# THE COMPARATIVE EFFECTIVENESS OF INDIVIDUALLY PRESCRIBED INSTRUCTION AND THE LECTURE DEMONSTRATION METHOD TO ACHIEVE BEHAVIORAL OBJECTIVES FOR A DESCRIPTIVE ASTRONOMY COURSE

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Submitted to the Faculty of the Graduate College
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in partial fulfillment of the requirements
for the Degree of
DOCTOR OF EDUCATION
July, 1971

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COURSE

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## ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Dr. Kenneth Wiggins, Chairman of his doctoral committee, for his personal concern toward the writer's total educational effort and for his direction of this study. His ability to sense student problems, his warmth, and his constant encouragement have been most helpful.

Gratitude is also expressed to Dr. Leon Schroeder who so patiently and skillfully served as a co-teacher and advisor during the development and execution of the IPI course in Elementary Astronomy. Through his counsel the course was strengthened both during its construction and again during its operation.

Additional thanks must go to Dr. Kenneth McCollom, Dr. Thomas Johnsten, and Dr. Jack Allison, members of the writer's doctoral committee, for their assistance and criticism from the viewpoints of their particular areas of expertise. With their help, this study has become a highly valued learning experience.

A loving thank you is hereby expressed to the writer's parents, Mr. and Mrs. Henry B. Oines, for their assistance in areas too numerous to mention. From the beginning, their encouragement has made this effort much easier.

Finally, the greatest thanks must go to the writer's family, his wife Beverly, his sons Douglas, Bryon, and Leif, and his daughters Sonja and Kristin. Without their support and personal sacrifices, this work

would not have been possible. To them goes the promise, "Dad will be home more in the future."

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# CHAPTER I

## INTRODUCTION

Traditionally, astronomy was included in the quadrivium, which combined with the trivium made up the seven liberal arts of the medival colleges and universities. Astronomy has persisted as a part of the undergraduate curriculum. While few colleges or universities offer an undergraduate degree in the subject, astronomy is taught at many institutions in this country as a part of the general science education still required of most students at the undergraduate level.

In past decades astronomy was often taught as a course in applied mathematics. Events in the last decade have changed the complexion of all sciences including astronomy. As a result, today astronomy is most often found within the physics department. The introductory astronomy course surveys the entire spectrum of physical laws which govern the universe as they pertain to astronomy.

The typical college student who enrolls in an introductory course in astronomy is probably very interested in learning more about the subject. At the same time, this student is probably enrolling to fulfill a curriculum requirement in physical science. It therefore behooves those who teach introductory astronomy to make the best use of the opportunity to communicate to students outside the fields of science and mathematics how astronomers and other scientists work in an attempt to discover the natural laws on which all science is based.

## Background for the Study

This study has two goals. The first was to develop a system of individually prescribed instruction (IPI) for an elementary astronomy course based on a set of terminal behavioral objectives describing the behavior that was desired of all students at the completion of the course. The course was to be designed principally for nonscience-non-mathematics majors at the freshman or sophomore level of college. This course was to be designed so that it would be capable of affecting the same gain in knowledge of astronomy as a standard lecture-demonstration course and at the same time retain or increase the positive attitudes that students had toward the subject of astronomy.

The second goal of this study was to evaluate the self-paced individually prescribed instruction system with respect to its ability to affect the growth in knowledge of astronomy and the maintenance of positive attitudes toward astronomy as described above, when compared to the lecture-demonstration method of teaching.

The use of behavioral objectives to define the outcome of the teaching-learning process has moved to the foreground as a result of the application of the systems approach (IPI) to this process. Kurtz (25), Stewart (41), and Walbesser (43) describe the integral role of behavioral objectives in learning systems, pointing out that in the absence of clearly defined objectives the teaching-learning process can only be evaluated in subjective terms. A system which incorporates clearly defined objectives provides a means of evaluating the outcomes of teaching practices, techniques, methods, etc. Such a system can by definition be adjusted to each learner to provide optimum learning situations for that learner.

It is the ability of an IPI system to adapt to a broad spectrum of learner differences that is its real strength. If two learners can, given the same behavioral objectives as the goal of their learning, achieve the objectives of the learning process by two very different means, then the individual differences inherent in all individuals can theoretically be accomodated. By allowing each learner to pursue the learning goals by employing the methods which are most suitable to his own interests, abilities, and desires, the teaching-learning process could be made more effective according to Stewart (41), Eiss (10), Kurtz (25), and Harrisberger (21).

The application of this philosophy to a general education course of an introductory nature seems particularly pertinent because of the broad spectrum of students which characteristically enroll for these courses.

## Statement of the Problem

The present study will compare a self-paced individually prescribed instructional system with the lecture-demonstration method for achieving behavioral objectives in elementary astronomy (cognitive effect), and compare the changes in student's attitudes toward astronomy (affective response) in each of these two groups.

This study will also examine the possible relationships between certain characteristics the students bring with them to the course and their ability to learn within each method when measured by their gain in knowledge of astronomy (cognitive effect).

## Significance of the Study

Stewart (41) discusses the need to change the present patterns of instruction. He states, "Educators must investigate ways of making our educational process more efficient and effective. Changes must be made in existing educational patterns."

Lindvall and Bolvin (26) alert those who would confuse priorities:

> . . .The goal of a structured program such as IPI is not to put a pupil in an efficient system. The system is only a means to a goal. The goal is to have each pupil operating as a self-directed learner within an individualized instructional program. The system is only one major factor in permitting the achievement of the goal.

The use of IPI systems for instruction then, may provide a means for more efficient and effective instruction. The major goal of new instructional systems should be to increase their effectiveness, and if in addition to being more effective they are also more efficient, so much the better.

Eiss (10) feels that the time has come to act when he states:

> What we need today is more action and less theorizing. True, we need to expand what is known about learning theory and psychological foundations for education. But we are far from utilizing our <u>present</u> knowledge effectively.

Studies of the effectiveness of self-paced individually prescribed instruction at the college and university level are very rare, or nonexistent. The present study may provide some evidence of the effectiveness of IPI when compared to lecture-demonstration method for achieving behavioral objectives and at the same time may provide some evidence for the effect each method has on student's attitudes toward the subject matter they are learning.

If significant differences between the methods, in the attitudes of the students, or in the interactions of certain student characteristics with the methods are found, this study may point out new directions for further study and refinement of later systems utilizing IPI or other new teaching methods.

## Limitations of the Study

This study was limited to those students who were enrolled in Astronomy 1104 during the spring semester of 1971 at Oklahoma State University. Both the experimental and the control sections had a somewhat lower enrollment than was previously expected; thus, reducing the size of the sample. In addition, the number of students which enrolled in each of the two sections was not equal; thus, further limiting flexibility in the statistic analysis of the results.

## Definition of Selected Terms

### Knowledge

Knowledge, in measured form, will be defined as a student's ability to perform assessment tasks which are described by behavioral objectives that have been developed for Astronomy 1104 at Oklahoma State University.

### Gain in Knowledge

The gain in knowledge of astronomy will be the difference between the pre-test and post-test scores. Both the pre-test and post-test will consist of assessment tasks based on the terminal objectives that were developed for the course.

Cognitive Effect

The cognitive effect will be synonomous with gain in knowledge.

Attitude

Attitudes are feelings or opinions rather than knowledge, and in this study will be measured by the score a student makes on an author constructed attitude scale of the Likert type as described by Edwards (9).

Affective Effect

The affective effect will be the difference in the pre-attitude score and the post-attitude score measured by the attitude scale described above.

LD Group

The students in the section taught by the lecture-demonstration (LD) method.

IPI Group

The students in the section taught by the self-paced individually prescribed instruction (IPI) method.

Lecture-Demonstration (LD)

Lecture-demonstration is defined as the method of teaching which consists of lectures and demonstrations employing appropriate equipment, models, and media to teach an introductory astronomy course. The instructor spends the majority of his time lecturing to a group of students who meet in a prescribed room at a prescribed hour several times each week. Tests are scheduled in advance for the purpose of evaluating the student's progress in the course.

<u>Individually Prescribed Instruction (IPI)</u>

Individually prescribed instruction is defined as a self-paced method of independent study based on behavioral objectives. Each student will generally work independently of the others with materials that have either been provided or suggested by the instructor(s) for the purpose of achieving the behavioral objectives that have been set down for the introductory astronomy course. A student will come to a prescribed meeting place when he needs assistance with his studies, or when he wishes to be evaluated on a unit of material.

<u>Behavioral Objective</u>

A behavioral objective is a statement of the behavior that a learner will exhibit when he has achieved that objective. Each behavioral objective will have the following six elements either clearly stated or implied:

1. The person who is to exhibit the behavior.
2. The observable performance (action) that the learner is expected to exhibit.
3. The conditions, objects, and information that will be given before the learner exhibits the desired behavior.
4. Who or what initiates the performance of the behavior of the learner.
5. The behavioral responses of the learner that will be acceptable.
6. Any special restrictions that are going to be imposed

on an acceptable response by the learner, i.e., time limitations.

## Learning Objectives

Learning objective is synonomous with behavioral objective.

## Instructional Objective

Instructional objective is synonomous with behavioral objective.

## Entry Level Behavior

Entry level behavior is defined as those behavioral objectives which the learner is capable of achieving at the time he begins the course.

## Terminal Objective

A terminal objective is a behavioral objective that has been established as desirable for all students finishing the course to be capable of achieving. A set of terminal objectives comprise the total final desired outcomes of the course for each student in that course.

## Assessment Task

An assessment task is an activity that the student is asked to perform to demonstrate that his behavioral response satisfies the response defined by a behavioral objective. The successful performance of an assessment task demonstrates that the learner has achieved the goal of the behavioral objective.

## Basic Assumptions

This study assumes that a pre-test post-test consisting of assessment tasks based on pre-determined terminal objectives is an adequate measure of the knowledge gained in astronomy by the students during the semester.

The study also assumes that any changes in attitude toward astronomy can be measured by a pre-attitude post-attitude scale of the Likert type.

Further, this study assumes that both the LD and IPI sections were attempting to achieve the same terminal objectives throughout the semester as determined prior to the beginning of that semester.

# CHAPTER II

# REVIEW OF THE LITERATURE

## The Changing Nature of Instruction

That instruction at the college level is about to change was emphasized by Mitzel (32) in The Impending Instructional Revolution when he said:

> The last three decades of the Twentieth Century will witness a drastic change in the business of providing instruction in schools and colleges. The idea of "Individualized Instruction" has been pursued in a desultory fashion by American educators for most of the century. There have been several different concepts of individualization, the most prevalent interpretation focusing on self-pacing or rate-tailoring. The impending Instruction Revolution will shortly bypass the simplex idea of individualizing instruction and move ahead to the more sophisticated notion of providing "Adaptive Instruction" for school and college learners, with focus on the tailoring of subject matter presentations to fit the special requirements and capabilities of each learner.

This change in the instructional pattern of schools and colleges is the result of two main forces. The first of these is the adaptation of technology to the problems of learners. Gagne (15), Callow (6), Wash (45), and Becker (2) address themselves to the role of the multimedia and computer influences on the learning processes. Words and phrases such as "Individually Prescribed Instruction," "The Automated Learning Management System," "Computer Assisted Instruction," and "The Interactive System" are now becoming more commonplace in educational circles, a recognition of the potential value that computers and other machines have in enhancing the learning process.

The second main force is the advance in the understanding of how individuals learn and under what conditions they learn. The work of men such as Gagne (13), Bloom (3), Markle and Tiemann (29), has led to new concepts in learning. The concept that learning should produce a visible change in the behavior of the individual has led to the idea of using "Behavioral Objectives" as definable and achievable goals for learners. If the desired learning can be stated in terms of the behavior that a learner will exhibit as the result of his learning, then several of the previously troublesome problems of instruction and learning disappear. These include the problem of what to teach, how to teach it, and how to evaluate the learner to see if he has learned what was being taught. Kurtz (25), Gagne (14), Walbesser (44), Mager (28), Eiss (10), and Wash (45) all discuss the various advantages of putting the final outcomes of teaching, i.e., learning, into behavioral terms to gain the advantages stated above. They point out that in the absence of observable behavioral changes which can be precisely defined in advance, the process of instruction becomes a matter of chance involving the use of subjective evaluation, with the end result that it can only be estimated what the learner has achieved in terms of learning.

Once clearly defined objectives become the goal of instruction, it is possible to determine whether those goals have been achieved by every learner who attempts to achieve them. If the learner fails to reach a goal, it is possible to continue the instructional process using various learning activities until the learner can demonstrate in a behavioral way that he has indeed reached the learning objective.

When a body of knowledge which is to be transferred to a learner has been stated in terms of behavioral objectives, these objectives can be ordered into a hierarchy of learning. Gagne and Paradise (13), Stewart (41), and Okey (35), discuss the need to order the objectives into a sequence which presupposes that some knowledge is required before a learner can acquire new knowledge which follows. Evidence that this concept has been recognized for some time is the fact that some courses have prerequisite course requirements attached to them. To facilitate an understanding of such hierarchies, Bloom (3) classified the levels of cognitive knowledge in _Taxonomy of Educational Objectives, Handbook I: Cognitive Domain_. With the aid of this taxonomy, and a knowledge of the subject matter to be transmitted, a learning hierarchy can be established to determine the order in which each of the educational objectives is presented to the learner.

## Developing an IPI Course

Lindvall and Cox (27) point out that all teachers are aware of the individual differences of the students in their classes. In an effort to accomodate these individual differences, it is necessary to develop instruction in a manner that includes the following elements:

1. Sequences of instructional objectives to define the curriculum (course).
2. Instructional materials to teach each objective.
3. An evaluation procedure for placing each pupil at the appropriate point in the curriculum (course).
4. A plan for developing individualized programs of study.
5. A procedure for evaluating and monitoring individual progress.

Stewart (41) states, "Course development involves two major states: (1) the behavioral analysis of the course content which is the preconstruction stage; and (2) the synthesis of learner behaviors which is the construction stage." He sees the task of the first stage as that of specifying learner behaviors and learning objectives so that the nature of the behavior can be discovered, past learning can be assessed, the behaviors to be modified can be identified, and the objectives can be communicated.

Stewart (41) sets a sequence of seven steps to be followed in the first stage. They are:

1. The first step in the analysis is the specification of the terminal behaviors (i.e., those behaviors which the course instructor wishes the learner to exhibit upon completion of the course). After each terminal behavior (objective) is stated, the following three questions should be asked:

   (a) Why should the student learn this behavior?
   (b) What is the student supposed to do with the behavior once he has attained it?
   (c) How long should the student retain the behavior after once attaining it?

   Answers to the first two questions could affect the inclusion of the objective in the course content and answers to the third question could affect the design of the instruction materials.

2. The construction of a post-test is the next step and will enable the observer to determine whether or not the terminal behaviors can be exhibited by the learner. Usually, a slight change in the wording of the specified behavior will result in the test item for this behavior.

3. The third step is the specification of the assumed entry behaviors of representative learners (i.e., those behaviors pertinent to the course content that are exhibited by prospective learners of the course) and the relevant characteristics of these learners (e.g., I. Q., educational background, etc.).

4. The fourth step is the construction of a pre-entry test that will enable the observer to determine whether or not the assumed entry behaviors can actually be exhibited by representative learners who would take the course.

5. The fifth step is the specification of learning objectives of the course content which will be achieved through learning experiences and convert the learner's entry behaviors into terminal behaviors.

6. The sixth step is the construction of a pretest that will enable the observer to determine which of the learning objectives of the course content, if any, have been learned previously by representative learners.

7. The last step of the analysis is a preliminary tryout of the pre-entry test, pretest, and post-test on a sample of students that are representative of the intended learners of the course.

This model emphasizes again the need to sequence the learning objectives. As Stewart (41) states:

> The most successful programs start the learner from where he is. This gives support to a very important learning principle: _Paths of learning proceed most effectively and efficiently when going from the known to the unknown_.

Gagne (17), Lindvall and Cox (27) and Walbesser (44) all agree on the importance of proper sequencing for most effective learning. In some cases however, sequencing can be arbitrary, as Lindvall and Cox (27) point out, when an objective is not directly tied to previous learning.

Stewart (41) suggests a "Matrix Method" of sequencing interrelated learning objectives. This method uses a grid on which the numbers of the learning objectives are placed. The instructor (course designer) then marks the intersection of learning objectives on the grid. The learning objective numbers are then moved about the axis of the grid in an attempt to form a diagonal of marks indicating proper sequence.

The experimental work of Gagne (13) (16) suggests that while a general sequence may be established, individuals differ in their response to a given sequence with regard to the amount of positive transfer that takes place from one learning objective to the next. This suggests that there is not absolute sequence that can be assumed.

Stewart (41) suggests the following steps to be followed in the construction stage of the course.

> The first step in the synthesis or course-construction stage is the examination of the adjusted learning objectives to determine the most efficient and effective media and methods to be used in presenting the material associated with each objective, keeping in mind why that particular objective or terminal behavior is desired, what the learner is expected to do with this behavior, what budget is available, what the feasibility is of the media and method, how portable the course materials have to be, etc.
>
> The second step of the construction or synthesis stage is the construction and preparation of the materials necessary to help the learner attain the learning objectives and terminal behaviors of the course, keeping in mind these four principles:
>
> 1. The content of the course is presented to the learner in small, single-concept steps or units that are appropriate to the learner's abilities; e.g., reading level, educational level, age, etc.
>
> 2. For each step or unit, the learner is covertly or overtly involved, depending upon the behavioral requirement of the step.
>
> 3. In steps or units where the system requests specific responses, immediate confirmation of the correct responses is usually available.
>
> 4. The course materials are self-paced to meet individual differences. This may necessitate a certain amount of branching from the main system to accommodate differences in learner abilities, or differences in entry behaviors.
>
> The third step is the assembly of course materials and examination of them for clarity, continuity, and subject-matter validity.
>
> The fourth step, and one of the most important steps of the course developments, consists of trying out the course materials on representative learners and revision of the materials based on learner comments and errors. The "tryout-and-revision" process is repeated enough times so that 90 percent of the learners are able to exhibit 90 percent of the terminal behaviors.

The importance of the learning materials to the success of the system is pointed out by Lindvall and Cox (27) who state, "He (the learner) should be engaged in activities suited to his interests, aptitudes, learning style, and other relevant personal qualities." Herein lies the strength of IPI. While each learner is different in just about every way, an IPI system can accommodate his differences so that he can learn at <u>his</u> maximum efficiency within the system. The five learning variables cited by Stewart (41) as being the most important are:

(a) Rate of learning.
(b) Amount to be learned.
(c) Mode of learning.
(d) Interpersonal relationships in learning.
(e) Motivation to learn.

The third phase of developing an IPI course is that of evaluation. Testing and evaluation in an IPI course is continuous. The learner constantly has an identifiable goal that he is striving to achieve, so that when he has achieved a course objective he will know that he can demonstrate the behavior defined by that objective. Lindvall and Cox (27) refer to this as a curriculum-embedded test. A curriculum-embedded test (CET) is a measure of performance on one particular objective in the learning sequence of the course. To reduce the frequency of testing, several CET are often administered at one time in the form of a post-unit test. At that time the learner is evaluated on several learning objectives. If the learner succeeds on 90 percent of the assessment tasks, then he is generally allowed to go on to the next unit, otherwise the learner is asked to go back and master the objective(s) that he has demonstrated he has not learned before he is allowed to continue to the next unit of the course.

## The Role of Feedback in an IPI System

A second important role that evaluation plays in an IPI course, was inferred by Stewart (41) earlier in this paper. It is that of modifying the course itself by:

1. Changing the course objectives; or
2. Changing the learning materials or activities.

This suggests that if a learner fails to achieve an objective that the system may be at fault, and not the learner. It also suggests that an IPI system is a closed system that can adjust itself to the product when compared with the objectives that have been established for it.

The comparison of the output (learner achievement) to the goals of the system (behavioral objectives) provides feedback to both the learner and the system. Conceptual schemes of this kind enable those who are working with the learning system to assess both the learner and the system with a great deal of objectivity in an attempt to adapt one to the other. The difference between the output of a system and the objectives established for that system will generate an "error signal" which, if the system is so designed, can cause the system to change in such a way that the output more nearly coincides with the objectives, thus reducing the size of the "error signal."

The usefulness of this kind of feedback in the learning process has been described by Gagne (17), Lindvall and Cox (27), and by Wash (45) who states:

> Perhaps the most important source of reinforcers to the learning process is derived from the feedback system developed as an essential part of the total learning experience. The idea of feedback is that it should provide more than knowledge of success or failure. It should become the catalyst necessary for maintaining the impetus of the "learning reaction." Feedback systems do provide

> information to the learner about this progress, but a more important consideration is that these systems provide for constant interaction of the learner with the components of the task to be accomplished. ....Adequate reinforcers from a feedback system lessen the need for rewards as an end-product of the learning effort. The lessened importance of a reward system is advantageous, since the behaviors exhibited by the learner being rewarded are often difficult to isolate. The chance of perpetuating inappropriate behaviors, or behaviors incorrectly perceived by the learner to be essential to the learning task is lessened. Feedback systems, then, are reinforcers and stimulus generators, so that when a system is sound, "learning behavior" is sustained and the learning process is maintained at a high level of efficiency.

Eiss (10) would agree when he states:

> Probably the weakest link in today's educational system is the lack of feedback information. Many instructors can tell what students dislike about their courses, but make no attempt to remedy the situation. Much of the present-day frustration and unrest shown by students can be traced to the complete lack of feedback in the school system, or to the failure of the administration to adjust the system to eliminate, or at least minimize, the cause of conflict.

If identifiable objectives have been stated for a system, then a comparison of the output with the objectives can be made and the necessary adaptations of the learner, or the system, can be made so that the output and the objectives become the same, i.e., no "error signal."

## The Role of the Teacher in an IPI System

The word 'teacher' in today's educational system is synonomous with the word 'lecturer.' This time-proven method of teaching has become so generally accepted that the inertia that must be overcome to change the role of the teacher in the classroom may be one of the major factors retarding changes in the nature of instruction. While lecturing is an effective method of transferring information from a professor to a student, it does not, as Fischler (12) notes, provide a mechanism for the student to interact with the professor.

It is granted, that in today's educational system a limited amount of student-professor interaction is possible particularly if that professor is an academic advisor to the student. As the demand for higher education increases, more and more individuals are seeking an education beyond high school. As students become more numerous, the opportunities for individualized attention diminish. The only way this trend can be reversed is by freeing the professors from their present role of lecturer so that they may become guides for learning (12).

The first step, according to Fischler (12), is to have the professors state the objectives of their courses in behavioral terms so that the students will know what the behavioral expectations are for him in any given course. If the next step is the adoption of IPI, then the professors are freed from the lecture podium to interact with each student as he progresses through the hierarchy of learning objectives. Lindvall and Bolvin (24) see the role of the teacher in an IPI system as one who makes the system function. Lindvall and Bolvin (26) see the teacher as being engaged in the following seven activities:

1. The evaluation and diagnosis of the needs and the progress of each student.

2. The development of individual study plans or prescriptions.

3. The development of immediate and long-range plans for the total class, which take individual needs and plans into account.

4. The planning organization of the classroom and the class period to create an effective learning environment.

5. The development, in cooperation with other members of the professional staff, of plans for any necessary large group instruction.

6. The supervision of the work of para-professionals such as technicians and teacher aides (graduate assistants).

7. The study and evaluation of the system so as to improve its operation in this classroom.

In an IPI system, the professor changes his role from a lecturer to a counselor, a diagnostician, and a prescriber of individualized learning experiences.

## Summary

The literature reveals that in theory there are psychological and technical reasons for an impending change in the patterns of instruction. While such changes have already begun at the elementary and secondary levels of our educational system, experimental studies at the college and university levels are notably absent.

Several IPI models were found. These models did not vary so much in substance as they did in detail. The over-riding consideration in all models incorporating a system approach to instruction, such as IPI, was the need to specify the behavioral response of the student to the teaching-learning process. When behavioral objectives have been defined for a course, it then becomes possible to evaluate the adaptation of the student to the system, and conversely, the system to the student.

The following chapter describes the procedures that were followed in developing and executing a self-paced individually prescribed instructional system based on behavioral objectives, and the hypotheses that were tested when this system was used.

## Chapter III

## DESIGN AND METHODOLOGY

The course involved in this study was Elementary Astronomy 1104, a four credit hour, non-laboratory course. The course is primarily a general education course for nonscience majors. This course carries no prerequisites in terms of either science or mathematics. The enrollment has typically been 150-200 students per semester. The method of instruction has been lecture demonstration including a liberal amount of audio-visual aids in the form of slides, overhead transparencies, 16mm films, and demonstration apparatus. Special astronomical viewing sessions were often scheduled to give every student an opportunity to gain the experience of viewing the heavens through an astronomical telescope. Final grades are determined by five one-hour examinations plus quizzes and a final examination.

### Description of the Sample

The characteristics of a parallel student group was obtained by a voluntary questionnaire (see Appendix A) distributed to the two hundred students enrolled in Astronomy 1104 in the Fall of 1970. The information requested was: a) his or her class in school; b) the college in which the student was enrolled; c) selected science and mathematics courses completed in high school and college; d) their college major; e) their gender; f) whether or not the course was satisfying a requirement in their curriculum; and g) who recommended that they take Astronomy 1104.

The results of this survey revealed that 49% of the class were Freshmen, 34% were Sophomores, 10% Juniors, and 7% were Seniors. A majority of the class was enrolled in the College of Arts and Sciences (72%), followed by the College of Business (16%), the College of Education (6%), with the balance (5%) distributed throughout other colleges.

Thirty-eight percent of the class reported that they were taking Astronomy 1104 to fulfill a requirement. Twenty-two per cent reported that their advisor had recommended that they take the course, while 11% reported that other students had recommended the course to them, and 67% reported that they had recommended the course to themselves.

The questionnaire revealed that 95% had taken Algebra, 88% had taken Geometry, 31% Trigonometry, and 26% Physics while they were in high school. Their college experience showed that 33% had taken Algebra, 11% Calculus, and 12% had taken college Physics.

The major field of concentration of this sample was very diverse with the largest group (35%) being made up of those who had not decided on a major at the time of the study. Of the remaining students, the major most often cited was Psychology (6.5%) followed by Journalism (5%), Mathematics (5%), Business Administration (3.5%), Sociology (3.5%), and other majors having smaller percentages.

## Design of the Study

The central role of the course terminal objectives in this study dictated a major effort in their selection and construction. The behavior (response) defined by these objectives form the basis for the final evaluation of the two learning systems incorporated in this study and the student responses to those systems. In addition, the terminal objectives form the apex of all the learning processes in which the learner's engage throughout the duration of the course, regardless of the method under which they are learning. The teaching-learning decisions that are made throughout the design-execution-evaluation sequence are also dicatated by the set of terminal objectives.

Thus, the first step was the selection of the course terminal objectives. This process involved identifying as many potential terminal objectives as feasible within the constraints imposed upon the process. A major guide for this task, in addition to the designers own knowledge and experience, was the textbook that had been selected for use by both groups. The textbook, An Introduction To Astronomy by Huffer and others (22), was selected on the basis of its appropriateness for the scope and level of the course. Collectively, more than fifty terminal objectives were identified. From these fifty, seventeen terminal objectives were ultimately selected on the basis of their inclusiveness, level of learning required for their achievement, and their appropriateness to the background and potential learning abilities of the prospective students as judged by the course designers. These terminal objectives can be found in Appendix H.

This study involved the use of two teaching strategies to elicit the same set of student responses to the terminal objectives that had been selected for the course. One group was taught by a method to be referred to as Lecture-Demonstration, and the other was taught by a method referred to as Individually Prescribed Instruction.

A description of the two methods follows:

1. Lecture-Demonstration Group (LD).

The astronomical concepts incorporated in the selected set of terminal objectives were presented by lecture with the aid of slides, overhead transparencies, and movie films. Appropriate demonstrations involving the use of apparatus were also included. The concepts that were presented were carefully developed in an attempt to anticipate student difficulties and questions. Questions were not encouraged during the course of the lecture period, however, students were encouraged to visit with the lecturer about their problems whenever they felt the need to do so.

A course syllabus was handed out at the beginning of the semester. This syllabus listed the chapters to be included in the lectures by date, the dates of the hour examinations, the dates and titles of films to be shown.

Four examinations plus ten unannounced quizzes and a final examination were used to determine the final course grade. The lowest grade on one of the four examinations or a combination of the ten quizzes was eliminated when the final grade was determined.

An information sheet given to the students at the beginning of the semester, explaining many of these course characteristics, is shown in Appendix E.

2. Individually Prescribed Instruction Group (IPI).

The astronomical concepts embodied in the set of terminal objectives were incorporated into twenty separate learning units. Each of these twenty units consisted of a complete learning package including a brief description of the nature of the material to be studied including the rationale for studying this particular body of knowledge, statements of the unit objectives (behavioral objectives), suggested learning activities, and where deemed appropriate, self-assessment items to be used by the student to gauge his ability to achieve the unit objectives. The unit objectives were selected on the basis of their appropriateness moving the student up the learning hierarchy to the terminal objectives of the course. A continuous effort to eliminate all objectives and their associated activities that did not contribute to the successful completion of the terminal objectives, was made. On the other hand, every effort was also made to include those unit objectives, and their associated activities, which were necessary to take all of the students enrolled in the course from their initial position in the learning hierarchy in astronomy to the terminal objectives of the course. A list of the titles of the twenty units and a sample unit learning package can be found in Appendix G.

Those students who participated in the IPI section of this course were provided one learning unit at a time. Following the student's demonstration of his mastery of the material in that unit, meaning he scored 90% or better on the unit assessment tasks for the behavioral objectives of that unit, he was given the next unit learning package for the course. His rate of progress through the units was determined only by himself. The only constraint that was emposed on this rate was that he was informed that the course would definitely end at the completion of the regular semester. The final grade received in this section was based on the percentage of the total number of units that had been completed by the student, and upon a final test given to all members of the course at the end of the semester.

An Astronomy Learning Laboratory was set up for use by the IPI section of the course. This laboratory contained all of the necessary equipment, film loops and machines to display them, slides and machines to displace them, books, periodicals, instructors, and other resources needed for the successful completion of all twenty learning units. The Astronomy Learning Laboratory was also used as the evaluation center for the IPI group. No regular classroom sessions were scheduled other than the first class meeting used for the purpose of explaining to the students how their learning during the semester was to take place. During the first two weeks of operation, the Astronomy Learning Laboratory was open from 2:30 p.m. to 5:00 p.m., after the second week, the hours were changed to 1:00 p.m. to 5:00 p.m. daily, plus morning hours by appointment. Students were allowed to come to the Learning Laboratory at any time on any day they so desired.

At the beginning of the semester, each student in the IPI section was provided with a list of names of films to be shown on a one-time basis for their group, and the date and time of its showing. Attendance at these sessions was held to be strictly voluntary, but recommended for all. Astronomical viewing sessions were also regularly scheduled at the beginning of the semester to be attended on a voluntary basis on the part of the students in the IPI section of the course.

An instructor was present in the Astronomy Learning Laboratory during all regularly scheduled hours. The instructor was available to the IPI students for consultation on their learning problems as well as to administer the unit assessments. The instructor would evaluate each unit assessment immediately upon its completion and advise the unsuccessful student on how he should precede from that point in order to become successful on his next attempt. If the student was successful, the instructor would provide that student with the next unit learning package along with some praise and encouragement to continue his successful completion of the following units.

A sign-in sign-out system was used in the Learning Laboratory to monitor the attendance of the IPI students. At the end of each week a summary of each students progress in the course was prepared for review and evaluation. Copies of the General Information Sheets given to the IPI students may be found in Appendix E.

## Hypotheses

Many questions are common to all studies on the comparitive effectiveness of two or more teaching-learning methods. The question that would probably be of the greatest general interest is, "Under which method did the greatest amount of learning take place?" Following closely behind would be questions concerning other factors that would be of interest to those considering adopting a new teaching method as their own. These secondary questions would be concerned with the relative effect of the two methods on students' attitudes toward the subject matter, and toward the methods themselves. They would also be concerned with the relative teaching effectiveness each of the methods had on students having more or less learning ability, on those students who were required to take the course as opposed to those that were taking the course as an elective, on students enrolled in a college that was more or less oriented toward mathematics and science compared to those who were not, and on male students versus female students.

While a final decision to adopt a new teaching method would of necessity have to be based on more information than would be provided by the answers to the questions posed above, this study addresses itself to answering such questions. These questions were formulated into the following hypotheses, each of which was tested at the 0.05 level of confidence.

The hypotheses tested in this study were:

1. There is no significant difference in the knowledge gained by students in the LD Group and those in the IPI Group as measured by the difference in their scores on a pre-test and post-test based on asess-ment tasks for the course terminal objectives.

2. There is no significant difference in the knowledge gained by the LD and IPI students that are enrolled in various colleges.

3. There is no significant interaction between the LD vs IPI methods of teaching and the students that are enrolled in various colleges when measured by their gain in knowledge.

4. There is no significant difference in the knowledge gained by the LD and IPI students of different class levels.

5. There is no significant interaction between the LD vs IPI methods of teaching and the students of different class levels when measured by their gain in knowledge.

6. There is no significant difference in the knowledge gained by the LD and IPI students having different high school science and mathematics preparation.

7. There is no significant interaction between the LD vs IPI methods of teaching and the students having different high school

science and mathematics preparations when measured by their gain in knowledge.

8. There is no significant difference in the knowledge gained by the LD and IPI students having different college science and mathematics preparation.

9. There is no significant interaction between the LD vs IPI methods of teaching and the students having different college science and mathematics preparation when measured by their gain in knowledge.

10. There is no significant difference in the knowledge gained by the LD and IPI students of different gender.

11. There is no significant interaction between the LD vs IPI methods of teaching and the students of different gender when measured by their gain in knowledge.

12. There is no significant difference in the knowledge gained by the LD and IPI students having different A.C.T. scores in mathematics.

13. There is no significant interaction between the LD vs IPI methods of teaching and the students having different A.C.T. scores in mathematics when measured by their gain in knowledge.

14. There is no significant difference in the knowledge gained by the LD and IPI students having different A.C.T. scores in natural science.

15. There is no significant interaction between the LD vs IPI methods of teaching and the students having different A.C.T. scores in natural science when measured by their gain in knowledge.

16. There is no significant difference in the knowledge gained by the LD and IPI students having different composite A.C.T. scores.

17. There is no significant interaction between the LD vs IPI methods of teaching and the students having different composite A.C.T. scores when measured by their gain in knowledge.

18. There is no significant difference in the knowledge gained by the LD and IPI students who were taking the course to fulfill a requirement and those who were not.

19. There is no significant interaction between the LD vs IPI methods of teaching and those students who were taking the course to fulfill a requirement vs those who were not when measured by their gain in knowledge.

20. There is no significant difference in the change in attitudes toward astronomy in the LD Group and those in the IPI Group as measured by the difference in their scores on a pre-test and a post-test of the Likert type.

## Independent Variables

Many Variables were common to the two groups involved in this study. The textbook An Introduction to Astronomy (22) was used in both sections. Both sections had the opportunity to view the same films, slides, and other media used in the course. All of the students included in this study were given several opportunities to observe astronomical objects using astronomical telescopes.

The major difference lay in the teaching methods adopted for each group, which was the basis for this study. This led to the effort to detect differences in outcome with the tests and measures to be described later.

There were a group of differences which were detectable and presumed controlled by virtue of random distribution between the LD and IPI Groups. Verification of this assumption was tested for each dependent variable by testing for significant differences between the means of these groups on the pre-test measure of that dependent variable. The independent variables which were detected and measured in this study include: gender, college in which the student was enrolled, the student's class level, high school and college science and mathematics preparation, A.C.T. scores in mathematics, A.C.T. scores in science, and composite A.C.T. scores. Most of the information on these variables was obtained via the questionnaire shown in Appendix A.

Other independent variables, such as cultural, economic, psychological, motivational, vocational, and personality differences, were recognized as being present but no attempt to detect or measure them was made in this study. The random distribution of these variables was also assumed and tested by the test described above.

## Instruments Used

Each student enrolled in Astronomy 1104 in the Spring of 1971 was an individual who had a unique background and unique experiences that he or she brought with them to the course. In order to ascertain some of the unique characteristics of each student, a questionnaire was prepared (See Appendix A) which asked the student to indicate the following: a) class level; b) college in which they were enrolled; c) reason for taking the course; d) who recommended the course; e) who made the final decision to take the course; f) previous experience with astronomical telescopes; g) selected courses in high school science and mathematics taken by the student; h) selected courses in college science and mathematics taken by the student; and i) the college major subject of the student. This questionnaire contained a statement informing the student that the questions asked did not pertain to any requirements for the course, but that they were being asked for information only.

The knowledge of astronomy that each student brought with them to the course, as it pertained to the terminal objectives that had been established for the course, needed to be measured. A pre-test consisting of assessment tasks for the terminal objectives of the course was therefore constructed. This instrument, shown in Appendix C, consisted of seventeen separate items, some of which consisted of more than one part. Each of these items requested that the student perform a task, or tasks, to deomonstrate his competence. The test was scored so that each of the seventeen items was equally weighted in the overall score awarded to the student on the pre-test.

To measure the knowledge that each student had gained during the semester, in terms of the terminal objectives for the course, a pretest consisting of assessment tasks on the terminal objectives was constructed. The tasks requested of the students on the post-test was not unlike those requested on the pre-test, since the nature of these tasks are defined by the terminal objectives. The two tests were not the same however, since the information given to the students to manipulate on each test was different. The post-test, shown in Appendix D, was scored in the same manner as the pre-test, i.e., each of the seventeen items was equally weighted and summed to produce a single final score for that test.

A measurement of the attitudes of the students in both groups toward astronomy was made at the beginning of the course and again at the end. This measurement was made with an author constructed Likert-type attitude scale consisting of 24 statements about astronomy. The students were asked to indicate their level of agreement or disagreement with each statement on a five point scale.

Approximately half of the statements were considered negative statements about astronomy and its role in society, the other half of the statements were considered to be positive. If the student indicated a high agreement with the positive statements and a low agreement with the negative statements he was considered to have a positive attitude toward astronomy. If, on the other hand, the student had a low agreement with the positive statements, and a high agreement with the negative statements, he was considered to have a negative attitude toward astronomy.

The scoring of the individual statements depended on whether it was considered a positive or a negative statement. If the statement was positive, the weight used was 5, 4, 3, 2, 1 as shown on the statement form. A high value indicated a high positive feeling, a low value indicated a negative feeling toward astronomy. If the statement was negative, the weighting of the responses was reversed, 5 = 1, 4 = 2, 3 = 3, 2 = 4, 1 = 5. In this manner a low response to a negative statement generated what was in effect a positive response. The result of this scoring scheme was a range of final scores for the individual which could range from a low of 24 to a high of 120. This procedure, called the method of summated ratings, is described by Edwards (9).

The attitude scale used in this study, shown in Appendix B, was constructed and tested on the Fall of 1970 Astronomy 1104 class. The reliability of the scale was tested using the method described by Edwards (9). Each item was found to differentiate between positive and negative attitudes between the upper and lower quartiles at the 0.05 level of confidence.

Edwards (9) warns that one may not in general make an interpretation of an attitude score on a summed-rating scale independently of the distribution of scores of some defined group. The neutral point on a summed-rating score is not the midpoint of the possible range of scores. The absence of such a point is not a handicap if two large groups are being compared. It is a handicap in attempting to pass judgement on the score of a single individual. In this study, only the comparison of group mean scores will be made.

The pre-attitude scale was administered at the first class meeting. The post-attitude scale was administered just prior to the final examination. The students were assured that these scales would not be examined until their final grades had been submitted to the Office of the Registrar.

## Statistical Procedures

Hypothesis 1 and hypothesis 20 each address themselves to the differences between the LD Group and the IPI Group. To test these hypotheses, a t-test of the pooled variance type described by Popam (38) was used to determine if the difference in the means of the groups represented a significant departure from differences which might be expected by chance alone. This method includes an F-ratio test of the homogeneity of the two groups. If the F-ratio test revealed heterogeneity, the appropriate t-test model was used to determine the significance of differences in the group means.

In addition to the above test for sample homogeneity, a second method of testing the groups for random distribution of independent variables was employed. Each time two or more groups were selected for analysis, these groups were tested for random distribution of independent variables on the pre-test scores of the dependent variable that was about to come under test: For example, if the LD Group was to be compared with the IPI Group on their gain in knowledge, these groups were first compared on their pre-test scores for knowledge. If this test revealed that the two groups had no significant difference in the pre-test scores, it was concluded that those independent variables that would influence knowledge in astronomy were randomly distributed between the two groups. This test of homogeneity on the dependent variable was used for all groupings for the purpose of statistical analysis in this study.

Hypotheses 2 through 19 were tested with a factorial analysis of variance as described by Bruning and Kintz (4). This method of analysis is capable of not only testing for significant differences in the means between multiple sets of groups, it also tests for significant interactions between these groups. In this study a 2 X 2 factorial analysis of variance was used to test pairs of hypotheses, i.e., group differences and interactions.

In the 2 X 2 factorial analysis of variance, four groups are required. These groups are derived by assigning subjects to a group on the basis of two independent variables, for example, females from the LD Group, males from the LD Group, females from the IPI Group and males from the IPI Group. Assignment to these groups should take place on a completely random basis. Bruning and Kintz (4) impose another constraint on this method by pointing out that each of the groups should contain an equal number of subjects, or at the very least, a proportional number of subjects.

In this study, the number of subjects which would fall into various groups, based on combinations of variables, would range from seven to fifty-five for some of the analyses that were performed. In order to equalize the number of subjects in each group so that statistical analysis could be carried out and still meet all of the criteria for validity, a special procedure was employed in this study.

The Oklahoma State University IBM 360/65 computer was used to carry out the following sequence of operations: a) sort all of the subjects in this study into their appropriate group; b) examine the final size of each of the four resultant groups and note the number of subjects in the smallest of these; c) randomly select subjects from the three remaining larger groups until each group contained the same number of subjects as the smallest group.; d) perform the factorial analysis of variance and print out the results. A commonly used random number generator (See Appendix I) called RANDU was used for the random selection of the subjects with the groups. A set of one hundred arbitarily chosen numbers was punched on cards and selected by chance to initialize this subroutine when these analyses were carried out.

## CHAPTER IV

## RESULTS OF THE STUDY

### Introduction

The goals of this study were to develop an IPI system of instruction in introductory astronomy and then to compare the gain in knowledge of astronomy between that system and the lecture-demonstration method. A comparison in the changes in attitude toward astronomy between the two sections was also a goal. In addition, an attempt was made to identify certain student characteristics that interact with the teaching methods that were incorporated. The results of the study are presented in this chapter.

### Population Distribution

The distribution of student characteristics within the LD and IPI Groups is shown in Table I. These results, obtained at the beginning of the course from the questionnaire shown in Appendix A, reveal that the relative number of students having the same characteristics within each of the two groups is about the same with the following exceptions: a) calculus and physics taken in college, and b) A.C.T. scores, principally in natural science.

While the A.C.T. scores could not be obtained for all subjects within each of the two groups, those that were obtained showed that

TABLE I

POPULATION DISTRIBUTION WITHIN LD AND IPI GROUPS*

| | LD Group (n = 86) | IPI Group (n = 32) |
|---|---|---|
| Gender | | |
| Male | 66.3 | 78.1 |
| Female | 33.7 | 21.9 |
| College Class | | |
| Freshman | 44.2 | 40.6 |
| Sophmore | 27.9 | 31.3 |
| Junior | 13.9 | 15.6 |
| Senior | 13.9 | 12.5 |
| College of Enrollment | | |
| Arts and Sciences | 70.9 | 65.6 |
| Other | 29.1 | 34.4 |
| Required or Elective | | |
| Required | 40.7 | 40.6 |
| Elective | 59.3 | 59.4 |
| High School Courses | | |
| General Science | 98.8 | 90.6 |
| Algebra | 96.5 | 100.0 |
| Geometry | 89.5 | 81.3 |
| Trigonometry | 47.7 | 40.6 |
| Physics | 36.1 | 31.3 |
| College Courses | | |
| Algebra | 38.4 | 40.6 |
| Trigonometry | 25.6 | 21.9 |
| Analytic Geometry | 20.9 | 25.0 |
| Calculus | 30.2 | 9.8 |
| Physics | 29.1 | 12.5 |
| A. C. T. Scores** | | |
| Mathematics $>$ 22 | 47.7 | 34.4 |
| Mathematics $\leq$ 22 | 31.4 | 43.8 |
| Natural Science $>$ 19 | 65.1 | 34.4 |
| Natural Science $\leq$ 19 | 14.0 | 43.8 |
| Composite $>$ 21 | 47.7 | 37.5 |
| Composite $\leq$ 21 | 31.4 | 40.6 |

*Figures given in percent of that group.

**A. C. T. scores not available for all subjects.

the LD Group scores in natural science were higher than those in the IPI Group on the average. Those in the LD Group showed twice as large a percentage of the students had a natural science score greater than 19 as compared to the IPI Group. The percentages of subjects having scores greater than 22 in mathematics and 21 for a composite score were about reversed between the two sections indicating that the LD Group tended to have higher A.C.T. scores in all three areas than did the IPI Group.

## Knowledge Comparisons

Comparisons of the knowledge gained by the LD and IPI Groups and various sub-groups was measured using a pre-test post-test technique. The gain in knowledge was measured as the difference in the scores between these two instruments.

To test the distribution of the independent variables between the LD and IPI Groups and to test hypothesis 1, a t-test was employed. The results of these tests are shown in Table II. The t-comparison of the pre-test scores between the two groups clearly shows a random distribution of the independent variables since $t_{0.05}(120) = 1.98$ and the computed $t(116) = 0.12$. This would indicate the acceptance of the hypothesis that there is no significant difference (0.05 level of confidence) between the LD and IPI Groups on their pre-test scores. The F-ratio test for homogeneity between these two groups also indicates that they are homogeneous.

TABLE II

COMPARISON OF LD VS IPI GROUPS ON DISTRIBUTION OF ALL INDEPENDENT VARIABLES AND COGNITIVE GAIN

| Test | Group | Mean Score | Standard Deviation | F Ratio | Degrees of Freedom | t Score |
|---|---|---|---|---|---|---|
| Distribution | LD | 40.32 | 11.77 | | | |
| of Variables | IPI | 40.03 | 13.40 | 1.32 | 116 | 0.12 |
| Cognitive | LD | 15.64 | 17.54 | | | |
| Gain | IPI | 43.41 | 17.30 | 1.03 | 116 | 7.67 |

The first hypothesis was:

$H_o1$: There is no significant difference (0.05 level of confidence) in the knowledge gained by students in the LD Group as measured by the difference in their scores on a pre-test and a post-test based on assessment tasks for the course terminal objectives.

The results shown in Table II indicate the rejection of this hypothesis. The computed $t(116) = 7.67$ compares with the tabulated $t_{0.001}(120) = 3.37$ using a two-tailed test. The computed $F(32,86) = 1.03$ also compares with the tabulated $F_{0.05}(24,60) = 1.70$ to indicate the rejection of the nonhomogeneity hypothesis, i.e., these two groups demonstrate homogeneity based on cognitive gain.

The second and third hypotheses were:

$H_o2$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students that are enrolled in various colleges.

$H_o3$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students that are enrolled in various colleges when measured by their gain in knowledge.

The test for the random distribution of independent variables between the groups selected to test hypotheses 2 and 3 indicate that these variables are randomly distributed between the LD and IPI Groups but are not randomly distributed between the Arts & Sciences and Other Groups measured on their pre-test scores as shown in Table IV. While the students in the Arts & Sciences group had a mean score on the pre-test which was more than nine points higher than the mean score of those in other colleges, the distribution of these students was uniform between the LD and IPI Groups as indicated by the lack of significant differences in the pre-test scores between the teaching methods or the interaction between methods and college as shown in Table IV.

Hypotheses 2 and 3 will both be accepted on the basis of the information shown in Tables V and VI. While no significant differences were found between the students in Arts & Sciences and Other Colleges, nor was any significant interaction indicated. These results do provide additional evidence for the rejection of $H_o1$.

Hypotheses 4 and 5 were:

$H_o4$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students of different class levels.

$H_o5$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students of different class levels when measured by their gain in knowledge.

TABLE III

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Arts & Sciences | 44.00 | 45.18 | --- | 44.59 |
| Other | 34.18 | 36.09 | --- | 35.14 |
| GROUP | 39.09 | 40.64 | | |

*n = 11 per cell

TABLE IV

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 7363 | 43 | 171 | | |
| Method* | 26 | 1 | 26 | 0.17 | n.s. |
| College** | 983 | 1 | 983 | 6.19 | $<.025$ |
| Method X College | 2 | 1 | 2 | 0.01 | n.s. |
| Error | 6352 | 40 | 159 | | |

*LD vs IPI

**Arts & Sciences vs Other

TABLE V

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Arts & Sciences | 17.27 | 38.54 | --- | 27.91 |
| Other | 4.91 | 46.36 | --- | 25.64 |
| GROUP | 11.00 | 42.45 | | |

*n = 11 per cell

TABLE VI

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 25900 | 43 | 602 | | |
| Method* | 10820 | 1 | 10820 | 31.13 | $<.001$ |
| College** | 57 | 1 | 57 | 0.16 | n.s. |
| Method X College | 1120 | 1 | 1120 | 3.22 | n.s. |
| Error | 13902 | 40 | 348 | | |

*LD vs IPI

**Arts & Sciences vs Other

Tables VII and VIII indicate that the distribution of the independent variables between the groups selected to test the above hypotheses was random, based on the subject's scores on the pre-test.

Tables IX and X show that both hypothesis 4 and hypothesis 5 should be accepted.

The sixth and seventh hypotheses involved high school science and mathematics backgrounds of the students. The tests of random distribution of independent variables between the groups selected to test these hypotheses revealed that random distribution could not be assumed between the group having a strong high school science and mathematics background and the group having a weak background in these same areas. Those having a strong background in high school science and mathematics scored an average of more than eight points higher on the pre-test. This experience was evenly distributed between the LD and IPI Groups with no significant interaction present as shown in Tables XI and XII.

Hypotheses 6 and 7 were:

$H_o$6: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students having different high school science and mathematics preparation.

$H_o$7: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students having different high school science and mathematics preparations when measured by their gain in knowledge.

The results found in Tables XIII and XIV show that both hypotheses will be accepted. Rejection of hypothesis 1 is again supported.

The test for the random distribution of the independent variables between the groups selected to test hypotheses 8 and 9 showed that

TABLE VII

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES
FOR LD AND IPI GROUPS DIVIDED BY CLASS*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Freshman | 44.07 | 36.46 | --- | 40.27 |
| Other | 43.77 | 39.38 | --- | 41.58 |
| GROUP | 43.92 | 37.92 | | |

*n = 13 per cell

TABLE VIII

COMPARISON OF LD VS IPI PRE-TEST SCORES
WHEN DIVIDED BY CLASS

| Facorial Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | SS | df | ms | F | p |
| Total | 8134 | 51 | 159 | | |
| Method* | 468 | 1 | 468 | 2.95 | n.s. |
| Class** | 22 | 1 | 22 | 0.14 | n.s. |
| Method X Class | 34 | 1 | 34 | 0.21 | n.s. |
| Error | 7610 | 48 | 159 | | |

*LD vs IPI

**Freshman vs Other

TABLE IX

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS DIVIDED BY CLASS*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Freshman | 16.15 | 41.46 | --- | 28.81 |
| Other | 7.23 | 48.15 | --- | 27.69 |
| GROUP | 11.69 | 44.81 | | |

*n = 13 per cell

TABLE X

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY CLASS

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 27034 | 51 | 530 | | |
| Method* | 14256 | 1 | 14256 | 57.17 | $<.001$ |
| Class** | 16 | 1 | 16 | 0.06 | n.s. |
| Method X Class | 792 | 1 | 792 | 3.18 | n.s. |
| Error | 11969 | 48 | 249 | | |

*LD vs IPI

**Freshman vs Other

TABLE XI

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses $\leq$ 3 | 39.80 | 37.53 | --- | 38.67 |
| No. Courses $>$ 3 | 48.20 | 45.27 | --- | 46.73 |
| GROUPS | 44.00 | 41.40 | | |

*n = 15 per cell

TABLE XII

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 10501 | 59 | 178 | | |
| Method* | 101 | 1 | 101 | 0.60 | n.s. |
| Background** | 976 | 1 | 976 | 5.80 | $<.025$ |
| Method X Background | 2 | 1 | 2 | 0.01 | n.s. |
| Error | 9422 | 56 | 168 | | |

*LD vs IPI

**No. Courses $\leq$3 vs No. Courses $>$3

TABLE XIII

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses $\leq 3$ | 9.87 | 39.87 | --- | 24.87 |
| No. Courses $> 3$ | 15.73 | 44.47 | --- | 30.10 |
| GROUP | 12.80 | 42.17 | --- | |

*n = 15 per cell

TABLE XIV

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 29799 | 59 | 505 | | |
| Method* | 12936 | 1 | 12936 | 44.05 | $<.001$ |
| Background** | 411 | 1 | 411 | 1.40 | n.s. |
| Method X Background | 6 | 1 | 6 | 0.02 | n.s. |
| Error | 16446 | 56 | 294 | | |

*LD vs IPI

**No. Courses $\leq 3$ vs No. Courses $> 3$

these variables were not significantly grouped as measured by the pre-test scores of the subjects in these groups. The results are shown in Tables XV and XVI.

Hypotheses 8 and 9 were:

$H_o 8$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students having different college science and mathematics preparation.

$H_o 9$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students having different college science and mathematics preparation measured by their gain in knowledge.

The results shown in Tables XVII and XVIII indicate that hypothesis 8 will be rejected and that hypothesis 9 will be accepted. Hypothesis 1 rejection is again supported. The rejection of hypothesis 8 (0.01 level of confidence) is indicated in the difference of the group means with those students that had a strong college science and mathematics background having an average gain in knowledge of more than eleven points greater than those having a weak college background in science and mathematics. The greatest difference occurred in the LD Group as shown in Table XVII.

Hypotheses 10 and 11 were:

$H_o 10$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students of different gender.

$H_o 11$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students of different gender when measured by their gain in knowledge.

TABLE XV

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses = 0 | 36.77 | 34.69 | --- | 35.73 |
| No. Courses > 0 | 36.77 | 44.00 | --- | 40.38 |
| GROUP | 36.77 | 39.35 | | |

*n = 13 per cell

TABLE XVI

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 5967 | 51 | 117 | | |
| Method* | 86 | 1 | 86 | 0.78 | n.s. |
| Background** | 282 | 1 | 282 | 2.54 | n.s. |
| Method X Background | 282 | 1 | 282 | 2.54 | n.s. |
| Error | 5317 | 48 | 111 | | |

*LD vs IPI

**No. Courses = 0 vs No. Courses > 0

TABLE XVII

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses = 0 | 2.08 | 42.38 | --- | 22.23 |
| No. Courses > 0 | 21.38 | 46.08 | --- | 33.73 |
| GROUP | 11.73 | 44.23 | | |

*n = 13 per cell

TABLE XVIII

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 27817 | 51 | 545 | | |
| Method* | 13731 | 1 | 13731 | 56.95 | <.001 |
| Background** | 1719 | 1 | 1719 | 7.13 | <.01 |
| Method X Background | 792 | 1 | 792 | 3.29 | n.s. |
| Error | 11574 | 48 | 241 | | |

*LD vs IPI

**No. Courses = 0 vs No. Courses > 0

Independent variables were not randomly distributed between the male and female groups selected to test these hypotheses as shown in Tables XIX and XX. The males scored an average of more than fifteen points higher on the pre-test. The independent variables were randomly distributed between the LD and IPI Groups as measured by the pre-test scores.

Based on the results shown in Tables XXI and XXII, hypothesis 10 will be accepted and hypothesis 11 will be rejected. Both of these decisions must be tentative, however. These results are based on a cell size of seven subjects per cell with a minimum of ten being the generally accepted rule for an analysis of this type. It is interesting to note that the first interaction is indicated by these results. The female subjects scored on the average more than five points greater gain in knowledge in the IPI Group while the males indicated an average gain in knowledge of twenty points more than the females in the LD Group.

The test for the random distribution of independent variables between the low mathematics A.C.T. score group and high mathematics A.C.T. score group, within the LD and IPI groups, indicated that random distribution based on the pre-test scores of these groups can be assumed, as shown in Tables XXIII and XXIV.

The hypotheses involving A.C.T. scores in mathematics are:

$H_o$13: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students having different A.C.T. scores in mathematics.

$H_o$14: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students

TABLE XIX

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES
FOR LD AND IPI GROUPS DIVIDED BY GENDER*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Male | | 46.43 | 48.57 | --- | 47.50 |
| Female | | 36.29 | 28.29 | --- | 32.29 |
| | GROUP | 41.36 | 38.43 | | |

*n = 7 per cell

TABLE XX

COMPARISON OF LD VS IPI PRE-TEST SCORES
WHEN DIVIDED BY GENDER

| Factorial Analysis of Variance | | | | | |
|---|---|---|---|---|---|
| Source | SS | df | ms | F | p |
| Total | 7051 | 27 | 261 | | |
| Method* | 60 | 1 | 60 | 0.28 | n.s. |
| Gender** | 1620 | 1 | 1620 | 7.49 | $<.025$ |
| Method X Gender | 180 | 1 | 180 | 0.83 | n.s. |
| Error | 5190 | 24 | 216 | | |

*LD vs IPI

**Male vs Female

TABLE XXI

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS DIVIDED BY GENDER*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Male | | 23.29 | 42.00 | --- | 32.64 |
| Female | | 3.29 | 47.71 | --- | 25.50 |
| | GROUP | 13.29 | 44.86 | | |

*n = 7 per cell

TABLE XXII

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY GENDER

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 14694 | 27 | 544 | | |
| Method* | 6977 | 1 | 6977 | 27.00 | $<.001$ |
| Gender** | 357 | 1 | 357 | 1.38 | n.s. |
| Method X Gender | 1157 | 1 | 1157 | 4.48 | $<.05$ |
| Error | 6202 | 24 | 258 | | |

*LD vs IPI

**Male vs Female

TABLE XXIII

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES
FOR LD AND IPI GROUPS WHEN DIVIDED BY
A. C. T. SCORES IN MATHEMATICS*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| MA Score $\leq$ 22 | | 33.91 | 38.18 | --- | 36.05 |
| MA Score $>$ 22 | | 42.91 | 42.00 | --- | 42.45 |
| | GROUP | 38.41 | 40.09 | | |

*n = 11 per cell

TABLE XXIV

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED
BY A. C. T. SCORES IN MATHEMATICS

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 6584 | 43 | 153 | | |
| Method* | 31 | 1 | 31 | 0.21 | n.s. |
| MA Score** | 451 | 1 | 451 | 3.00 | n.s. |
| Method X MA Score | 74 | 1 | 74 | 0.49 | n.s. |
| Error | 6028 | 40 | 151 | | |

*LD vs IPI

**MA Score $\leq$ 22 vs MA Score $>$ 22

having different A.C.T scores in mathematics when measured by their gain in knowledge.

Tables XXV and XXVI show that both of these hypotheses will be accepted.

Tables XXVII and XXVIII show that those subjects that had high A.C.T. scores in natural science scored significantly higher on the pre-test than those who had low scores. Random distribution of the independent variables between these two groups does not exist on the basis of this test, it does exist between the LD and IPI groups selected to test the next hypotheses, however.

Natural science A.C.T. scores were included in hypotheses 14 and 15 which were:

$H_o$14: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students having different A.C.T. scores in natural science.

$H_o$15: There is no significant interaction (0.05 level of confidence) between the LD and IPI methods of teaching and the students having different A.C.T. scores in natural science when measured by their gain in knowledge.

Tables XXIX and XXX show that both hypotheses 14 and 15 will be accepted.

A comparison of those students having high vs low composite A.C.T. scores was made. The test for the distribution of independent variables between the groups selected for analysis revealed that these variables were randomly distributed between the LD and IPI groups but not between the high and low A.C.T. composite scores, as shown in Tables XXXI and XXXII.

TABLE XXV

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY A. C. T. SCORES IN MATHEMATICS*

| | LD | IPI | | Group |
|---|---|---|---|---|
| MA Score $\leq$ 22 | 8.82 | 43.18 | --- | 26.00 |
| MA Score $>$ 22 | 24.36 | 47.73 | --- | 36.05 |
| GROUP | 16.59 | 45.45 | | |

*n = 11 per cell

TABLE XXVI

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY A. C. T. SCORES IN MATHEMATICS

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 22026 | 43 | 512 | | |
| Method* | 9164 | 1 | 9164 | 32.10 | $<$.001 |
| MA Score** | 1110 | 1 | 1110 | 3.89 | n.s. |
| Method X MA Score | 333 | 1 | 333 | 1.17 | n.s. |
| Error | 11420 | 40 | 286 | | |

*LD vs IPI

**MA Score $\leq$ 22 vs MA Score $>$ 22

TABLE XXVII

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE*

| | LD | IPI | | Group |
|---|---|---|---|---|
| NS Score $\leq$ 19 | 32.00 | 30.73 | --- | 31.36 |
| NS Score $>$ 19 | 49.27 | 45.45 | --- | 47.36 |
| GROUP | 40.64 | 38.09 | | |

*n = 11 per cell

TABLE XXVIII

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 7184 | 43 | 167 | | |
| Method* | 71 | 1 | 71 | 0.67 | n.s. |
| NS Score** | 2816 | 1 | 2816 | 26.32 | $<$.001 |
| Method X NS Score | 18 | 1 | 18 | 0.17 | n.s. |
| Error | 4279 | 40 | 107 | | |

*LD vs IPI

**NS Score $\leq$ 19 vs NS Score $>$ 19

TABLE XXIX

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE*

| | LD | IPI | | Group |
|---|---|---|---|---|
| NS Score $\leq$ 19 | 13.54 | 42.91 | --- | 28.23 |
| NS Score $>$ 19 | 12.00 | 48.27 | --- | 30.14 |
| GROUP | 12.77 | 45.59 | | |

*n = 11 per cell

TABLE XXX

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 23053 | 43 | 536 | | |
| Method* | 11847 | 1 | 11847 | 42.95 | $<$.001 |
| NS Score** | 40 | 1 | 40 | 0.15 | n.s. |
| Method X NS Score | 131 | 1 | 131 | 0.48 | n.s. |
| Error | 11034 | 40 | 276 | | |

*LD vs IPI

**NS Score $\leq$ 19 vs NS Score $>$ 19

Hypotheses 16 and 17 were:

$H_o 16$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students having different composite A.C.T. scores.

$H_o 17$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching and the students having different composite A.C.T. scores when measured by their gain in knowledge.

The results of this study, shown in Tables XXXIII and XXXIV, indicate that both hypothesis 16 and hypothesis 17 will be accepted. The mean knowledge gained was more than six points greater for the high A.C.T. composite score group and the low scoring group mean was slightly greater in the IPI group than the high scoring group; but neither of these effects was found to be significant at the 0.05 level. Further evidence for the rejection of hypothesis 1 was found in these results.

Do those students who are taking the course as a requirement gain more or less from the course than those taking it as an elective? Hypotheses 18 and 19 address themselves to this question. They were:

$H_o 18$: There is no significant difference (0.05 level of confidence) in the knowledge gained by the LD and IPI students who were taking the course to fulfill a requirement and those who were not.

$H_o 19$: There is no significant interaction (0.05 level of confidence) between the LD vs IPI methods of teaching students who were taking the course to fulfill a requirement vs those who were not when measured by their gain in knowledge.

TABLE XXXI

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY COMPOSITE A. C. T. SCORES*

| | LD | IPI | | Group |
|---|---|---|---|---|
| CM Score $\leq$ 21 | 35.42 | 30.58 | --- | 33.00 |
| CM Score $>$ 21 | 44.92 | 47.50 | --- | 46.21 |
| GROUP | 40.17 | 39.04 | | |

*n = 12 per cell

TABLE XXXII

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY COMPOSITE A.C.T. SCORES

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 8222 | 47 | 175 | | |
| Method* | 15 | 1 | 15 | 0.11 | n.s. |
| CM Score** | 2093 | 1 | 2093 | 15.49 | $<$.001 |
| Method X CM Score | 165 | 1 | 165 | 1.22 | n.s. |
| Error | 5948 | 44 | 135 | | |

*LD vs IPI

**CM Score $\leq$ 21 vs CM Score $>$ 21

TABLE XXXIII

GROUP AND SUB-GROUP MEANS OF COGNITIVE EFFECT FOR LD AND IPI GROUPS WHEN DIVIDED BY COMPOSITE A. C. T. SCORES*

| | LD | IPI | | Group |
|---|---|---|---|---|
| CM Score $\leq 21$ | 7.50 | 43.75 | --- | 25.63 |
| CM Score $> 21$ | 22.08 | 41.92 | --- | 32.00 |
| GROUP | 14.79 | 42.83 | | |

*n = 12 per cell

TABLE XXXIV

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY COMPOSITE A. C. T. SCORES

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 23745 | 47 | 505 | | |
| Method* | 9436 | 1 | 9436 | 31.91 | $<.001$ |
| CM Score** | 488 | 1 | 488 | 1.65 | n.s. |
| Method X CM Score | 809 | 1 | 809 | 2.73 | n.s. |
| Error | 13013 | 44 | 296 | | |

*LD vs IPI

**CM Score $\leq 21$ vs CM Score $> 21$

A test of the groups selected to test these hypotheses revealed that independent variables were randomly distributed between these groups as shown in Tables XXXV and XXXVI.

The results of this study shown in Tables XXXVII and XXXVIII reveal that while those taking the course as an elective gained more than six points more knowledge than did those who were taking it as a requirement, the difference was not significant. Hypotheses 18 and 19 will be accepted.

## Attitude Comparisons

A comparison of the change in attitude toward astronomy between the LD and IPI Groups was made. This change was measured by using a pre-test post-test measurement with their change in attitudes being the difference in the score made on these two instruments. A test for the random distribution of independent variables that can effect attitude was made by testing the pre-test scores for significant differences between the LD and IPI Groups.

The results of this study, shown in Table XXXIX, reveal that those independent variables which might influence attitudes toward astronomy were randomly distributed between the LD and IPI groups. The pre-test scores also demonstrated that the groups were homogeneous on their attitudes toward astronomy.

Changes in attitude toward astronomy was involved in hypothese 20 which was:

$H_o$20: There is no significant difference (0.05 level of confidence) in the change in attitudes toward astronomy in the LD Group and those in the IPI Group as measured by the difference in their

TABLE XXXV

GROUP AND SUB-GROUP MEANS OF PRE-TEST SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY REQUIREMENT CRITERIA*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Required | | 36.77 | 40.85 | --- | 38.81 |
| Elective | | 38.77 | 38.85 | --- | 38.81 |
| | GROUP | 37.77 | 39.85 | | |

*n = 13 per cell

TABLE XXXVI

COMPARISON OF LD VS IPI PRE-TEST SCORES WHEN DIVIDED BY REQUIREMENT CRITERIA

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 7326 | 51 | 143 | | |
| Method* | 56 | 1 | 56 | 0.37 | n.s. |
| Criteria** | 0 | 1 | 0 | 0.00 | n.s. |
| Method X Criteria | 52 | 1 | 52 | 0.35 | n.s. |
| Error | 7218 | 48 | 150 | | |

*LD vs IPI

**Required vs Elective

TABLE XXXVII

GROUP AND SUB-GROUP MEANS OF COGNITIVE SCORES FOR LD AND IPI GROUPS WHEN DIVIDED BY REQUIREMENT CRITERIA*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Required | | 14.54 | 37.92 | --- | 26.23 |
| Elective | | 18.85 | 46.08 | --- | 32.46 |
| | GROUP | 16.69 | 42.00 | | |

*n = 13 per cell

TABLE XXXVIII

COMPARISON OF LD VS IPI COGNITIVE EFFECT WHEN DIVIDED BY REQUIREMENT CRITERIA

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 21212 | 51 | 416 | | |
| Method* | 8326 | 1 | 8326 | 32.41 | $<.001$ |
| Criteria** | 505 | 1 | 505 | 1.96 | n.s. |
| Method X Criteria | 48 | 1 | 48 | 0.19 | n.s. |
| Error | 12333 | 48 | 257 | | |

*LD vs IPI

**Required vs Elective

scores on a pre-test and a post-test of the Likert type.

TABLE XXXIX

COMPARISON OF LD VS IPI GROUPS ON DISTRIBUTION OF INDEPENDENT VARIABLES AND CHANGE IN ATTITUDE

| Test | Group | Mean Score | Standard Deviation | F Ratio | Degrees of Freedom | t Score |
|---|---|---|---|---|---|---|
| Distribution | LD | 84.19 | 8.32 | | | |
| of Variables | IPI | 84.84 | 7.24 | 1.32 | 116 | 0.39 |
| Change in | LD | 4.09 | 10.54 | | | |
| Attitude | IPI | 4.16 | 8.42 | 1.57 | 116 | 0.03 |

The findings of this study, shown in Table XXXIX, indicate that both groups increased their positive attitudes toward astronomy during the course of the semester. Both their pre-test mean scores and their positive changes in attitude were similar. Hypothesis 20 will be accepted.

CHAPTER V

# SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

## Summary

This study was carried out by first developing an individually prescribed instruction system which incorporated self-pacing. A twenty-unit course based on seventeen terminal objectives, selected from numerous objectives identified by the co-designers of the course, was constructed. Each unit consisted of from two to five unit objectives that were a part of the learning hierarchy leading to the terminal objectives.

Unit Learning Packages were developed, each consisting of a statement of each unit objective, a set of suggested learning activities, and several self-assessment items to be used by the student to evaluate his own ability to achieve the unit objectives where they were deemed necessary by the course designers. A sample Unit Learning Package can be found in Appendix G.

An Astronomy Learning Laboratory was established. This laboratory contained the equipment, media, and literature that were needed for the successful completion of all of the course objectives. The Astronomy Learning Laboratory was open with an instructor in attendance from 1:00 p.m. to 5:00 p.m. Monday through Friday. Students in the IPI Group would come to work in this laboratory on the day and hour of their own choosing.

Because of the self-paced feature of the IPI section, that section was monitored closely to follow the progress of each member through the course to its completion. A sign-in sign-out system was used in the Astronomy Learning Laboratory to monitor the time spent in that facility by each student. This monitoring revealed that at the end of the semester each member of the IPI section which is included in this study had made an average of 27.9 visits to the laboratory during the semester. The average visit lasted 62 minutes meaning the average student spent a total of 28 hours in the learning laboratory during the semester. This compares with about 46.5 hours spent in the classroom by the students in the LD section, assuming perfect attendance.

A series of films dealing with astronomical topics was scheduled throughout the semester. These films were shown to the LD section during regular class hours. The same films were shown for those in the IPI section at a scheduled time and place announced at the beginning of the semester. Attendance at these showings for students in the IPI Group was voluntary.

Weekly evening viewing sessions were offered to both sections on a voluntary attendance basis for the purpose of viewing astronomical telescopes.

Twenty of the thirty-two students in the IPI section which are included in this study completed all twenty units of the course. One of these students completed the twenty units four weeks prior to the end of the semester. One student in this section had completed five units when the semester ended.

## Conclusions

Differences in the knowledge gained by the LD and IPI Groups was demonstrated to be significant at the 0.001 level of confidence in both the t-test on the groups as a whole and the nine factorial analyses of variance that were carried out to analyze differences in cognitive effect on sub-groups within the treatment groups. These ences were measured by the difference in pre-test post-test scores on assessment tasks for the seventeen terminal objectives of the course.

Of the nine organimistic variables studied, five of these variables showed significant differences between subjects on the pre-test. These variables were: 1) college in which the student was enrolled; with those enrolled in Arts & Sciences scoring significantly higher than those in other colleges; 2) high school science and mathematics background; those having a strong background; scoring significantly higher on the pre-test than those having a weak background; 3) gender, the males scored significantly higher on the pre-test than the females; 4) A.C.T. score in natural science, those having a higher NS score scored higher on the pre-test; and 5) composite A.C.T. scores; again, the higher A.C.T. score coincided with the higher pre-test score. None of these differences were repeated when the cognitive effect was measured, meaning that the knowledge gained was not statistically different within any of the five groups that demonstrated a difference on the pre-test.

Those students in both the LD and IPI sections that have taken none of the college science and mathematics courses included in this study showed no statistical difference in their pre-test scores but did show a significant difference in the knowledge gained (0.01 level of confidence). The major difference in this group was found in the LD Group where those who had taken one or more of the college science and mathematics courses included in this study showed a mean gain in knowledge that was ten times greater than the mean of those who had taken no college science or mathematics courses.

One interaction was discovered in this study. The female subjects in the IPI Groups had a mean cognitive effect that was 5.71 points higher than the males in that group while the males in the LD Group had a mean cognitive effect that was 20.00 points greater than the females in that group. No firm conclusion can be drawn from this measurement however, since the number of subjects available for this test was only seven per cell with ten generally considered to be the minimum number necessary to produce statistically significant results.

Further measures of the comparison of gain in knowledge between the LD and IPI Groups can be found in Appendix J. These results indicate that when the gain in knowledge was measured with a 100 item multiple choice test, known also as the final test, the LD Group scored significantly higher (0.05 level of confidence) when compared with the IPI Group using a t-test. When repeated measures of comparison between groups on the nine organimistic variables, using the same subjects that were selected for these comparisons on the cognitive effect, only two of the nine measures detected significant differences between the LD and IPI Groups. While one organimistic variable (college science and mathematics background) showed a significant difference on the cognitive effect, five organimistic variables showed significant differences on the final test. One interaction was also detected, that being between

A.C.T. scores in mathematics and teaching method (LD vs IPI). Those subjects having an A.C.T. score greater than twenty-two in mathematics had a mean score on the final test that was 12.37 points higher than those subjects having a lower A.C.T. score in mathematics. The difference in the IPI section between the same groups was 0.64 points.

The difference between the LD and IPI Groups on the final test as measured by the t-test may not be reliable because of the apparent role that science and mathematics background and innate abilities as measured by the A.C.T. test played a role in the final test scores. These variables may not have been uniformly distributed between the two sections as indicated in Table I.

One factor that may have influenced both measures of the response of the LD and IPI subjects to the treatments included in this study was the conditioning of each group to certain evaluation techniques. The LD section was tested four times during the semester with multiple choice and true-false items on each examination. The IPI section was tested over each unit that a subject completed with an examination consisting of assessment tasks for the unit objectives. If conditioning was a factor, such conditioning would favor the IPI Group on the measurement of cognitive effect and the LD Group on the final test.

Assuming that the seventeen terminal objectives defined for the course represented the complete set of desirable outcomes for an introductory astronomy course, it must be concluded that the IPI Group was significantly superior to the LD Group in terms of the knowledge of astronomy that they gained during the period covered by this study.

If it cannot be assumed that the terminal objectives represented the complete set of desirable outcomes for an introductory astronomy course, but that some of these outcomes can be measured by the final test, then, the superiority of the IPI method of instruction comes into some doubt. It would then be possible to conclude that neither the LD nor IPI methods were demonstrated to be superior. On the other hand, the unanimous measures favoring the IPI method on cognitive effect versus the somewhat doubtful measures favoring the LD method on the final test would seem to indicate to this investigator that the IPI method has been demonstrated to be superior when all factors are taken together.

In an effort to compare the effect of the teaching methods employed in this study on the student's attitudes toward the subject matter being taught, a measure of their changes in attitude toward astronomy was made using a pre-test and post-test technique. It was found that within the range of sensitivity that this measure was capable of detecting, no significant difference between the LD and IPI sections existed either at the beginning of the semester or at the end of the semester. Both sections indicated a small positive increase in their attitudes toward astronomy during the course of this study.

The following conclusions result from this study:

1. There was a strong statistically significant difference (0.001 level of confidence) in the knowledge gained when comparing the LD and IPI Groups. This difference favored the IPI Group.

2. Only those students having taken one or more of those college science and mathematics courses included in this study, versus those that had taken none, showed a statistically different gain in knowledge. None of the other eight organimistic variables studied were found to show a significant difference in knowledge gained.

3. Gender produced the only statistically significant detectable interaction between the nine organimistic variables studied and the teaching methods (LD vs IPI) employed. No firm conclusion can be drawn from this finding; however, because there was not a sufficient number of subjects included in this test.

4. There was no detectable difference in the changes in attitude toward astronomy when comparing the LD and IPI Groups.

## Recommendations

1. On the basis of the findings of this study, it is strongly recommended that self-paced individually prescribed instruction be continued at the introductory level of astronomy.

2. It is recommended that further study of the relative merits of IPI be carried out, particularly with regard to the efficient uses of resources. No attempt was made to evaluate the faculty effort or physical resources required to execute this course. The positive results shown by the IPI Group in this study would indicate to this investigator that some additional use of resources should not be the sole reason for rejecting the IPI method of teaching. The comparative effectiveness of each method should be weighed against the use of resources before a final judgement is made.

3. It is recommended that additional experimental studies be carried out to determine the effectiveness of individually prescribed instruction at all levels of college instruction. While it seems logical that introductory courses lend themselves most rapidly to this type of instruction, other more advanced courses may also be found suitable, and indeed desirable candidates for individualized instruction.

4. Effective and efficient learning systems should be a goal of all who are involved in the teaching-learning process. Continued study of the relationship between various student characteristics and the learning system should be carried out until each student can be placed in the learning system that is best suited to his own unique set of characteristics.

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## APPENDIX A

## QUESTIONNAIRE

ASTRONOMY 1104

Name______________________________ Student No.__________ (1) Male
Last First Middle (2) Female

To Respond - Circle the correct answer

Class (1) Fr. (2) So. (3) Jr. (4) Sr. (5) Other__________(specify)

College (1) Agriculture (2) Arts and Sciences (3) Business
(4) Education (5) Engineering (6) Home Economics
(7) Technical Institute (8) Unclassified (9) Graduate

Why are you taking this course?

(1) It is required (2) As an elective

Who Recommended this course?

(1) Your college advisor (2) Other students (3) High School teacher
(4) Parents (5) Self

Who made the final decision?

(1) Advisor (2) Self (3) Self and Advisor

Have you had experience using an astronomical telescope?

(1) Yes (2) No

If your answer is Yes; would you be willing to help with the observing sessions for the General Astronomy class, and on public viewing nights?

(1) Yes (2) No

The following questions do not pertain to any requirements for this course. They are being asked for information only.

Which of the following High School courses have you taken?

(1) Algebra (2) Geometry (3) Trigonometry (4) Physics (5) Astronomy
(6) General Science

Which of the following College courses have you taken?

(1) Algebra (2) Trigonometry (3) Analytic Geometry (4) Calculus
(5) Physics

Have you decided on your college major yet?

(1) Yes (2) No

If your answer was Yes; please write your major in the following blank.

______________________________
College Major

APPENDIX B

ATTITUDE SCALE

Name ______________________

Please check the following as quickly and candidly as possible. Responses will not be considered until after final grades are determined.

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| Astronomy does not have any practical value. | 5 | 4 | 3 | 2 | 1 |
| The rings of Saturn are not really interesting. | 5 | 4 | 3 | 2 | 1 |
| I hope that I can see a major comet in the next few years. | 5 | 4 | 3 | 2 | 1 |
| Galaxies may be fascinating to some people, but I do not find them interesting. | 5 | 4 | 3 | 2 | 1 |
| Studying about binary star systems is interesting. | 5 | 4 | 3 | 2 | 1 |
| The Hubble classification of galaxies is a waste of time. | 5 | 4 | 3 | 2 | 1 |
| If OSU had another Astronomy course, I would enroll for it. | 5 | 4 | 3 | 2 | 1 |
| It is fascinating to think about living on another planet. | 5 | 4 | 3 | 2 | 1 |
| A telescope in space would be worth the effort to put it there. | 5 | 4 | 3 | 2 | 1 |
| I would not be interested in joining the American Association of Variable Star Observers. | 5 | 4 | 3 | 2 | 1 |
| Astronomy is not one of the more advanced sciences | 5 | 4 | 3 | 2 | 1 |
| I would not like to be an amateur astronomer. | 5 | 4 | 3 | 2 | 1 |
| Looking through a telescope becomes boring after a while. | 5 | 4 | 3 | 2 | 1 |
| I believe that a career in Astronomy would be a rewarding one. | 5 | 4 | 3 | 2 | 1 |
| I would like to know more about quasi-stellar sources. | 5 | 4 | 3 | 2 | 1 |
| OSU should not have an observatory of its own. | 5 | 4 | 3 | 2 | 1 |
| I think that Astronomy is so interesting that I am going to recommend it to my friends. | 5 | 4 | 3 | 2 | 1 |
| If there were more astronomers, the world would be a better place to live. | 5 | 4 | 3 | 2 | 1 |
| "Astronomical numbers" do not interest me. | 5 | 4 | 3 | 2 | 1 |
| It is interesting to know how the universe was formed. | 5 | 4 | 3 | 2 | 1 |
| The U.S. Space Program should concentrate more on research in Astronomy. | 5 | 4 | 3 | 2 | 1 |
| I plan to subscribe to <u>Sky and Telescope</u>. | 5 | 4 | 3 | 2 | 1 |
| I am not interested in trying to understand the H-R diagram. | 5 | 4 | 3 | 2 | 1 |
| The government should not spend more money on Astronomy. | 5 | 4 | 3 | 2 | 1 |

APPENDIX C

PRE-TEST

Astronomy 1104

Name ______________________________

In the interest of trying to improve this course in Elementary Astronomy, you are about to participate in an activity that may prove to be frustrating. You may not be able to do some of the things that you will be asked to do in the next few minutes, but DO NOT WORRY! This exercise will not influence your final grade in this course one way or the other, nor will the results of your work on this exercise predict your final grade in this course, so DO NOT WORRY!

If you have now laid your worries aside, and it is hoped that you have, then one more admonition, please do your best, in other words, try as hard as you can.

Your cooperation is greatly appreciated.

1. Before you are the pictures of six astronomical objects, each identified with a number. Each of these objects is at a different distance from our Sun. Rank these objects according to their distance from the Sun by placing the number of the object in the proper blank.

| | |
|---|---|
| ________ Closest to the Sun | ________ 4th |
| ________ 2nd | ________ 5th |
| ________ 3rd | ________ Farthest from the Sun |

Each of these same six objects has a different true size. Rank these objects according to their true size by placing the number of each object in the proper blank.

| | |
|---|---|
| ________ Largest | ________ 4th |
| ________ 2nd | ________ 5th |
| ________ 3rd | ________ Smallest |

2. Before you is a picture of the surface of the Moon. Certain features are pointed out by numbered arrows. A single arrow with a given number is used to point to small distinct features, while two arrows bearing the same number are used to point out a feature that is found immediately between them. Below you will find a list of the names of lunar features, each being preceeded by a blank. Place the number found on each of the arrows in the picture in the blank that preceeds the name of that feature.*

| | |
|---|---|
| ________ crater | ________ highlands |
| ________ walled plain | ________ limb |
| ________ mare (sea) | ________ ray |
| ________ rill | ________ dome |
| ________ terminator | ________ mountains |

*More than one arrow may be pointing at a feature having the same name. In that case, that blank would contain two or more numbers.

3. Before you are the spectrograms of four different stars. Rank these stars from the coolest to the hottest by placing the number of each spectrogram in the appropriate black given below.

_______ Coolest _______ 2nd _______ 3rd _______ Hottest

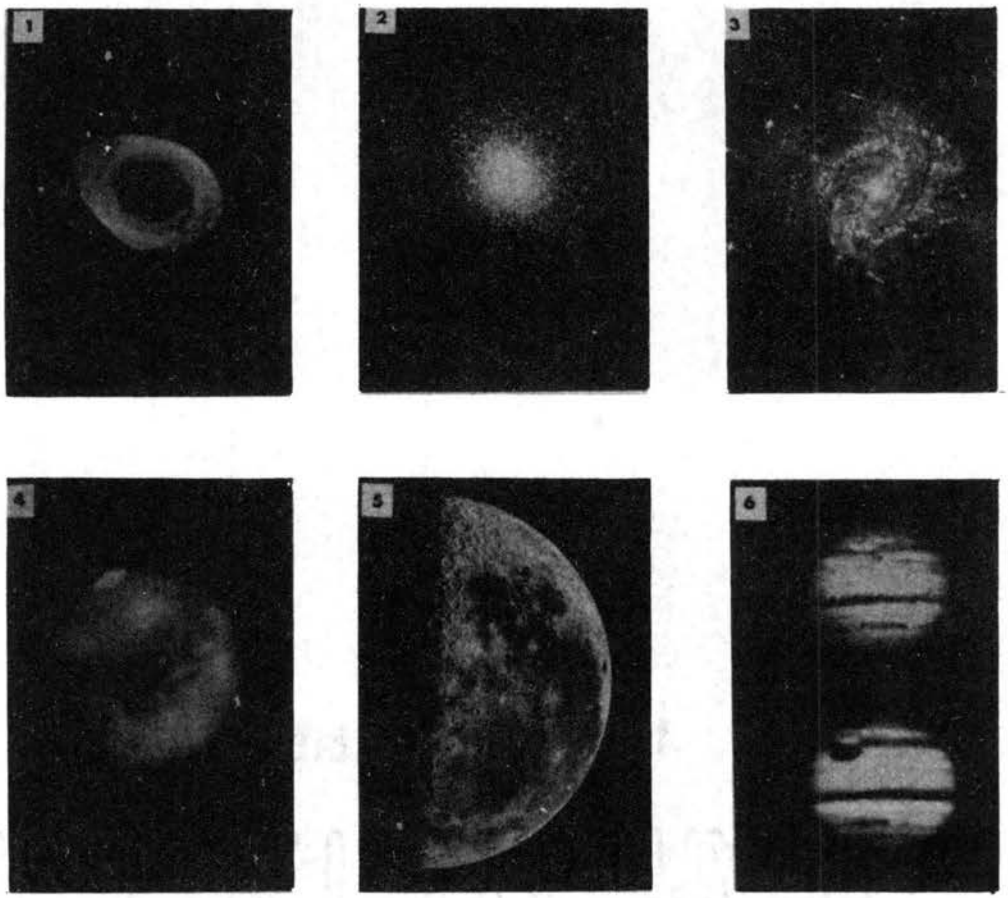



Figure 1. Photograph used for question #1 on the pre-test

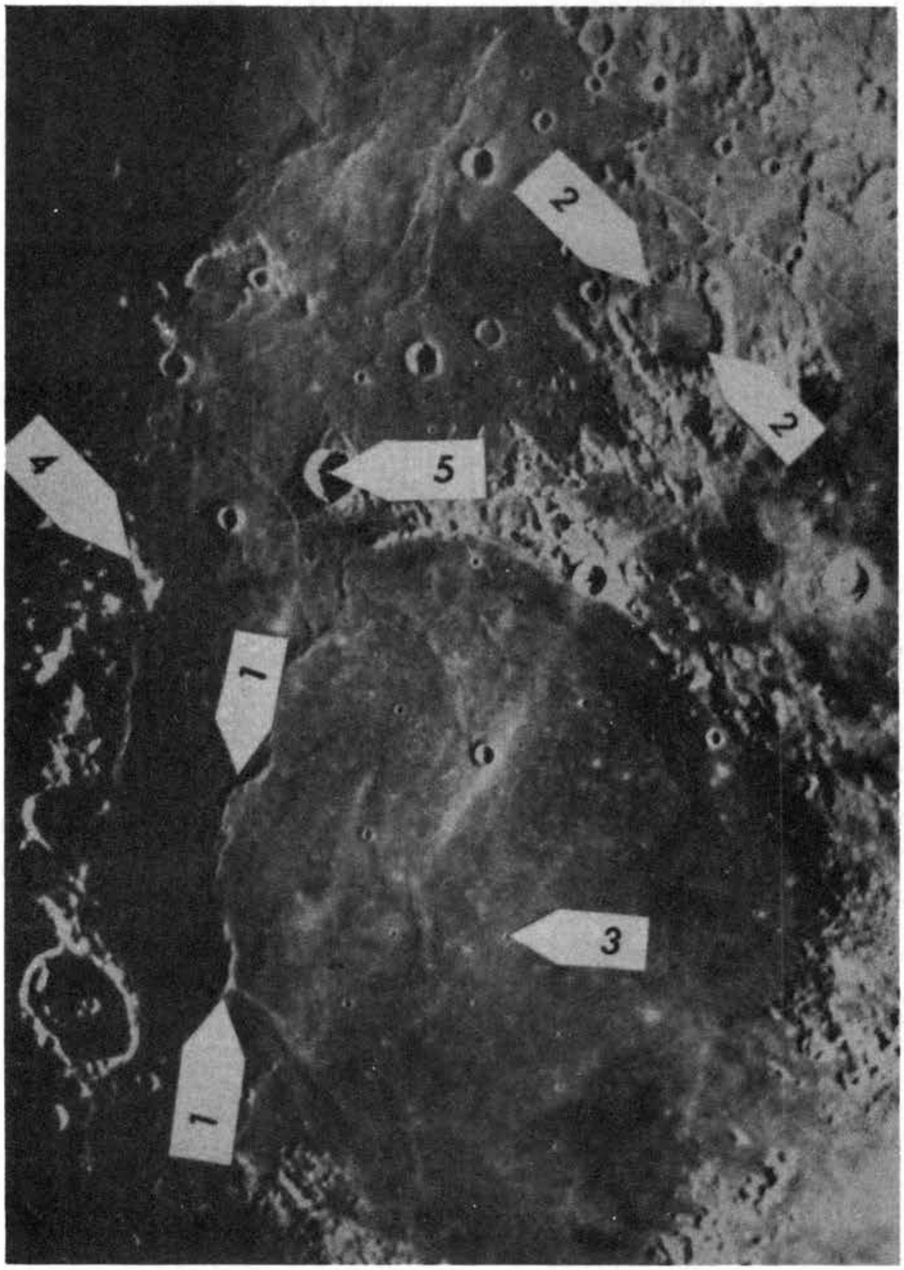



Figure 2. Photograph used for question #2 on the
pre-test

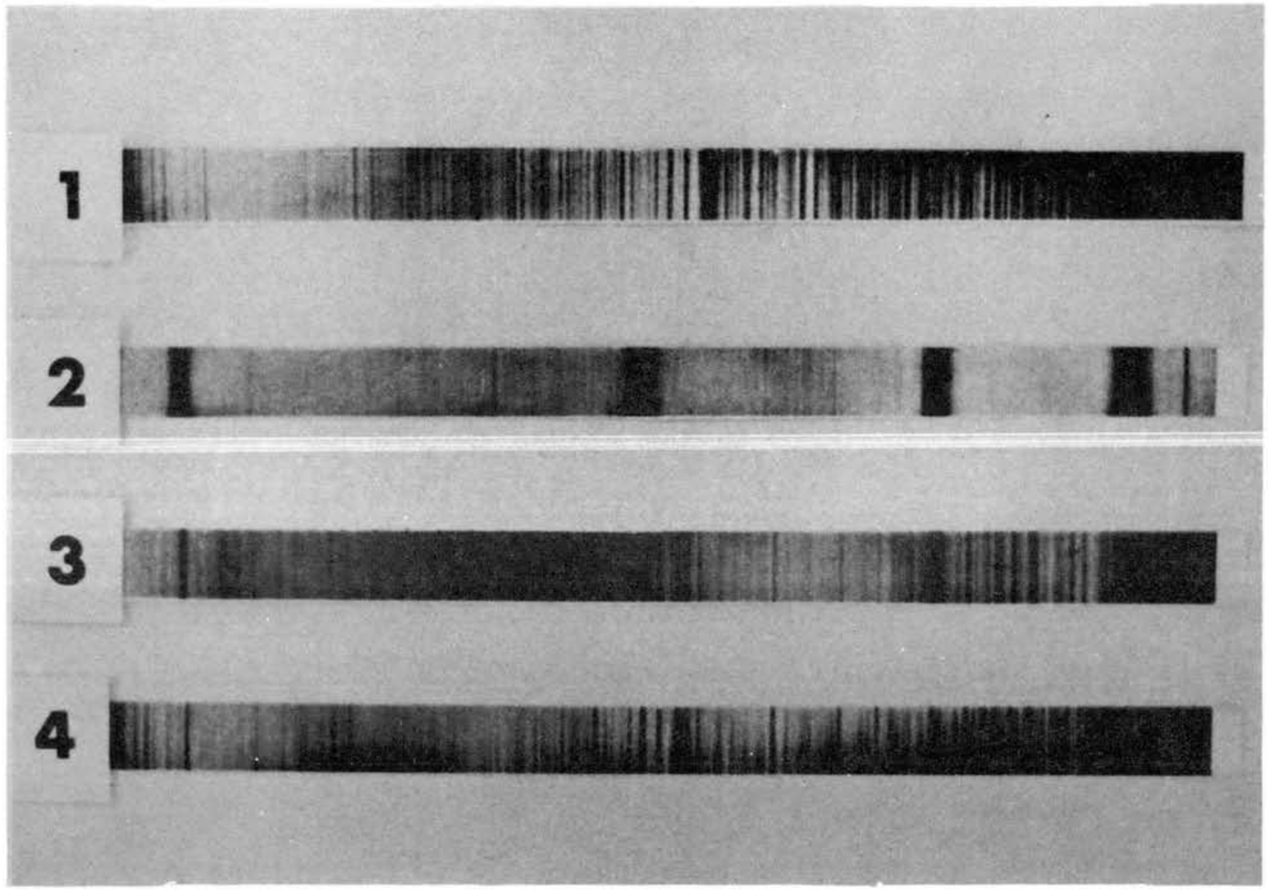



Figure 3. Photograph used for question #3 on the pre-test

4. Before you is a white light photograph of the Sun. Certain features are pointed out by the numbered arrows. A single arrow having a given number is used to point out small distinct features, while a pair of arrows bearing the same number is used to point out larger features that are found between the arrows. Below is a list of the names of solar features, each preceeded by a blank. Place the number found on each of the arrows in the photograph in the blank that preceeds the correct name of the feature.*

| | |
|---|---|
| ________ sunspot | ________ spot umbra |
| ________ spot group | ________ spot penumbra |
| ________ pore | ________ granulation |
| ________ limb | ________ faculae |

*More than one arrow may be pointing at a feature having the same name. In that case, that blank would contain two or more numbers.

5. Before you is a picture of six different galaxies. Classify each of these by placing the number of each galaxy in the blank which preceeds its proper Hubble classification given below.

| | |
|---|---|
| ________ Sa | ________ E1 |
| ________ Sb | ________ E3 |
| ________ Sc | ________ E5 |
| ________ SBa | ________ E7 |
| ________ SBb | ________ Irr |
| ________ SBc | |

Using modern theories of galactic evolution, rank these six galaxies from oldest to youngest by placing their number in the proper blank below.

| | |
|---|---|
| ________ Oldest | ________ 4th |
| ________ 2nd | ________ 5th |
| ________ 3rd | ________ Youngest |

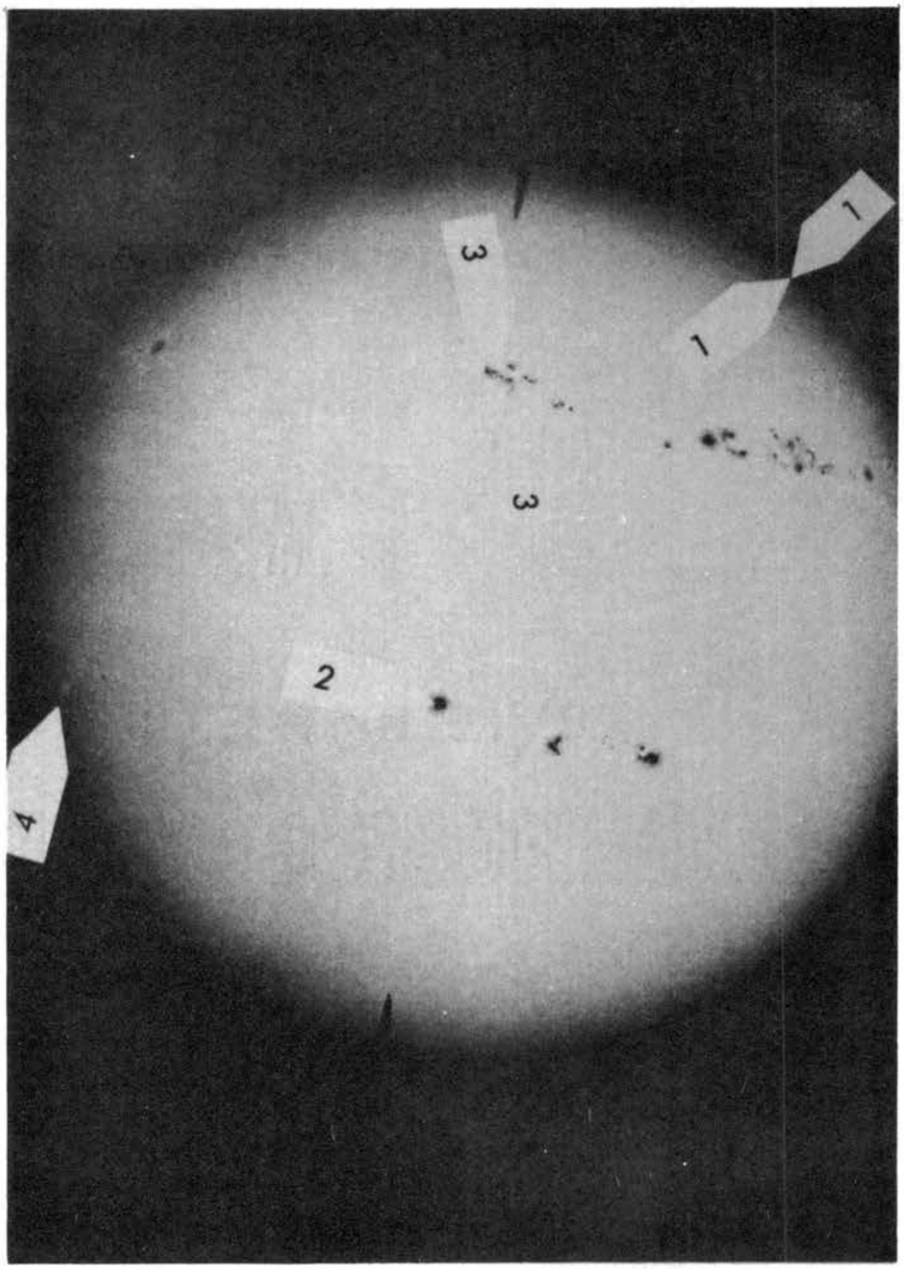



Figure 4. Photograph used for question #4 on the pre-test

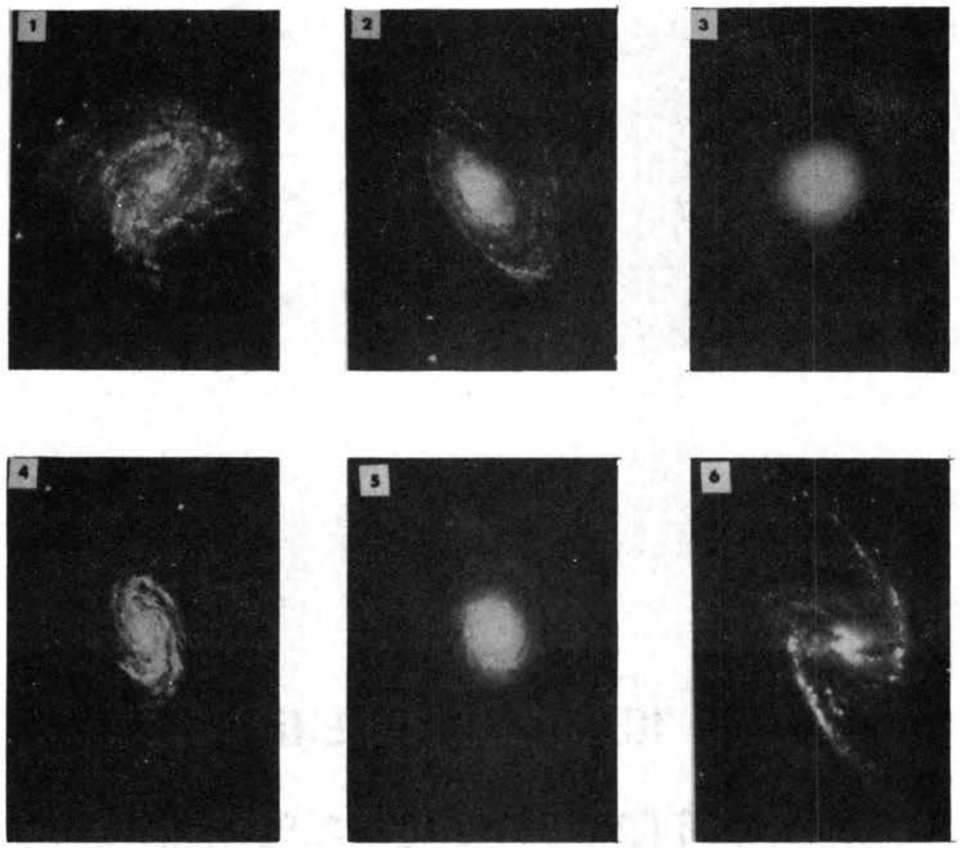


Figure 5. Photograph used for question #5 on the pre-test

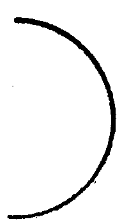
6. Below are the three steps of the Proton-Proton Reaction. Following each step, write a sentence in plain language stating what the nuclear equation says symbolically.

1. ${}_{1}H^{1} \quad + \quad {}_{1}H^{1} \longrightarrow {}_{1}H^{2} \quad + \quad {}_{+1}e^{0}$

2. ${}_{1}H^{2} \quad + \quad {}_{1}H^{1} \longrightarrow {}_{2}He^{3} \quad + \quad \text{gamma ray}$

3. ${}_{2}He^{3} \quad + \quad {}_{2}He^{3} \longrightarrow {}_{2}He^{4} \quad + 2\,{}_{1}H^{1}$

7. Starting with the semi-circle given below, draw a cross-sectional view of the Sun's photosphere, chromosphere, and corona. Clearly label each of these regions and indicate the temperature of each region in °Kelvin on this same diagram. Still using the same diagram, indicate by marking and labeling the location of sunspots, prominences, and flares.



8. Below you will find (a) a list of names of types of variable stars, and (b) several descriptions of stars belonging to one of these types. Classify each star described by placing the letter corresponding to its description in the blank preceeding the description.

A. Cepheid
B. RR Lyrae
C. Spectrum Variables
D. RV Tauri
E. Novae
F. R Corona Borealis
G. P Cygni
H. Supernovae
I. Flare Stars

________ An eruptive variable which begins and ends as a subdwarf star that reaches an absolute magnitude of -6 to -9 at maximum which is reached very rapidly followed by a slow decline in brightness lasting several months.

________ A yellow supergiant star which pulsates regularly with a period of from 3 to 50 days. This type of variable star has a period-luminosity relationship. The rise to maximum is rather rapid with slower decline in brightness.

________ Main sequence stars which suddenly become brighter for a few minutes and then return to normal brightness.

________ The most spectacular of the eruptive variables about which little is known because of their rarity. These variables reach an absolute magnitude of -14 to -18 or even -20 and are followed by the presence of a shell of expanding gas around them.

9. The following is a list of five planets found in the solar system. Rank these planets in the order that they would be found starting from the Sun and going outward. Place a 1 in the blank preceeding the closest planet, a 2 for the second closest, etc.

________ Uranus
________ Pluto
________ Venus
________ Earth
________ Saturn

The following is another list of five planets. Rank this list according to their diameters (size) beginning with 1 for the largest, 2 for the second largest, etc.

________ Mercury
________ Mars
________ Earth
________ Saturn
________ Neptune

10. Below are five descriptions of various stages of evolution of stars. Rank these from the earliest to the latest stages by placing a 1 in the blank preceeding the earliest, 2 second, etc.

_______ Nuclear fusion produces heavy elements.

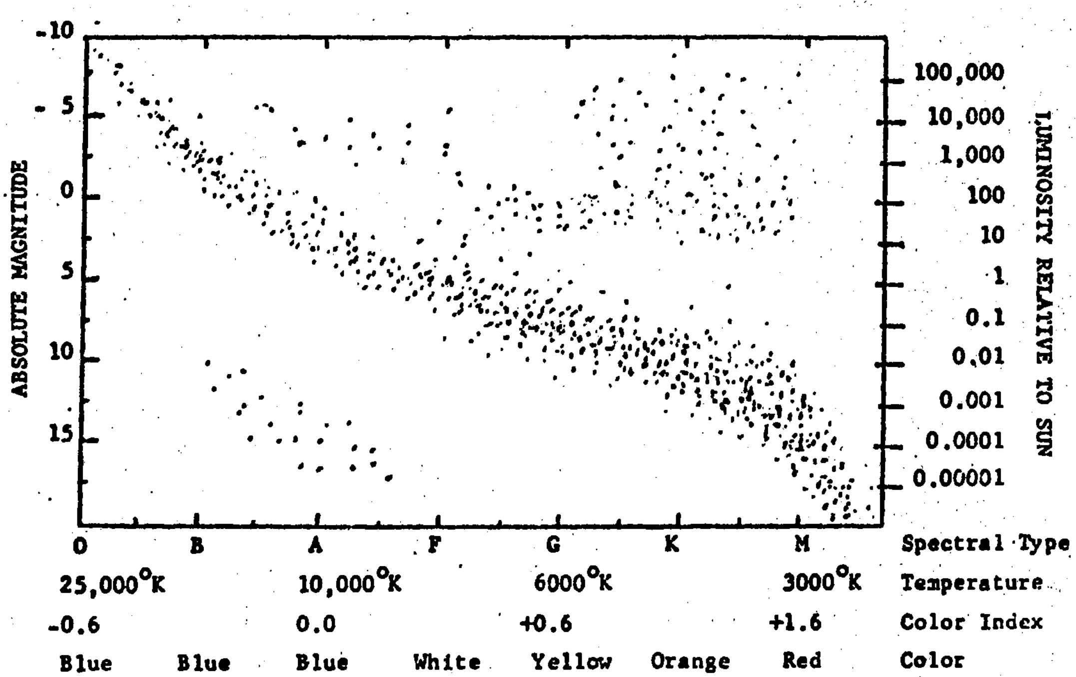
_______ Thermal and mechanical equilibrium is established.

_______ Nuclear reactions begin to take place at the center of the star.

_______ Gas and dust contracts into a region of greater density.

_______ A large portion of the stars' mass is violently ejected into space.

11. Using the descriptions given above, draw a connecting line around all of those stars represented on the H-R diagram given below that are in that stage of evolution. Identify each group by clearly labeling the areas enclosed by your lines with the same rank number that you gave them above.



12. Below are five descriptions of planets in our solar system. Write the name of the planet being described in the blank preceeding the description. A given planet may be described here more than once.

_______________ This planet exhibits distinct seasonal changes including polar ice caps that grow and recede, the temperature reaches about 85°F on the equator.

_______________ This planet is mostly hydrogen (maybe up to 65%). A mysterious red spot can be seen in its atmosphere.

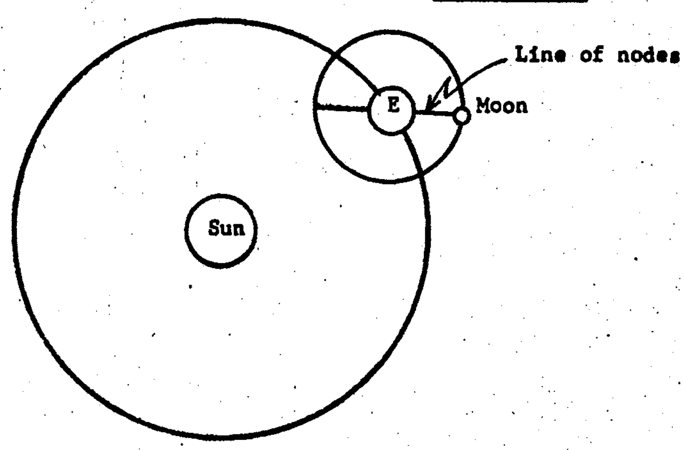
_______________ This planet's axis of rotation is inclined 82° from the perpendicular to the plane of its orbit. This planet is near the limit of visibility to the unaided eye.

_______________ This planet would float in water, if an ocean large enough could be found. Bands of color are seen in the atmosphere of this planet.

_______________ This planet is named for the god of the underworld. This planet can sometimes be found inside the orbit of its nearest plantary neighbor.

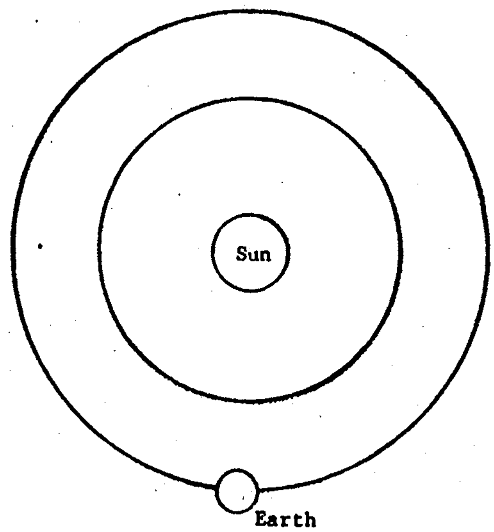
13. Below is a diagram showing the sun, the earth, the moon, and the line of nodes of the moon as seen looking down from the north. On this same diagram, sketch in and label the new positions of the earth, the moon, and the line of nodes of the moon as they would appear at the time of the next solar eclipse. It is assumed that this eclipse would take place at the optimum time, i.e. in the middle of the eclipse season. Estimate how much time, in months, will elapse before this event takes place.

_____________ months.



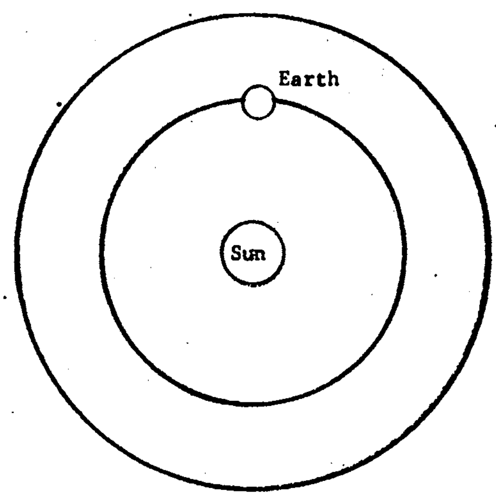
14. Below is a diagram of the sun, the earth, the orbit of the earth, and the orbit of an inferior planet (a planet between the earth and the sun) as seen from the north looking downward. On this diagram, mark the position of the inferior planet when it is at each of the points given in the accompanying list, and label that position with the letter it has in the list.

A. Superior conjunction
B. Inferior conjunction
C. Greatest eastward elongation
D. Greatest westward elongation




15. Below is a diagram of the sun, the earth, the orbit of the earth, and the orbit of a superior planet (a planet beyond the earth) as seen looking downward from the north. On this diagram, mark the position of the superior planet when it is at each of the following points given in the accompanying list, and label that position with the letter it has in the list.

A. Opposition
B. Conjunction
C. Western quadrature
D. Eastern quadrature



16. Below are two lists, one is a list of the methods of measuring astronomical distances, the other is a list of astronomical objects. Indentify all of the suitable methods of measuring the distance to these objects by placing the letters of those methods in the blank which preceeds each object.

A. Stellar parallax
B. Spectroscopic parallax
C. Dynamical parallax
D. Interstellar lines
E. Pulsating Variable Stars
F. Eruptive Variable Stars
G. Red Shift

__________ A star that is within a few light years of the sun.

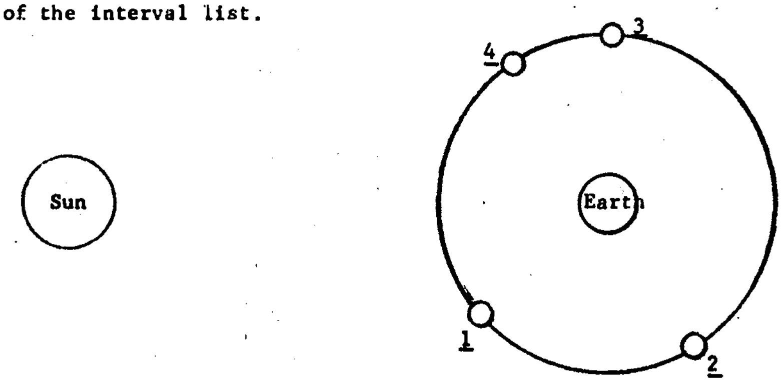
__________ A star whose spectral class and luminosity type are known that is within our galaxy.

__________ A binary star system in our galaxy.

__________ A globular star cluster.

__________ A very distant galaxy.

17. Below is a diagram of the Sun, Earth, and the Moon which is shown in four different positions as seen from the north looking down. Indicate the phase of the Moon and the interval of time that the Moon could be seen from a given spot on the earth by writing the number of that position once in a blank of the phase list and once in a blank of the interval list.




________ New Moon
________ Full Moon
________ waxing crescent
________ waning crescent
________ waxing gibbous
________ waning gibbous
________ 1st quarter
________ 3rd quarter

________ midnight - noon
________ 2 a.m. - 2 p.m.
________ 4 a.m. - 4 p.m.
________ 6 a.m. - 6 p.m.
________ 8 a.m. - 8 p.m.
________ 10 a.m. -10 p.m.
________ noon - midnight
________ 2 p.m. - 2 a.m.
________ 4 p.m. - 4 a.m.
________ 6 p.m. - 6 a.m.
________ 8 p.m. - 8 a.m.
________ 10 p.m. -10 a.m.

APPENDIX D

POST-TEST

Astronomy 1104
Final Test
Part A

Name______________________________

1. Before you are the photographs of six astronomical objects, each being identified with a number. Each of these objects has a different mass. Rank these objects according to their mass by placing the number on the photograph of the object in the proper blank below.

________ Greatest mass ________ 4th

________ 2nd ________ 5th

________ 3rd ________ Least mass

Each of these same six objects is located a different distance from the sun. Rank these objects according to their distance from the sun by placing the number on the photograph of the object in the proper blank below.

________ Farthest from the sun ________ 4th

________ 2nd ________ 5th

________ 3rd ________ Closest to the sun

2. Before you is a photograph of the surface of the moon. Certain features are pointed out by numbered arrows. A single arrow with a given number is used to point to a small distinct feature, while two arrows bearing the same number are used to point out a feature that is found immediately between them. Place the number found on each of the arrows in the photograph in a blank given below that precedes the name of that feature.*

__________ crater __________ highlands

__________ walled plain __________ limb

__________ mare (sea) __________ ray

__________ rill __________ dome

__________ terminator __________ mountains

*More than one arrow may be pointing at a feature having the same name. In that case, that blank would contain two or more numbers.

3. Before you are the spectrograms of four different stars. Rank these spectra from the coolest to the hottest by placing the number of each in the appropriate blank given below.

_______ Coolest _______ 2nd _______ 3rd _______ Hottest

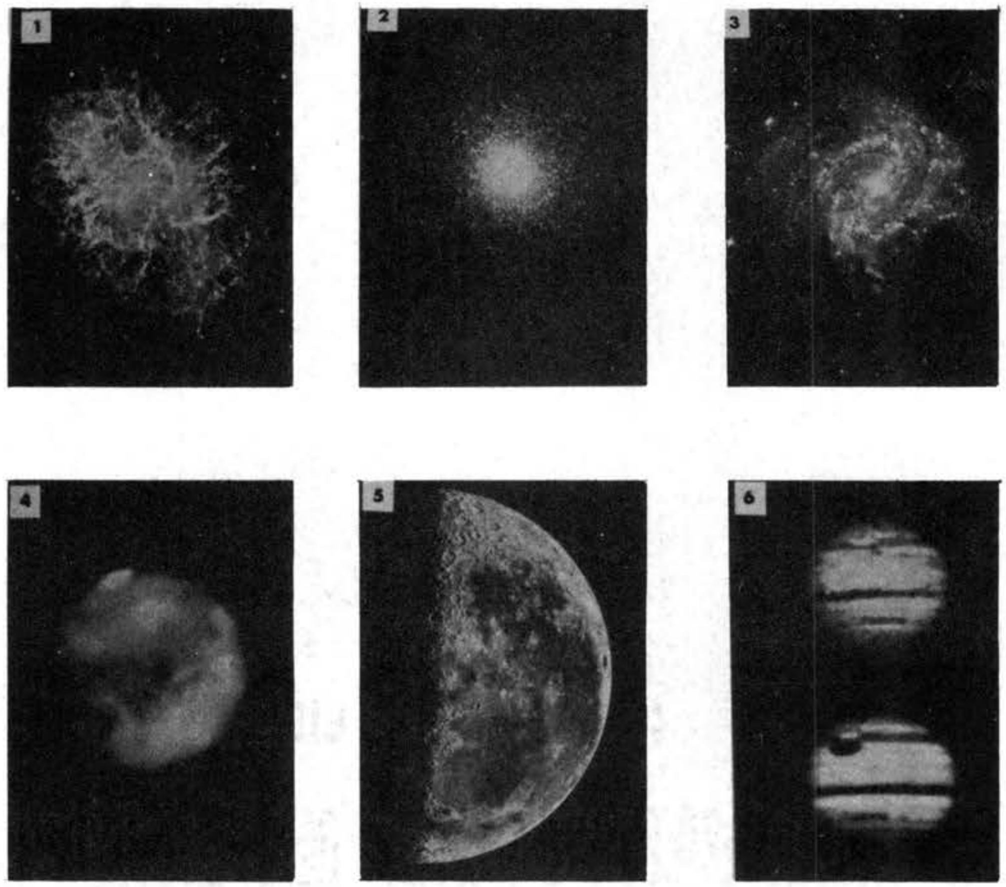


Figure 6. Photograph used for question #1 on the post-test

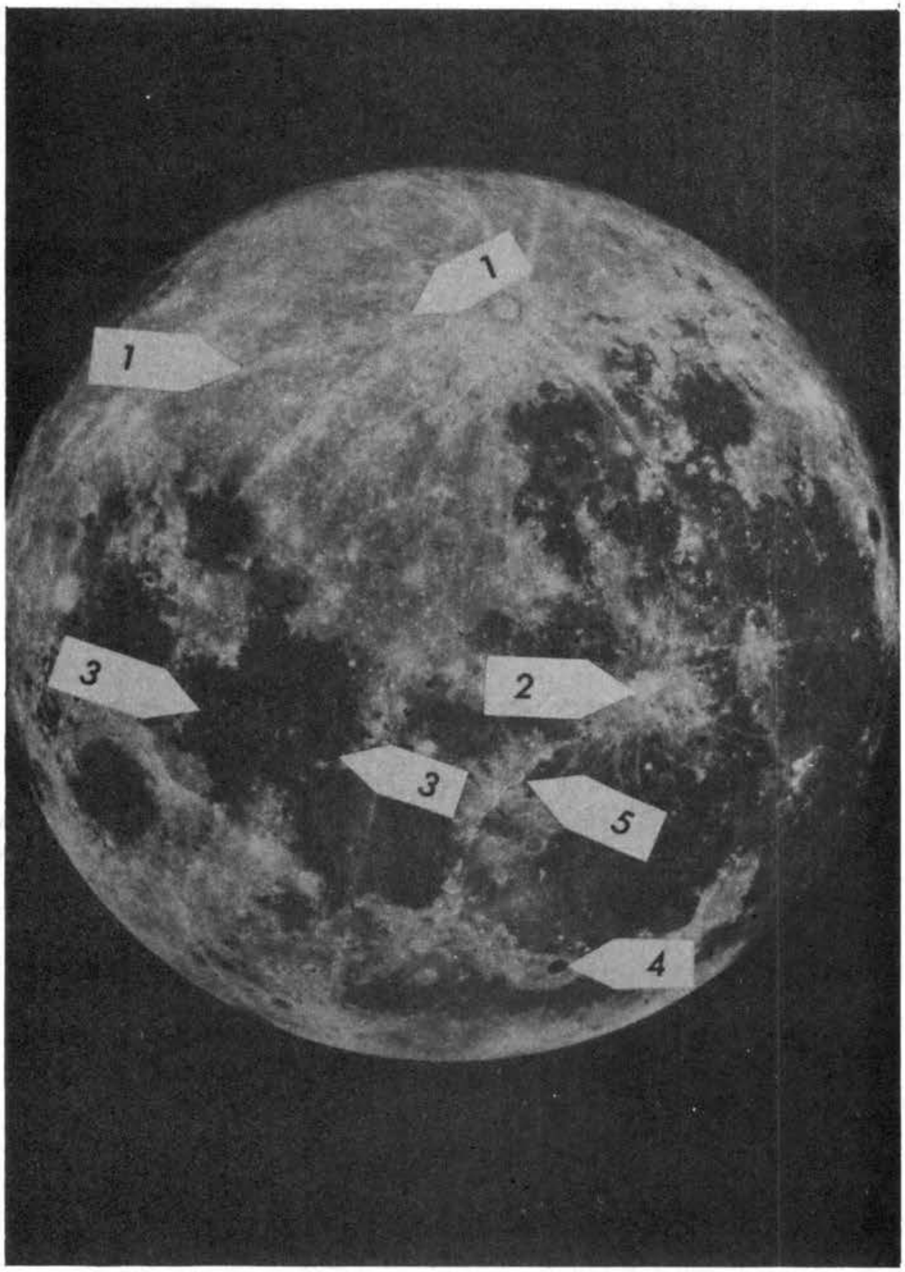



Figure 7. Photograph used for question #2 on the post-test

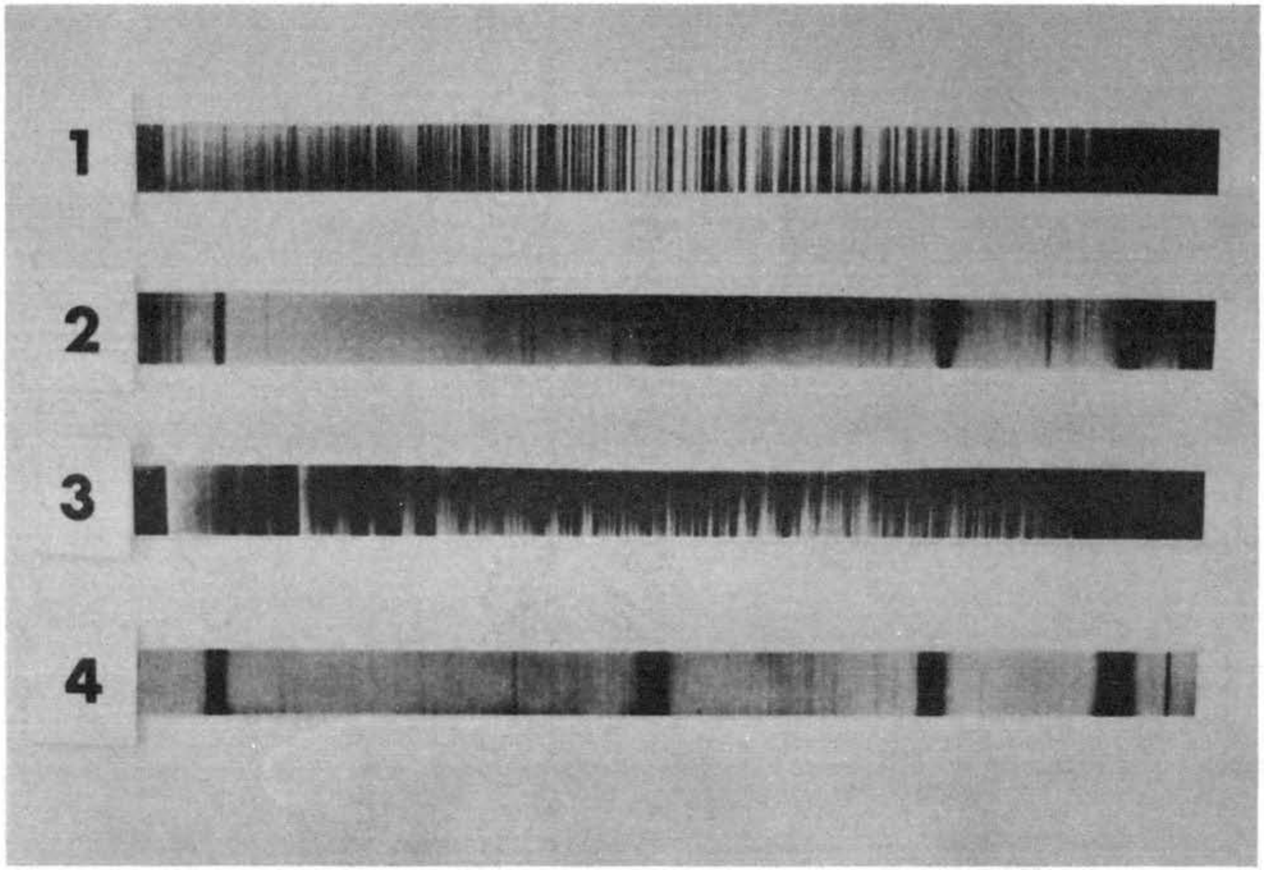



Figure 8. Photograph used for question #3 on the post-test

4. Before you is a white light photograph of the sun. Certain solar features are pointed out by numbered arrows. A single arrow is used to point out a small distinct feature and pairs of arrows bearing the same number are used to point out larger features that are found between the arrows. Place the number found on each arrow in the blank that precedes the correct name of that feature.*

| | | | |
|---|---|---|---|
| ________ | sunspot | ________ | spot umbra |
| ________ | spot group | ________ | spot penumbra |
| ________ | spot pore | ________ | granulation |
| ________ | limb | ________ | faculae |

*More than one arrow may be pointing at a feature having the same name. In that case, that blank would contain more than one number.

5. Before you are the photographs of six galaxies. Classify each of these galaxies according to their Hubble classification by placing the number on the photograph of each galaxy in the blank that precedes its proper Hubble classification given below.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ________ | Sa | ________ | SBa | ________ | S0 | ________ | E9 |
| ________ | Sb | ________ | SBb | ________ | E1 | ________ | Irr |
| ________ | Sc | ________ | SBc | ________ | E5 | | |

Using the present theory of galactic evolution, rank these six galaxies from youngest to oldest by placing their number in the proper blank below.

| | | | |
|---|---|---|---|
| ________ | Youngest | ________ | 4th |
| ________ | 2nd | ________ | 5th |
| ________ | 3rd | ________ | Oldest |

6. Below are the nuclear equations for the three steps of the Proton-Proton Reaction. In the blank spaces provided following each equation, write a sentence that states in plain language what the equation states symbolically.

$${}_1H^1 + {}_1H^1 \longrightarrow {}_1H^2 + {}_{+1}e^0$$

________________________________________________

________________________________________________

$${}_1H^2 + {}_1H^1 \longrightarrow {}_2He^3 + \gamma$$

________________________________________________

________________________________________________

$${}_2He^3 + {}_2He^3 \longrightarrow {}_2He^4 + 2\,{}_1H^1$$

________________________________________________

________________________________________________

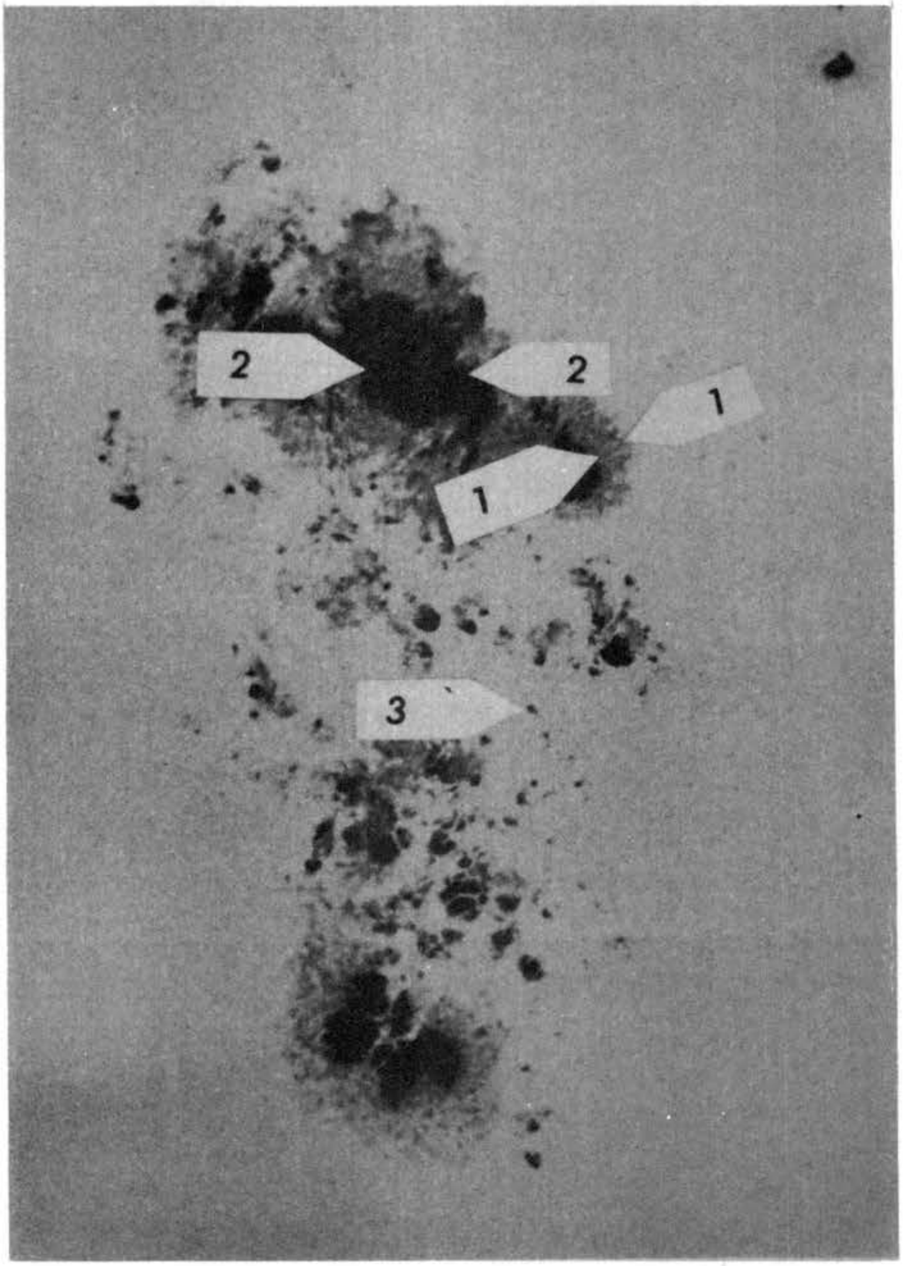



Figure 9. Photograph used for question #4 on the post-test

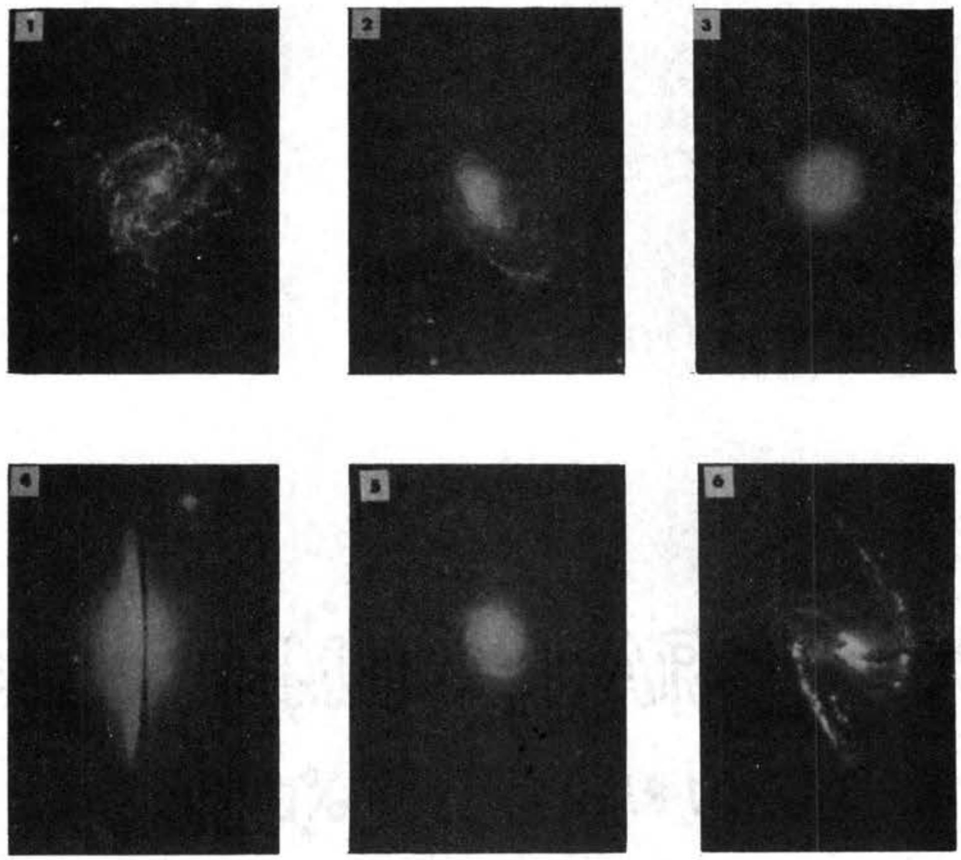
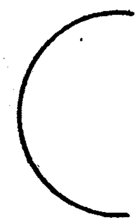


Figure 10. Photograph used for question #5 on the post-test

7. Using the semi-circle given below to represent the photoshpere, draw a cross-sectional view of the sun's chromosphere, and corona. Clearly label each region and indicate the approximate temperature in °Kelvin of each of these regions.



8. Place the letter preceding the name of the class of variable star in the blank which precedes the description of that class.

A. Type I Cepheid
B. Type II Cepheid
C. RV Tauri
D. Novae
E. Supernovae
F. RR Lyrae
G. P Cygni
H. Irregular Variables
I. Flare Stars
J. R Corona Borealis

________ A yellow supergiant star which pulsates regularly with a period of from 3 to 50 days. This type of variable star obeys the period-luminosity relationship.

________ An eruptive variable which begins and ends as a subdwarf star that reaches an absolute magnitude of -6 to -9 at maximum which is reached very rapidly followed by a slow decline in brightness lasting several months.

________ A red giant star of spectral class M1 having an absolute magnitude of -1 or greater. Mira (Omicron Ceti) is the best known of this class.

________ This class of variable belongs to spectral class A or F. With periods of 1 day or less, this class does not obey the period luminosity law.

________ Main sequence stars which suddenly become brighter for a few minutes and then return to normal brightness.

9. Rank the following list of five planets according to their sidereal periods of revolution about the sun. Place a 1 in the blank preceding the planet having the greatest sidereal period, a 2 for the second longest, etc.

________ Uranus
________ Pluto
________ Venus
________ Earth
________ Saturn

Rank the following list of five planets according to their mass. Place a 1 in the blank preceding the planet having the least mass, a 2 for the second smallest mass, etc.

_______ Mercury  _______ Mars

_______ Earth  _______ Saturn

_______ Neptune

10. Below are five descriptions of various stages of stellar evolution. Rank these stages from earliest to latest by placing a 1 in the blank preceding the earliest, 2 second earliest, etc.

_______ Nuclear fusion produces heavy elements.

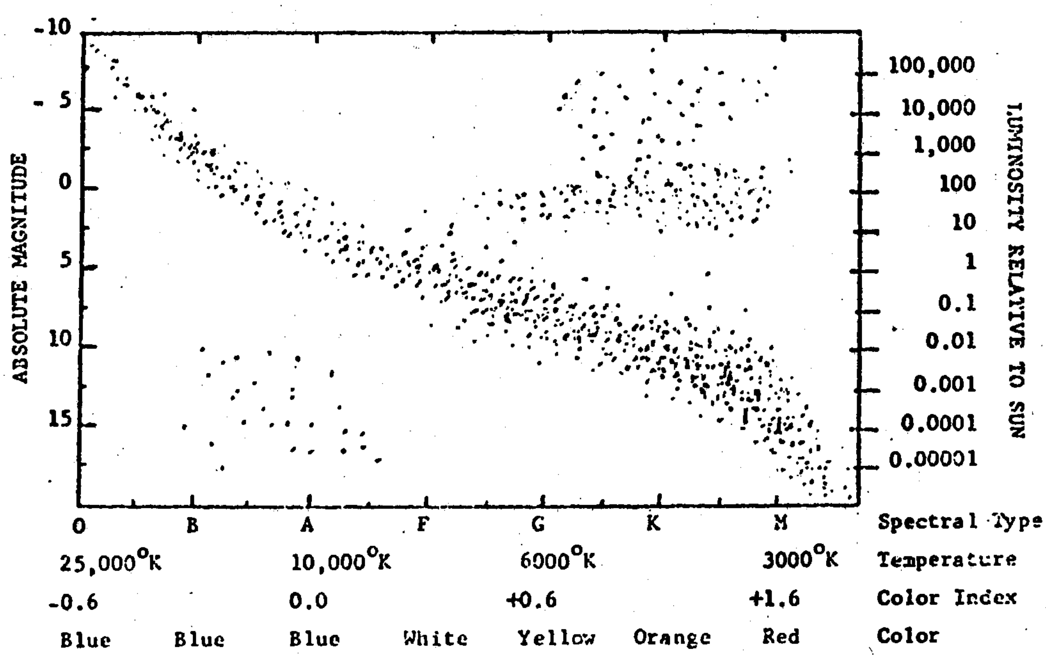
_______ Nuclear reactions have ceased, star cooling.

_______ Nuclear reactions begin at the center of the star.

_______ Thermal and mechanical equilibrium is established.

_______ Star is producing energy by gravitational contraction.

11. Using the descriptions given above, draw a line around all of the points on the H-R diagram which represent stars in that particular stage of evolution. Identify each group by clearly labeling the areas enclosed by your lines with the same rank number that you gave them above.



12. Below are five descriptions of planets in our solar system. Write the name of the planet being described in the blank preceding the description. A given planet may be described more than once.

_______________ Irregularities in the motion of this planet lead to the discovery of Pluto. Surface temperatures on this planet are far below zero on the fahrenheit scale.

_______________ The planet with extensive polar caps and which appears blue-white in color photographs.

_______________ The planet with four "Galilean" satellites. This planet has an atmosphere that exibits multi-colored bands parallel to its equator.

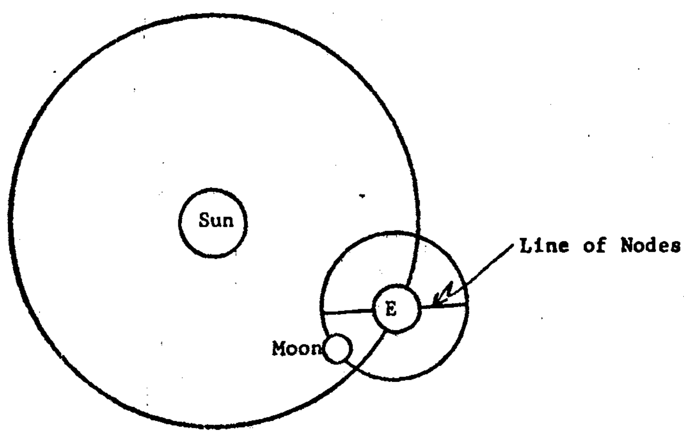
_______________ The planet having the lowest density of all the planets, the 10th natural satellite belonging to this planet was recently discovered.

_______________ This planet has the shortest period of rotation. Its atmosphere contains ammonia and methane.

13. Below is a diagram of the sun, earth, moon, and the line of nodes of the moon as seen looking down from the north. On this diagram, sketch and label the positions of the earth, moon, and the line of nodes of the moon as they would appear at the time of the next lunar eclipse assuming that this eclipse will take place at the optimum time, i.e., at the middle of the eclipse.

Estimate the time, in months, that will elapse before this event occurs.

_____________ months.



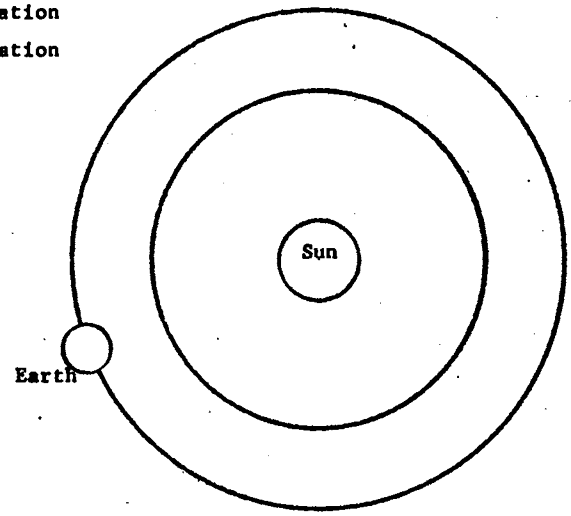
14. Below is a diagram of the sun, the earth, the orbit of the earth, and the orbit of an inferior planet as seen looking downward from the north. On this diagram, mark the position of the inferior planet when it is at each of the points in the accompanying list relative to the sun and the earth. Label each position with the letter given it in the list.

A. Greatest Eastward Elongation

B. Greatest Westward Elongation

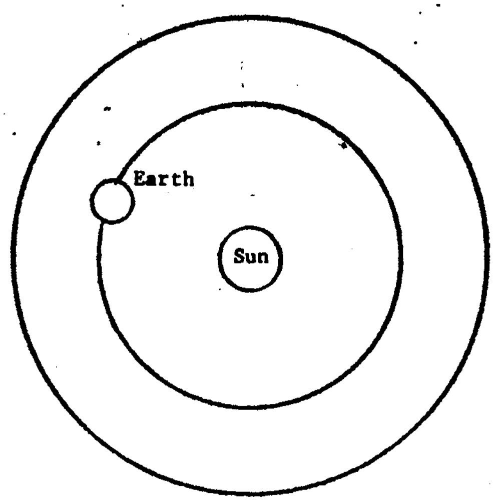
C. Inferior Conjunction

D. Superior Conjunction




15. Below is a diagram of the sun, the earth, the orbit of the earth, and the orbit of a superior planet as seen looking downward from the north. On this diagram, mark the position of the superior planet when it is at each of the points in the accompanying list relative to the earth and the sun. Label each position with the letter given it in the list.

A. Conjunction
B. Opposition
C. Eastern Quadrature
D. Western Quadrature

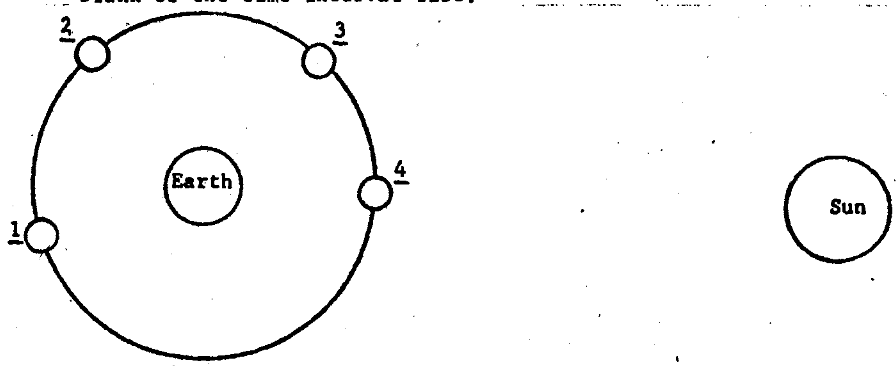


16. Below are two lists, one is a list of methods for measuring astronomical distances, the other is a list of astronomical objects. Identify the most suitable method of measuring the distance to each of these objects by placing the letter corresponding to that method in the blank which precedes the description of the object.

A. Stellar parallax
B. Dynamical parallax
C. Spectroscopic parallax
D. Interstellar lines
E. Cepheid variables
F. Novae
G. Red Shift

_______ Globular clusters.
_______ Very distant galaxies.
_______ Binary stars.
_______ Stars within a few light years of the sun.
_______ Single stars at a great distance from the sun.
_______ Near-by galaxies.

17. Below is a diagram of the sun, earth and moon as seen looking downward from the north. The moon is shown in four different positions relative to the sun and earth. Indicate the phase of the moon and the local time interval that the moon would be above an observers visible horizon for each of the four positions shown by writing the number of that position once in the appropriate blank of the phase list, and once in the correct blank of the time-interval list.




_______ New Moon
_______ Full Moon
_______ waxing crescent
_______ waning crescent
_______ waxing gibbous
_______ waning gibbous
_______ 1st quarter
_______ 3rd quarter

_______ midnight - noon
_______ 2 a.m. - 2 p.m.
_______ 4 a.m. - 4 p.m.
_______ 6 a.m. - 6 p.m.
_______ 8 a.m. - 8 p.m.
_______ 10 a.m. -10 p.m.
_______ noon - midnight
_______ 2 p.m. - 2 a.m.
_______ 4 p.m. - 4 a.m.
_______ 6 p.m. - 6 a.m.
_______ 8 p.m. - 8 a.m.
_______ 10 p.m. -10 a.m.

APPENDIX E

GENERAL INFORMATION SHEETS

ASTRONOMY 1104

SPRING 1971

| | |
|---|---|
| COURSE: | Elementary Astronomy--MWThF - 1:30 - Physical Sciences 141 |
| INSTRUCTOR: | Leon W. Schroeder |
| OFFICE: | P.S. 218 |
| OFFICE HOURS: | "Pot Luck" and by appointment - telephone extension 7525. NO calls at home, please. |
| TEXT: | An Introduction to Astronomy - Huffer, et. al. |

Hour examinations will be given as scheduled in the attached calendar. In addition to the four one-hour examinations, pop quizzes and take-home problems will be given during the semester. They will count the equivalent of one (1) hour-examination. Your grade will in part be determined on the basis of four hour examinations. This means that the lowest exam grade (or equivalent) will be dropped. NO makeup exams will be given. If you miss an examination, for any reason, your grade will be zero for that test and that score will then be the one dropped for the purpose of determining grades. The final examination will be over the entire semester's work and will count 20% of the semester grade. Exam papers will be returned as soon as possible. If you find an error in the grading and wish your exam to be reconsidered, it must be returned at the next class period with a written statement describing the error. This deadline must be met.

The following scale is tentatively adopted for letter grades corresponding to numerical grades. It is subject to revision at the end of the semester although this is unlikely since one examination is not counted.

| | |
|---|---|
| A | 90-100 |
| B | 80-89 |
| C | 70-79 |
| D | 50-69 |
| F | Below 50 |

Astronomy 1104

Section #2

Self-Paced--Individually Prescribed Instruction

In Elementary Astronomy

Self-paced--individually prescribed instruction? What does that mean?

Self-paced means that you can work at your own pace in this course. You can go right ahead just as fast as you want to go, the only limitation being that the course will terminate at the end of the semester.

Individually prescribed instruction means that you learn in a manner that suits you best. If you like to read all night and sleep all day, fine! All that will be required of you is that you get up long enough to come in and demonstrate that you have been learning. If, on the other hand, you can best learn by viewing films, or by working on projects in the laboratory, or by discussing the subject matter with your friends and/or the instructors, then that is the way you can proceed through this course.

All of this may be very new to you, but we feel that by working together that we can all enjoy learning. There will be a system, and here is how it will work:

(a) Your textbook will continue to be the basis for this course and should be consulted by you regularly. Basically, each chapter in your text will constitute a learning unit. There will be twenty such learning units in this course, and when you have finished all twenty, the course is just about finished for you. In addition to the twenty units, you will take a final exam on the day scheduled for a final exam in this course. There will also be another exam which will be given near the end of the semester. That exam will be announced well in advance so that you will not miss it.

(b) When you begin to work on a learning unit, you will be given a learning activities package which will include the following:

(1) A list of the learning objectives for that unit. These objectives will be stated in such a way that they will tell you what you will be expected to be able to do when you have completed that learning unit.

(2) A series of suggested learning activities. These activities will be so designed that they will help most of you to quickly and efficiently achieve the learning objectives.

(3) A series of self-assessment items. These will be several things that you can do to help you decide if you have achieved the learning objectives.

(c) When you feel that you are ready, you can ask your instructor to let you take the unit assessment. The unit assessment will consist of a series of activities for you to perform in order to demonstrate to the instructor that you have reached the objectives of that unit.

If you score 90% or better on the unit assessment, you are then given the learning activities package for the next unit.

(d) If you do not score 90% or better on your unit assessment, then your instructor will suggest additional activities for you to perform to help you prepare for the next attempt. In other words, you keep on working on the same unit until you can score 90% or better on the unit assessment. Should you take the unit assessment more than one time, you will be penalized 10% for each try, in other words the second time the maximum possible score will be 90%, the third time 80%, etc. You must still score 90% of the total to move on to the next unit.

(e) Your final grade in this course will be based on the following:

(1) The number of units that you have completed by the end of the semester.

(2) The number of times that you repeated unit assessments.

(3) The score you make on the two final tests. (20%)

One point should be emphasized here, and that is there is no reason why everyone in this section cannot receive an A for this course. There will be no learning objectives that are so difficult that everyone cannot reach these objectives. The important thing is to get started early and work to stay on a schedule.

(f) The final point is that as a part of the system we want to see you at least once a week. Check in at the Astronomy Learning Laboratory to sign-in, say hi, and let us know how you are doing.

It will become clear to you how this course operates after a very short time, but in the meantime you may find it helpful to read the list of questions and answers on the following pages. Keep one thing in mind, all of this is being done in an effort to help you learn more astronomy faster and more efficiently than you otherwise might. With your cooperation, it is hoped that you will learn more astronomy, and enjoy doing it.

For Your Information
Astronomy 1104
Section #2

No lectures in Astronomy?

That may not be exactly true. If an instructor has something so important to say that he feels a lecture is necessary for him to say it, a lecture will be scheduled and announced well in advance on a bulletin board in the Astronomy Learning Laboratory. But here is the nice part, you can come if you want to, but if you are busy with something else, or if the topic sounds boring to you, then do not come. Your attendance will not affect your grade, one way or the other.

When and where will you come to class?

There will be no more classes as such, from now on you will come to the Astronomy Learning Laboratory located in Physical Sciences 107. When you come to the Learning Laboratory, you are asked to sign-in, and when you leave, sign-out. While you are there you can take a unit assessment, if you are ready, or you may work on the suggested activities for the unit you are currently working on by using the equipment and other learning aids that have been set up for you. You may just come in to check on the latest information in Sky and Telescope, or to tell the instructor that you are bored. In any case, the center for this course for you from now on will be the Astronomy Learning Laboratory. In the beginning, the Learning Laboratory will be open 2:30-5:00 p.m. daily. This schedule is flexible and can be changed on demand. (Usage)

Must you work alone?

No! As a matter of fact, you are encouraged to work with two or three other students who are taking this same course in this same section. The only time that you will really need to work alone is when you are taking the unit assessments, and during the final tests.

Should you try to attain more than the minimal standards?

Positively!!! We hope that you will want to do more than just "get by". The more effort that you make above this minimum, the more you will learn. How much do you really want to learn, the minimum or more? It's your education for your future, and you are paying for it. You be the judge, but if you decide that you want to do more, the facilities of the Astronomy Learning Laboratory, and more, are yours. Try it sometime.

Must you do the learning activities?

Our recommendation is a strong Yes! Why? First, we think that you will enjoy many of the activities. And second, we have observed that many students like to kid themselves into thinking that they can do certain things when they really can't. Imagining what you can do and being able to do it are quite different. It's a human trait, and we all do it. In any case, should you fail to score 90% or better on your first try on a given unit assessment, you will be asked to do the learning activities before you are given a second chance.

Experience has taught us that 9 out of 10 times a student will be successful the first time if he has performed the learning activities carefully and thoughtfully.

Must you attend the film showings?

Again, our recommendation is - yes. The list of films that you have been given has been set up to coincide with the textbook discussions of various topics in astronomy at about the time you would be working on these topics if you were proceeding through the course at a "normal" rate. If you have already completed the unit which includes the topics of the scheduled films, then all the better, the film will now provide you with the opportunity to learn more about these topics. If you have not yet reached the unit involved, then the films could be helpful to you in the sense that they may give you a head start on that unit. In any case, it is recommended that you attend, but as in the case of the lectures (if any), your attendance or non-attendance will have no effect on your final grade in this course one way or the other.

How fast should you progress?

As stated previously, there are 20 units in Elementary Astronomy. There are about 16 weeks in the semester. That means that you should complete about 1.25 units/week. Do not, however, count on the fact that the last unit is as easy as the first. On the average you should try to complete at least two units a week, in that way by the time those units that require a little more time come around, you will have the extra time to devote to them. None of you should have any difficulty in completing all of the units before the end of the semester, if you do not procrastinate.

<u>Can you finish the course before the end of the semester?</u>

Sure, why not? With the exception of the two final tests, the sooner you finish the better. You will then have all kinds of extra time to devote to your other studies.

<u>What about the observing sessions?</u>

An integral part of any introductory astronomy course is the observing sessions. At these sessions you will each be given the opportunity to view with your own eyes the sights the heavens hold in store for you. Like the lectures (if any) and the film viewing sessions, the observing sessions are optional at your own discretion, however, it is strongly recommended that you give it a try, at least once.

At the beginning of the semester, the observing sessions will be scheduled for every Tuesday night (weather permitting) at 8 p.m. Later on, observing sessions will be conducted whenever four or more of you request them at least 24 hours in advance. In addition, observing sessions will be held (weather permitting) whenever there is an event of special astronomical interest such as an eclipse, a comet, etc. Whenever possible, these sessions will be announced well in advance on the Astronomy Learning Laboratory bulletin board.

<u>Any more questions?</u>

If you have further questions, please ask your instructors. As you get started in Astronomy, Self-Paced, Individually Prescribed Instruction, the strange game you are playing will become clearer. We are here to help <u>you</u>.

Good Luck and Happy Learning!

FILMS FOR ASTRONOMY 1104

Section #2

Showings: 2:30 p.m., Physical Sciences 103

| DATE | TITLE |
|---|---|
| Jan 18 | UNIVERSE |
| Jan 28 | LIGHT WAVES AND THEIR USES<br>MEASUREMENTS OF THE SPEED OF LIGHT |
| Feb 1 | THE ASTRONOMER<br>CHARTING THE UNIVERSE WITH OPTICAL AND RADIO TELESCOPES |
| Feb 4 | THE STORY OF PALOMAR |
| Feb 10 | THE WANDERERS |
| Feb 17 | INTRODUCTION AND LOCATION OF CELESTIAL POINTS<br>CELESTIAL NAVIGATION - NAUTICAL ASTRONOMY |
| Feb 25 | THE VAN ALLEN RADIATION BELTS |
| Mar 3 | EARTH IN MOTION<br>CELESTIAL MECHANICS AND THE LUNAR PROBE |
| Mar 4 | APOLLO FLIGHTS |
| Mar 8 | THE NEAREST STAR |
| Mar 11 | SUN IN ACTION<br>SOLAR PROMINENCES |
| Mar 18 | ECLIPSES OF THE SUN AND MOON |
| Mar 29 | THE SOLAR FAMILY<br>JUPITER, SATURN, AND MARS IN MOTION |
| Apr 9 | EXPLORING THE UNIVERSE |
| Apr 15 | THE PLANETS |
| Apr 29 | HOW MANY STARS? |
| May 6 | THE REALM OF THE GALAXIES |

APPENDIX F

OBSERVING MANUAL

# Astronomy 1104

## Observing Manual

One of the most rewarding experiences known to man is to view with his own eyes the wonderous sights the heavens hold in store for him. At first glance through a telescope one tends to be somewhat disappointed by the fact that it is not possible to see the detail and brillance found in the modern astronomical photographs. However, even a modest telescope reveals many splendid sights not visible to the unaided eye. The time you spend observing will be most enjoyable and rewarding.

## The Purposes of the Weekly Observing Sessions

The three main purposes of the weekly observing sessions are:

1. To help you to become familiar with the night sky and the objects found in it.

2. To help you to learn the use of the astronomical telescope.

3. To help you to learn how to locate objects on the celestial sphere.

At the end of this semester you should be able to:

1. Properly set up and align an astronomical telescope equipped with an equatorial mount.

2. Properly adjust the setting circles on an astronomical telescope.

3. Be able to use the setting circles on an astronomical telescope to either (a) locate an object having a known position on the celestial sphere, or (b) to describe the location on an object on the celestial sphere.

4. Be able to locate any three of the major visible constellations by pointing them out with a flashlight beam to the instructor.

## Preparation for Observing Sessions

In the beginning you will find yourself feeling frustrated and confused by the apparent complexity of astronomy. No one can learn everything they need to know in a short time, so first of all be patient with yourself and you will be amazed at just how rapidly you do learn.

Your work in the classroom will provide you with a great deal of helpful information but there are other good sources of information with which you should become familiar. In addition to many good reference books in the library, you should consult the monthly magazine entitled, <u>Sky and Telescope</u>.

This excellent magazine is found on the periodical shelves on the main floor of the library. Two sections of this magazine are of particular interest and should be consulted before each observing session which you attend. They are, the <u>Observers Page</u> and <u>Wondering Through (Name of Month) Skies</u>. As you read these sections, make some notes about what you would like to observe and bring those notes along with you to the observing session.

## The Telescope

The following section on the telescope will help you to become familiar with the instrument and its operation. You should read this section carefully, but do not worry if you do not understand all of it at first. It will become clear to you as you use the telescope.

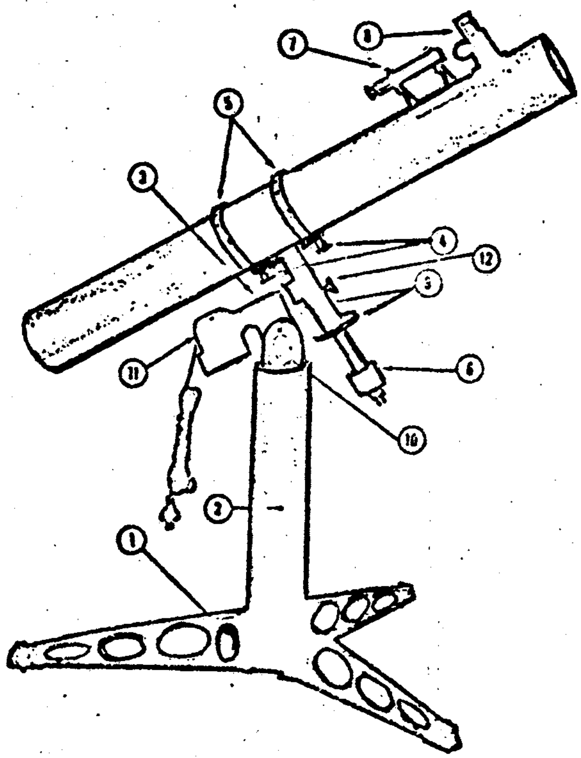
<u>A word of caution</u>! While the telescope is not a delicate instrument, it can be damaged through misuse and abuse, so the best rule of thumb is, USE COMMON SENSE.

In addition, do not make adjustments that you are not familar with, and do not <u>force</u> anything. If it will not move, ask the instructor to help you.

## Some More Hints

1. Bring your Star and Satellite Path Finder to the observing sessions.
2. A small pocket-size flashlight is useful, if you have one.
3. Any pair of binoculars are very useful when observing the heavens. If you have access to a pair, bring them along.
4. Be prepared to face the elements, i.e. dress warmly enough if the weather is cool, bring mosquito repellent if you think it might be needed, etc.

INSTRUCTIONS FOR MODEL RV-6, SIX INCH DYNASCOPE




(1) Three outriggers are assembled to the pier by means of wing nut at this point.

(2) Pier. When outriggers are secured pier should be solid. Adjust riggers till most stability is reached.

(3) Equatorial Head complete. This head is packed in some instances, separately and should be fastened to base at top of pier. The entire head should be adjusted at (10), to correspond with the latitude at your observing station. With Electric Drive Housing falling South, the Equatorial Head and the telescope should point North and lie in a north to south line as in photo. When lined up on the North Star, the Head is locked in position and ready for celestial operation. If mount is moved to another location, readjustment may be needed.

(4) Saddle and locks. The telescope is fastened to the Saddle at this point and can be removed whenever desired.

(5) Adjustable circular cradle. Permits moving the telescope into the best position for balance and eye level. As accessories or various eyepieces are added, which cause an unbalanced condition, you need only to loosen the adjusting nuts and reposition the telescope tube so it is at proper balance. It is a good idea to mark the positions of best balance if rings are removed from the telescope.

(6) Counterweight. Balances entire weight of telescope. Should never be removed while telescope is mounted as the telescope would fall. A number of weights are provided and although they have been adjusted to the shaft, should be checked and readjusted to the shaft, should be checked and readjusted for telescope weight.

(7) 6 X 30 Finderscope and adjusting bracket. The adjustments on bracket will enable you to align the finder so it points at exactly the same point as the telescope proper. When object seen in center of eyepiece of telescope is also in center of cross hairs in finder, alignment is OK.

(8) Double draw eyepiece holder. Has inner section which should be withdrawn part way to hold 1¼" eyepiece. Focus then by rack and pinion. Long focal length eyepieces as well as negative ones can thus be used. Three eyepieces are furnisned.

(9) Setting Circles are fully adjustable. Knurled lock screws. (10) Polar axis should be adjusted to your latitude. This can be done by adjusting the head angle to point at North Star. Easy way is to sight on the North Star thru the telescope and lock into position. When scope is rotated about the polar axis, it will be following objects in their respective paths. Declination axis, locked by adjustment (12) is for altitude and is locked when scope is used about the polar axis.

(11) Electric Drive motor.

## HOW TO USE THE SETTING CIRCLES

Attached to the Polar Axis is a graduated circle marked off in hours and minutes. This is an Hour Circle (sometimes referred to as "RA CIRCLE"), and its figures correspond to the co-ordinates of right ascension of celestial objects.

Attached to the Declination Axis is a graduated circle marked off in degrees, minutes, and seconds. These figures correspond to the co-ordinates of declination of celestial objects.

Note: Before the setting circles can be used correctly, the equatorial head of the telescope must be properly set to the latitude of the observing site. With the polar axis pointing at the true pole and fixed in that position (pointing the main telescope at Polaris is sufficient for most purposes) the declination circles should be set and fastened at 90 degrees.

The hour circle is "slip ring" type. To use the slip ring circle to locate stars you must first have a star chart or ephemeris giving the RA (right ascension) and declination co-ordinates of celestial objects.

Locate a bright known star, such as Vega, and note its right ascension at any given time. Train the main telescope so that this star is in the center of the field. Set the hour circle reading to correspond to the right ascension time of the known star. The hour circle is now in proper position for observing and need not be touched again for the rest of the night. The declination can also be used for other settings. From these, the position of other stars can be determined and brought into view by setting the instrument to the proper right ascension time on the slip circle and proper declination reading on the declination circle.

In order to pick up the second star, first look up and note its RA and Dec. Now, from this RA time, subtract the total amount of elapsed time since the first setting of circle on the known star to the moment. The result will be the correct new RA time of the second star. Now move the telescope so that the slip ring circle indicates this new RA time, and also adjust the declination to properly indicate the correct declination setting for the star. The second star should now be in the field of view.

You must keep track of the total elapsed time between the first setting of the night to the moment of change and subtract this total from the known RA time of each new star you are seeking. For example: let us say you have been observing the first star for 1/2 hour since the first setting, and you now wish to locate the second star which has an RA of 6h. Subtract the 1/2 hr from 6h and the new setting would be 5.5h. The Declination is always clamped firmly in its declination reading whereas the polar axis alone must move freely during observation.

THE TWENTY BRIGHTEST STARS

AND POLARIS

| Star Name | Constellation | Vis. Mag. | R. A. | | Decl. | | On Meridian at 8:00 p.m. |
|---|---|---|---|---|---|---|---|
| Sirius | Canis Major | -1.6 | $6^h$ | $43^m.6$ | $-16^\circ$ | $39'.9$ | Mar. 1 |
| Canopus | Carina | -0.9 | 6 | 23.2 | -52 | 40.5 | Feb.24 |
| $\alpha$ Centauri | Centaurus | 0.1 | 14 | 37.1 | -60 | 41.3 | Jun.29 |
| Vega | Lyra | 0.1 | 18 | 35.7 | +38 | 45.0 | Aug.30 |
| Capella | Auriga | 0.2 | 5 | 14.0 | +45 | 56.1 | Feb. 5 |
| Arcturus | Bootes | 0.2 | 14 | 14.0 | +19 | 22.1 | Jun.24 |
| Rigel | Orion | 0.3 | 5 | 12.8 | - 8 | 14.5 | Feb. 5 |
| Procyon | Canis Minor | 0.5 | 7 | 37.4 | + 5 | 19.1 | Mar.14 |
| Acherner | Eridanus | 0.6 | 1 | 36.4 | -57 | 25.2 | Dec.16 |
| $\beta$ Centauri | Centaurus | 0.9 | 14 | 01.3 | -60 | 12.0 | Jun.21 |
| Betelgeuse | Orion | 0-1v | 5 | 53.2 | + 7 | 24.1 | Feb.15 |
| Altair | Aquila | 0.9 | 19 | 49.0 | + 8 | 46.3 | Sep.21 |
| $\alpha$ Crucis | Crux | 1.0 | 12 | 24.6 | -62 | 54.0 | May 29 |
| Aldebaran | Taurus | 1.1 | 4 | 33.9 | +16 | 26.3 | Jan.26 |
| Pollux | Gemini | 1.2 | 7 | 43.1 | +28 | 06.9 | Mar.15 |
| Spica | Virgo | 1.2 | 13 | 23.3 | -10 | 58.4 | Jun.12 |
| Antares | Scorpius | 1.2 | 16 | 27.2 | -26 | 21.2 | Jul.27 |
| Fomalhaut | Piscis Austrinus | 1.3 | 22 | 55.7 | -29 | 48.8 | Nov. 8 |
| Deneb | Cygnus | 1.3 | 20 | 40.2 | +45 | 09.0 | Oct. 8 |
| Regulus | Leo | 1.3 | 10 | 06.5 | +12 | 08.6 | Apr.23 |
| Polaris | Ursa Minor | 2.1 | 1 | 59 | +89 | 06 | |

APPENDIX G

UNIT TITLES AND SAMPLE UNIT LEARNING PACKAGE

INTRODUCTORY ASTRONOMY

OKLAHOMA STATE UNIVERSITY

| | | |
|---|---|---|
| Unit | I | Introduction |
| Unit | II | The Nature of Light and Spectra |
| Unit | III | The Optics of a Telescope |
| Unit | IV | Kepler's Laws of Planetary Motion |
| Unit | V | The Coordinate Systems |
| Unit | VI | The Celestial Sphere |
| Unit | VII | The Planet Earth |
| Unit | VIII | The Earth as a Timekeeper |
| Unit | IX | The Moon |
| Unit | X | The Sun |
| Unit | XI | Eclipses |
| Unit | XII | The Solar System |
| Unit | XIII | Comets and Meteors |
| Unit | XIV | Stellar Spectra |
| Unit | XV | Variable Stars |
| Unit | XVI | Binary and Multiple Star Systems |
| Unit | XVII | The Galaxy |
| Unit | XVIII | The Universe |
| Unit | XIX | Astronomical Numbers |
| Unit | XX | Stellar and Galactic Evolution |

**Astronomy 1104**

**Section 2**

**Unit #2**

Everything that we know about the universe (with the exception of the earth and the moon) we have learned by studying the radiations (mostly light) that are sent to the earth by the stars and clouds of gas. To interpret the information that is being sent, we need to know something about the nature of the radiations that are bringing us this information. This knowledge allows us to infer the nature of the body that is sending the information (radiation).

Study chapter 3 in your textbook. Keep in mind that you should be learning the meaning of those words that are new to you.

As you are studying, see if you can find the answers to the following questions:

1. Under what three conditions does light <u>not</u> travel in a straight line?

   ----------------------

   ----------------------

   ----------------------

2. Why is it necessary to know the speed of light in a vacuum?

   ----------------------

3. Does light always travel at the same speed?

   ----------------------

4. What are the three sources of continuous spectra?

   ----------------------

   ----------------------

   ----------------------

5. What is the source of bright line spectra?

   ----------------------

6. Absorption spectra can be recognized when ------------ appear in a continuous spectrum.
7. What color of light has the longest wavelength? ------- shortest? -------
8. What color of light has the highest frequency? ------- lowest? -------
9. When a star is moving toward you, is the color of its light shifted to the blue or to the red end of the spectrum? ------- why? ------------

Learning Objectives (Unit #2)

1. At the end of this unit you will be able to match the correct definition of any of the words found in the given vocabulary list to that word by placing the letter preceeding the word in a blank preceeding the definition.

2. At the end of this unit you will be able to look through a spectroscope at three different sources of light and be able to select the source of the continuous spectrum, the source of the bright line spectrum and the source of the absorption spectrum.

3. Given the distances two observers are from the same object, you will be able to select the correct relative apparent brightness of that object as measured by the observers from four given values.

4. Given the apparent brightnesses of two objects having the same intrinsic brightness, you will be able to select the value of their relative distance from the observer from four given values.

Learning Activities (Unit #2)

Assuming that you have studied chapter 3, go to the Astronomy Learning Laboratory and do the following:

1. Locate the hand-held spectroscopes and light sources. If you can not discover how to use this equipment, ask the instructor, he is there to help you. Please observe all written instructions. They are there for your convenience and safety.

2. First look at the incandescent light (ordinary light bulb). Next look at the flourescent lights in the ceiling. Do you see any difference?

3. Now use your spectroscope to view the helium source. CAUTION: THESE SOURCES ARE POWERED BY A HIGH VOLTAGE. DO NOT TOUCH THEM WHEN THE SWITCH IS TURNED ON!!!! (Ask your instructor for help and directions here if you need them.) Write a description of what you see.

4. Now look at the Argon and Nitrogen sources. Describe what you see. Look at the period table of the elements in chapter 2 of your book and note the atomic number of each of these elements and compare them to your observations. Can you see why what you have observed is sometimes compared to fingerprinting? If you are interested in further explainations, consult other astronomy and physics books.

5. Now return to the incandescent light source and alternately place the three small viles of colored liquid, that are located near that source, in front of the slit in your spectroscope while you are viewing the continuous spectrum of the source. Describe what you observe.

6. Go to the film loop projector and view the film Absorption Spectra.

You should now be capable of determining whether you are looking at an absorption spectrum, a continuous spectrum, or a bright line spectrum. If you have any doubts, go back and check yourself.

The following activities may be done either at home or in the Learning Laboratory.

7. Write the inverse square law.

8. Two observers, one at a distance of 1 mile, the other 3 miles from a single 100 watt bulb burning in an open field clearly visible to both, measure the brightness of the bulb as they see it. (Apparent brightness) Which observer measures the greatest brightness? ------------- How much brighter does his measurement say the bulb is than the other observers measurement say it is? -------------- Answer given below.

9. The brightness of 1000 watt bulb at a distance of 10 feet from an observer would have the same brightness as a ------- watt bulb at a distance of 1 foot from the observer. For the theoretically correct answer, look at the bottom of this page.

10. The brightness of two sources, each 10 feet from the observer was measured. $S_1$ was found to be 10 times brighter than $S_2$. If their brightness were measured again each at a distance of 100 feet, how much brighter would $S_1$ be than $S_2$? Why? Answer at bottom of page.

The following should be done in the Learning Laboratory.

11. Measure the brightness of a light source at different distances using a photographic light meter. Find out if your measurements confirm the theoretical calculations that you have been doing above.

12. View the film loop The Doppler Effect. (While this activity will not aid you in terms of immediate objectives, it will become important in the future.)

---

Answer to number 8.

$$\frac{B_1}{B_2} = \frac{D_2^2}{D_1^2} = \frac{3^2}{1^2} = \frac{9}{1} = 9$$

The observer 1 mile from the bulb measures the brightness to be 9 times greater than the observer 3 miles from the bulb.

Answer to number 9. A 10 watt bulb.

Answer to number 10. $S_1$ would be 10 times brighter than $S_2$, however, both $S_1$ and $S_2$ would only appear 1/100 of their brightness at 10 feet.

## Vocabulary List

| | |
|---|---|
| refraction | diffraction |
| law of reflection | light |
| diffusion | index of refraction |
| one candle | inverse square law |
| albedo | reflectivity |
| spectrum | dispersion |
| angstrom | ether |
| Fraunhofer lines | Kirchhoff's laws |
| continuous spectrum | bright lines |
| absorption spectrum | Doppler effect |

**Self Assessment** (Unit #2)

Match the following words with their definitions.

A. law of reflection
B. index of refraction
C. Doppler effect
D. Kirchhoff law
E. diffusion
F. albedo

_______ Incandescent gases at low pressure give discontinusous spectra consisting of bright lines.

_______ A measure of the refracting power of a transparent substance.

_______ The apparent change in wavelength or frequency of sound, light, or other waves that is produced by the relative motion of the source and/or the observer.

_______ The fraction of incident sunlight that a planet or minor planet reflects.

_______ The scattering of light by reflection from a rough surface.

Place an X in the blank preceeding the correct answer.

How much brighter does the Sun appear to be on Mercury than it does on Earth?
Distance from the Sun to Mercury = 57.9 million km = 0.387 AU
Distance from the Sun to Earth = 149.5 million km = 1.00 AU

____ 2.58 times

____ 5.73 times

____ 6.65 times

____ 7.68 times

Place an X in the blank preceeding the correct answer.
The brightness of a certain spectral class star is known for a distance of 10 parsecs. An astronomer measures the brightness of a star of this class and discovers that it is only 1/50 of that known brightness. How far away from the astronomer is this star?

____ 50 parsecs

____ 71 parsecs

____ 500 parsecs

____ 25,000 parsecs

If you feel that you are not ready for the unit assessment, consult the instructor at the Learning Laboratory.

first answer 6.65 times
second answer 71 parsecs

form 021

Astronomy 1104

Section 2

Unit #2

Name______________________________

After adjusting your spectroscope, look at the three light sources and write the letter which identifies the source in the proper blank below.

__________ continuous spectrum

__________ bright-line spectrum

__________ absorption spectrum

Match the words in the left-hand column to their definitions in the right-hand column by placing the letter preceeding the word in the proper blank.

A. Fraunhofer line
B. Kirchhoff's law
C. Doppler effect
D. index of refraction
E. absorption spectrum
F. law of reflection
G. albedo
H. reflectivity
I. continuous spectrum
J. refraction
K. dispersion
L. ether

________ The ratio of the speed of light in a vacuum to its speed in a substance; a measure of the refracting power of a transparent substance.
________ Dark lines superimposed on a continuous spectrum.
________ The apparent change in frequency of light produced by the motion of the source and/or the observer.
________ A spectrum of light comprised of radiation of a continuous range of colors.
________ The bending of light rays passing from one transparent medium to another.
________ The seperation of different wavelengths being refracted by different amounts.
________ The fraction of incident light that a planet or minor planet reflects.
________ Incandescent solids, liquids, or gases under high pressure produce continuous spectra.
________ A hypothetical medium through which light is transmitted; once thought to permate all space.
________ The angle of reflection is equal to the angle of incidence.

Place an X in the blank preceeding the correct answers in the following two exercises.

The apparent brightness of Jupiter is about 2.175 times greater when that planet reaches its closest point to the Earth than it is when it is at its greatest distance from us. Assuming that both planets move around the Sun in circular orbits, how many times closer to the Earth is Jupiter at its closest point than it is at its farthest point?

______ 1.475 times

______ 2.175 times

______ 7.825 times

______ 11.655 times

How much brighter does the Sun appear to us (distance about 100,000,000 miles) than it would to someone living on a planet revolving around the closest star ( $\alpha$ Centauri, distance about 25,000,000,000,000 miles)?

______ 250,000 times

______ 625,000,000 times

______ 50,000,000 times

______ 625,000,000,000 times

APPENDIX H

TERMINAL BEHAVIORAL OBJECTIVES

## Terminal Objectives for Astronomy 1104

### Objective 1

Given photographs of six astronomical objects, the student will rank them according to any one or a combination of the following physical properties:

1. distance from the sun
2. apparent brightness
3. size
4. mass

### Objective 2

Given a photograph of the lunar surface having several lunar features indicated by arrows that are labeled with a number, the student will select from a list of names of lunar features those indicated in the photograph by placing the correct label number on the appropriate arrow in a blank preceding the name of the feature.

### Objective 3

Given no less than three and no more than five spectra of stars, the student will rank them according to spectral class from either (1) the coolest to the hottest, or (2) the hottest to the coolest, when asked to do so by the instructor.

### Objective 4

Given white light (photographs of the Sun) and a spectroheliogram with numbered arrows pointing to selected features, the student will identify these features by placing the number of the arrow in a blank preceding the given name of the feature found in a list of such names.

### Objective 5

Given the photographs of six galaxies, the student will identify the Hubble classification of each and rank them from young to old according to present theories of galatic evolution by listing their identification numbers in the proper order.

### Objective 6

Given the nuclear equations for (1) the carbon cycle, and/or (2) the proton-proton reaction, the student will write a single sentence for each equation stating in plain language the meaning of that equation.

Objective 7

Given a semi-circle, the student will draw a diagram of a cross-section of the sun showing the location of the photosphere, chromosphere, corona, prominences, sunspots, and flares. On the same diagram the student will indicate the approximate temperature of each region in $^{o}K$ when asked to do so.

Objective 8

Given several statements, each describing unique properties of a given class of variable star, and a list of the names of classes of variable stars, the student will classify the star described by matching the star class described to the name of that class.

Objective 9

Given a list of the names of planets in the solar system, the student will rank them according to any one or a combination of the following physical properties:

1. diameter
2. mass
3. distance from the Sun
4. number of natural satellites (known)
5. period of rotation
6. sidereal period
7. synodic period
8. surface temperature

Objective 10

Given several descriptions of various stages of stellar evolution, the student will rank them from earliest to latest by placing a number of the rank in a blank preceding each description.

Objective 11

Given descriptions of various stages of stellar evolution, the student will draw a line enclosing those points on a given H-R diagram that represent stars in that stage of stellar evolution when asked to do so by the instructor.

Objective 12

Given several descriptive statements, each having at least two distinctive facts about a planet in the solar system, the student will identify the planet being described by writing the name of that planet in the blank which precedes the statement.

Objective 13

Given a diagram of the sun, moon, earth, the orbits of the moon and earth, and the moon's line of nodes, the student will draw a new configuration showing the new position of the earth, moon, and the moon's line of nodes for either (1) the next solar eclipse or (2) the next lunar eclipse and estimate to the nearest month the time that will elapse before this event occurs.

Objective 14

Given a diagram showing the sun, the earth, the orbit of the earth, and the orbit of an inferior planet, the student will locate the following points by marking and labeling them on the diagram.

1. Superior conjunction
2. Inferior conjunction
3. Greatest eastward elongation
4. Greatest westward elongation

Objective 15

Given a diagram showing the sun, the earth, the orbit of the earth, and the orbit of a superior planet, the student will locate the following points by marking and labeling them on the diagram.

1. Conjunction
2. Opposition
3. Eastern quadrature
4. Western quadrature

Objective 16

Given a list of astronomical objects and a list of names of methods for measuring astronomical distances, the student will match the most suitable method of measuring the distance to the listed objects by placing the number corresponding to that method in the blank which precedes the name of (or description of) the object.

Objective 17

Given a diagram showing the moon in four different numbered positions relative to the sun and the earth, the student will select the phase and local interval of time that the moon would be visible for each numbered position by placing the number of that position in a blank preceding a given list of phases, and also in a blank preceding a given list of time intervals.

APPENDIX I

COMPUTER PROGRAM

```
      COMMON IGROUP,NS,NA,NB,NC
      DIMENSION SA(4,100), SB(4,100), SC(4,100), SD(4,100),NPG(4),
     1  ISN(100),X(4,100),Y(4,100),Z(4,100),W(4,100)
      READ(5,42)  IX
   42 FORMAT(I10)
      NSAMP = 100
      IGROUP = 4
      NA = 2
      NB = 2
      NC = 1
      DO 1 I = 1,4
    1 NPG(I) = 0
      DO 5 I =1,86
      READ(5,100) K,C,D,A,B
  100 FORMAT(16X,I1,T45,F2.0,T51,F1.0,T55,F2.0,T59,F3.0)
      NUM = 1
      IF(K .NE. 2)    NUM = 2
    8 NPG(NUM) = NPG(NUM) + 1
      SA(NUM,NPG(NUM)) = A
      SB(NUM,NPG(NUM)) = B
      SC(NUM,NPG(NUM)) = C
      SD(NUM,NPG(NUM)) = D
    5 CONTINUE
      DO 11 I = 1,32
      READ(5,100) K,C,D,A,B
      NUM = 3
      IF (K .NE. 2)   NUM = 4
    9 NPG(NUM) = NPG(NUM) + 1
      SA(NUM,NPG(NUM)) = A
      SB(NUM,NPG(NUM)) = B
      SC(NUM,NPG(NUM)) = C
      SD(NUM,NPG(NUM)) = D
   11 CONTINUE
      DO 15 I=1,IGROUP
        IF (NPG(I) .LT. NSAMP) NSAMP=NPG(I)
   15   CONTINUE
      DO 16 I=1,IGROUP
      DO 12 KI=1,NSAMP
   12 ISN(KI)=0
        RXX=NPG(I)
        NUK=1
```

```
          DO 17 J=1,100
            CALL RANDU(IX,IY,YFL)
            IX=IY
            LR2=YFL*(RXX-.0001) +1
              DO 18 K=1,NUK
              IF (ISN(K) .EQ. LR2) GO TO 17
 18           CONTINUE
            ISN(NUK)=LR2
            X(I,NUK)=SA(I,LR2)
            IF (NUK .EQ. NSAMP) GO TO 16
            NUK=NUK+1
 17         CONTINUE
 16       CONTINUE
      NS=NSAMP
      IF (NS .LT. 2) GO TO 990
      CALL FACTOR
      GO TO 1
  990 WRITE(6,4111)
 4111 FORMAT(1X,'THERE WAS LESS THAN TWO SAMPLES PER GROUP')
  991 WRITE(6,191)
  191 FORMAT('1')
      STOP
      END


      SUBROUTINE RANDU(IX,IY,YFL)
      IY=IX*65539
      IF(IY) 5,6,6
    5 IY=IY+2147483647+1
    6 YFL=IY
      YFL=YFL*.4656613E-9
      RETURN
      END
```

APPENDIX J

THE FINAL TEST AS A COMPARISON

The 100 item multiple choice test that has been used in Astronomy 1104 as the final semester examination was administered to both the LD and IPI Groups at the end of the semester included in this study. This examination is not available for publication, however, it can be stated that it is a teacher-constructed instrument designed to evaluate the astronomy students over both material found in the textbook used in the course and material disseminated in the lectures. Each item had five possible choices, four of these choices were given as a part of the item, the fifth choice was "none of these."

A t-test comparison of the differences in the means between the LD and IPI Groups is shown in Table XL. These results show that the mean score of the LD Group was 4.37 points higher than the mean score of the IPI Group and that this difference was significant at the 0.05 level. The tabulated t-value was $t_{0.05}(200) = 1.98$ compared with the calculated $t(116) = 2.17$.

TABLE XL

COMPARISON OF THE LD VS IPI GROUPS
ON THE FINAL TEST

| Group | Mean Score | Standard Deviation | F Ratio | Degrees of Freedom | t Score |
|---|---|---|---|---|---|
| LD | 45.87 | 10.02 | | | |
| IPI | 41.50 | 8.92 | 1.26 | 116 | 2.17 |

Further comparisons of these results were made between the LD and IPI Groups, using the same samples selected for measures on the other dependent variables made earlier in this study. For example, the subjects selected at random for comparison of the LD and IPI Groups when divided by gender on the pre-test and again for the cognitive effect were the same subjects used to compare the LD and IPI Groups when divided by gender on the final test. No pre-test of the multiple choice type described here was administered at the beginning of the semester.

The results of the additional comparisons are found in Tables XLI through LVIII located in this appendix.

It should be pointed out, that on examination of the comparison tables, significant differences between the LD and IPI Groups on the final test appear in only two of the nine cases studied. Other significant differences are found between groups having different high school science and mathematics backgrounds, between groups of different gender, between groups divided by A.C.T. scores in mathematics, between groups having different A.C.T. scores in natural science, and between groups having different composite A.C.T. scores. Four of these five significant differences correspond to significant differences found on the pre-test (between groups enrolled in different colleges) and one found on the final test scores (between groups having a different A.C.T. score in mathematics) did not correspond to significant differences found on the other measure.

It could be asserted, from the findings stated above, that those variables which produced significant differences on the pre-test measure persisted throughout the semester to reveal themselves again at the end of the semester on the final test. Assuming such persistance, it is interesting to note that it did not appear in the measurement of the cognitive effect in a single case.

One interaction was discovered in these data. Table LII shows that those subjects having an A.C.T. score greater than twenty-two in mathematics scored significantly higher on the final test if they were in the LD Group, than they did if they were in the IPI Group.

TABLE XLI

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Arts & Sciences | 46.45 | 41.63 | --- | 44.05 |
| Other | 38.18 | 40.91 | --- | 39.55 |
| GROUP | 42.32 | 41.27 | | |

*n = 11 per cell

TABLE XLII

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY COLLEGE IN WHICH ENROLLED

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 3531 | 43 | 82 | | |
| Method* | 12 | 1 | 12 | 0.15 | n.s. |
| College** | 223 | 1 | 223 | 2.84 | n.s. |
| Method X College | 157 | 1 | 157 | 1.99 | n.s. |
| Error | 3140 | 40 | 79 | | |

*LD vs IPI

**Arts & Sciences vs Other

TABLE XLIII

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST
FOR LD AND IPI GROUPS DIVIDED BY CLASS*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Freshman | | 46.46 | 40.08 | --- | 43.27 |
| Other | | 45.46 | 42.08 | --- | 43.77 |
| | GROUP | 45.96 | 41.08 | | |

*n = 1[illegible] per cell

TABLE XLIV

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST
WHEN DIVIDED BY CLASS

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 4157 | 51 | 82 | | |
| Method* | 310 | 1 | 310 | 3.90 | n.s. |
| Class** | 3 | 1 | 3 | 0.04 | n.s. |
| Method X Class | 29 | 1 | 29 | 0.37 | n.s. |
| Error | 3814 | 48 | 79 | | |

*LD vs IPI

**Freshman vs Other

TABLE XLV

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses $\leq 3$ | 40.20 | 38.40 | --- | 39.30 |
| No. Courses $> 3$ | 50.93 | 45.67 | --- | 48.30 |
| GROUP | 45.57 | 42.03 | | |

*n = 15 per cell

TABLE XLVI

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY HIGH SCHOOL SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 4998 | 59 | 85 | | |
| Method* | 187 | 1 | 187 | 2.95 | n.s. |
| Background** | 1215 | 1 | 1215 | 19.16 | $<.001$ |
| Method X Background | 45 | 1 | 45 | 0.71 | n.s. |
| Error | 3550 | 56 | 63 | | |

*LD vs IPI

**No. Courses $\leq 3$ vs No. Courses $> 3$

TABLE XLVII

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND*

| | LD | IPI | | Group |
|---|---|---|---|---|
| No. Courses = 0 | 41.46 | 39.32 | --- | 40.69 |
| No. Courses > 0 | 48.00 | 42.38 | --- | 45.19 |
| GROUP | 44.73 | 41.15 | | |

*n = 13 per cell

TABLE XLVIII

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY COLLEGE SCIENCE AND MATHEMATICS BACKGROUND

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 3997 | 51 | 78 | | |
| Method* | 166 | 1 | 166 | 2.27 | n.s. |
| Background** | 263 | 1 | 263 | 3.60 | n.s. |
| Method X Background | 54 | 1 | 54 | 0.74 | n.s. |
| Error | 3513 | 48 | 73 | | |

*LD vs IPI

**No. Courses = 0 vs No. Courses > 0

TABLE XLIX

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST
FOR LD AND IPI GROUPS DIVIDED BY GENDER*

| | | LD | IPI | | Group |
|---|---|---|---|---|---|
| Male | | 51.71 | 42.57 | --- | 47.14 |
| Female | | 36.71 | 37.86 | --- | 37.29 |
| | GROUP | 44.21 | 40.21 | | |

*n = 7 per cell

TABLE L

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST
WHEN DIVIDED BY GENDER

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 3191 | 27 | 118 | | |
| Method* | 112 | 1 | 112 | 1.21 | n.s. |
| Gender** | 680 | 1 | 680 | 7.37 | < .025 |
| Method X Gender | 185 | 1 | 185 | 2.01 | n.s. |
| Error | 2213 | 24 | 92 | | |

*LD vs IPI

**Male vs Female

TABLE LI

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY A. C. T. SCORES IN MATHEMATICS*

| | LD | IPI | | Group |
|---|---|---|---|---|
| MA Score $\leq$ 22 | 39.63 | 41.09 | --- | 40.36 |
| MA Score $>$ 22 | 52.00 | 41.73 | --- | 46.86 |
| GROUP | 45.82 | 41.41 | | |

*n = 11 per cell

TABLE LII

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY A. C. T. SCORES IN MATHEMATICS

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 3006 | 43 | 70 | | |
| Method* | 214 | 1 | 214 | 4.39 | $<$.05 |
| MA Score** | 465 | 1 | 465 | 9.53 | $<$.005 |
| Method X MA Score | 378 | 1 | 378 | 7.76 | $<$.01 |
| Error | 1950 | 40 | 49 | | |

*LD vs IPI

**MA Score $\leq$ 22 vs MA Score $>$ 22

TABLE LIII

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE*

| | LD | IPI | | Group |
|---|---|---|---|---|
| NS Score $\leq$ 19 | 36.64 | 38.27 | --- | 37.45 |
| NS Score $>$ 19 | 50.55 | 44.36 | --- | 47.45 |
| GROUP | 43.59 | 41.32 | | |

*n = 11 per cell

TABLE LIV

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY A. C. T. SCORES IN NATURAL SCIENCE

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 3337 | 43 | 78 | | |
| Method* | 57 | 1 | 57 | 1.13 | n.s. |
| NS Score** | 1100 | 1 | 1100 | 21.87 | $<$.001 |
| Method X NS Score | 168 | 1 | 168 | 3.34 | n.s. |
| Error | 2012 | 40 | 50 | | |

*LD vs IPI

**NS Score $\leq$ 19 vs NS Score $>$ 19

TABLE LV

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY COMPOSITE A. C. T. SCORES*

| | LD | IPI | | Group |
|---|---|---|---|---|
| CM Score $\leq 21$ | 41.50 | 39.25 | --- | 40.38 |
| CM Score $> 21$ | 49.25 | 42.08 | --- | 45.67 |
| GROUP | 45,38 | 40.67 | | |

*n = 12 per cell

TABLE LVI

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY COMPOSITE A. C. T. SCORES

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 2997 | 47 | 64 | | |
| Method* | 266 | 1 | 266 | 5.04 | $<.05$ |
| CM Score** | 336 | 1 | 336 | 6.37 | $<.025$ |
| Method X CM Score | 73 | 1 | 73 | 1,37 | n.s. |
| Error | 2322 | 44 | 53 | | |

*LD vs IPI

**CM Score $\leq 21$ vs CM Score $> 21$

TABLE LVII

GROUP AND SUB-GROUP MEANS ON THE FINAL TEST FOR LD AND IPI GROUPS WHEN DIVIDED BY REQUIREMENT CRITERIA*

| | LD | IPI | | Group |
|---|---|---|---|---|
| Required | 42.85 | 39.15 | --- | 41.00 |
| Elective | 45.38 | 42.54 | --- | 43.96 |
| GROUP | 44.12 | 40.85 | | |

*n = 13 per cell

TABLE LVIII

COMPARISON OF LD VS IPI GROUPS ON THE FINAL TEST WHEN DIVIDED BY REQUIREMENT CRITERIA

Factorial Analysis of Variance

| Source | SS | df | ms | F | p |
|---|---|---|---|---|---|
| Total | 4081 | 51 | 80 | | |
| Method* | 139 | 1 | 139 | 1.74 | n.s. |
| Criteria** | 114 | 1 | 114 | 1.43 | n.s. |
| Method X Criteria | 2 | 1 | 2 | 0.03 | n.s. |
| Error | 3826 | 48 | 80 | | |

*LD vs IPI

**Required vs Elective

VITA 3

Ronald K. Oines

Candidate for the Degree of

Doctor of Education

Thesis: THE COMPARATIVE EFFECTIVENESS OF INDIVIDUALLY PRESCRIBED INSTRUCTION AND THE LECTURE DEMONSTRATION METHOD TO ACHIEVE BEHAVIORAL OBJECTIVES FOR A DESCRIPTIVE ASTRONOMY COURSE

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