THE PATH OF THE SUN FOR DIFFERENT SEASONS FOR QUESTIONS 28 TO 30

28. Which letter shows the path of the sun on the first day of winter?
   A. a   B. b   C. c   D. d

29. Which letter shows the path of the sun on the first day of fall?
   A. a   B. b   C. c   D. d
UNIT TEST
Page Four

30. Letter "c" shows the path of the sun for the first day of
   A. winter  B. summer  C. fall  D. spring

31. If the ecliptic line is high in the sky at midday, the season must be
   A. winter  B. summer  C. fall  D. spring

THIS TEST WILL NOT USE NUMBERS 32, 33, 34

35. The north circumpolar constellation that helps us find the ecliptic is
   A. Ursa Major  B. Ursa Minor  C. Cephus  D. Draco

36. How many degrees is the ecliptic from that north circumpolar constellation?
   A. 9  B. 180  C. 90  D. 23½

37. A point where the moon crosses the ecliptic is called a
   A. zenith  B. node  C. nadir  D. horizon

38. How many times in a month does the moon cross the ecliptic?
   A. 2  B. 3  C. 4  D. 0

39. An eclipse of the moon would take place if the moon is on the ecliptic and is in this position around the earth. (pick one letter):
   \[ \text{Sun} \quad a \quad \text{Earth} \quad d \quad b \]

40. The moon changes how far it is from the earth. If it were at the greatest distance during its eclipse, the moon would be
   A. all dark  B. part dark  C. bright  D. not moving

41. The moon revolves around the earth about once a
   A. season  B. month  C. year  D. day
UNIT TEST
Page Five

42. The ecliptic line goes through these constellations
   A. Zodiac  B. North  C. South  D. equator
   Circumpolar  Circumpolar

43. The moon appears to move "backward" (from E to W) this many degrees per day
   A. 1  B. 13  C. 23  D. 90

USE THESE DRAWINGS FOR ANSWERS TO QUESTIONS 44 TO 47

44. Which phase is an early crescent?
   A. a  B. b  C. c  D. d

45. Which phase is a last quarter?
   A. a  B. b  C. c  D. d

46. Which phase could you see just before the sun rises in the morning?
   A. a  B. b  C. c  D. d

47. Which phase would appear 90° to the left ( ) of the sun?
   A. a  B. b  C. c  D. d
APPENDIX C

OPINIONNAIRE
ASTRONOMY OPINIONNAIRE

Your Name: ____________________________ First ____________________________ Last

Please check the answer that most agrees with how you feel about science astronomy lessons. Answer how you really feel and not how you think you should feel; you will not be graded on this.

| 1. Reading astronomy is difficult.              | STRONGLY AGREE | AGREE | DON'T KNOW | DISAGREE | STRONGLY DISAGREE |
| 2. We spend too much time doing experiments.   |               |      |            |          |                   |
| 3. I am learning a lot in astronomy this year |               |      |            |          |                   |
| 4. What we do in the planetarium is what a real astronomer would do. |               |      |            |          |                   |
| 5. In the planetarium we study important things. |               |      |            |          |                   |
| 6. I dislike coming to the planetarium.        |               |      |            |          |                   |
| 7. I read more astronomy materials than I did before this year. |               |      |            |          |                   |
| 8. I enjoy doing the astronomy experiments.    |               |      |            |          |                   |
| 9. I can solve problems better than before.    |               |      |            |          |                   |
| 10. My friends enjoy doing astronomy experiments. |               |      |            |          |                   |
| 11. What I am learning in astronomy will be useful to me outside school. |               |      |            |          |                   |
| 12. I think about things we learn in the planetarium when I am not in school. |               |      |            |          |                   |
13. I do not want to take any more astronomy classes than I have to take.

14. Reading astronomy is more fun than it used to be.

15. Experiments are hard to understand.

16. Astronomy is dull for most people.

17. The things we do in the planetarium are useless.

18. The kinds of experiments I do in the planetarium are important.

19. I learn a lot from doing my astronomy experiments.

20. Most people like planetarium lessons.

21. Finish this sentence any way you wish. Write on this paper.

I think the planetarium ________________________________
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AN EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF MANIPULATIVE USE IN PLANETARIUM ASTRONOMY LESSONS FOR FIFTH AND EIGHTH GRADE STUDENTS

by

JAMES D. EDOFF

December, 1982

Adviser: E. Brooks Smith
Major: Curriculum and Instruction
Degree: Doctor of Education

The purpose of this investigation was to conduct an experimental comparison between one planetarium unit of study which included direct manipulation and one which excluded direct manipulation of an instructional object to discover which method was most effective for increasing achievement and attitude change among fifth and eighth grade students.

The population studied was the entire fifth and eighth grade student body (N=542) of Fitzgerald Public Schools in Warren, Michigan. Students were randomly assigned to sections of three groups for treatment variation. Group I experienced three lessons in the planetarium, which separately included the topics of the celestial sphere and time, seasonal changes, and lunar phases and motion. While attending a lesson, group I students outlined location points and objects on a plastic hemisphere with a marking pencil. Group II students were presented exactly the same lessons as group I students, but instead of using the manipulative, they physically affirmed
understanding by pointing out described features or locations. Group III experienced none of the three topic lessons in the planetarium.

Three topic post-tests were administered immediately after the students completed lessons in the planetarium, and a delayed unit post-test was given three weeks after completion of the unit to measure retention of learned material. Each topic post-test contained recall, application, and observation questions. To measure the attitude of group I and group II students, a twenty item opinionnaire was given before and after the unit of instruction.

Analysis of variance procedures which considered the variables of previous experience, manipulative opportunity, grade, and gender rejected five of the six null hypotheses and the following conclusions were realized:

1. The inclusion of student object manipulation during a planetarium unit of instruction will improve a student's retention of learned information and understanding of lunar phases and motion.

2. Among the students in this investigation, attitude toward astronomy was not significantly altered, and grade levels, not gender, demonstrated differences in learning ability.

3. If students have had orientation to the planetarium chamber, they will learn more during a planetarium lesson.

4. Students using a manipulative were better able to recall presented information and had a slightly improved ability to apply presented knowledge and to observe astronomical locations.
AUTOBIOGRAPHICAL STATEMENT
Personal Data
Born July 22, 1947, Detroit, Michigan
Married to Guri Lynn Chambers, August 16, 1969
Two children: Erik, age 7, and Heather, age 3
Resident of Troy, Michigan

Education
Highest honors, Kimball High School, Royal Oak, Michigan
B.A. cum laude, Kalamazoo College, 1969
M. Ed. of Educational Leadership, Wayne State University, 1978
Ed. Spec. in Curriculum Development, Wayne State University, 1980

Employment
1969-to-date
Science teacher, Fitzgerald Public Schools, Warren, Michigan
1970-to-date
Planetarium Director, Fitzgerald Public Schools, Warren, Michigan
1978-1981
Consultant, Macomb Intermediate School District
1979-to-date
Chairman, Michigan Junior Academy of Science, Arts, and Letters

Professional Organizations
Great Lakes and International Planetarium Associations
Phi Beta Kappa
National and Michigan Science Teachers Association
Michigan Academy of Science, Arts, and Letters
Fitzgerald, Michigan, and National Education Associations