1962

Automated Teaching of Space Biology in the High School Science Classroom

Mary Stephanetta Kolanowski

Loyola University Chicago

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AUTOMATED TEACHING OF SPACE BIOLOGY
IN THE HIGH SCHOOL SCIENCE CLASSROOM

A Dissertation
Presented to
the Faculty of the Graduate School
Loyola University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Sister Mary Stephanetta Kolanowski, C.S.S.F.
June 1962
LIFE

A native Chicagoan, Sister Mary Stephanetta Kolanowski received her early education at the St. Wenceslaus Elementary School and at Good Counsel High School. In 1933, she entered the Congregation of the Sisters of St. Felix (the Felician Sisters). After receiving a Bachelor of Science degree at the Catholic Sisters College, Washington, D. C., in 1943, the writer pursued graduate study at the Catholic University of America and in 1946 received a Master of Science degree in the field of Zoology. Her master's thesis is entitled "A Comparative Study of the Egg, Larva, and Pupa of Five Species of Drosophila." Further enrichment in the field of science was attained through courses at the Diocesan Teachers College, Prairie du Chien, Wisconsin; De Paul University, Chicago, and the University of Notre Dame, Notre Dame, Indiana. Her teaching career began in the elementary school, but a greater portion was spent in the secondary school where she served in the capacity of an assistant principal and taught biology, general science, mathematics, home nursing, and classroom driver education. She also taught several Loyola extension courses.

From 1956 to 1959, the author devoted part time to graduate work in the field of Education at Loyola University, Chicago; and thereafter until the present date was engaged in full-time study toward the degree of Doctor of Philosophy.
The writer holds membership in the Science Teachers Association, the American Biology Teachers Association, the Chicago Catholic Science Teachers Association, the Department of Audio-Visual Instruction (DAVI), and the National Council of Measurements Used in Education.

The author's publications include the following:

"Planning the Assembly Schedule," The Catholic School Journal, LVI (September, 1956), 210-211.


Biology Can Be Fun, (Portland, Maine: J. Weston Walch Publishing Company, 1958) - Three sets of educational games for Biology classes--ZOOLIO; HERBO; and MANNO.
ACKNOWLEDGMENTS

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The writer is particularly indebted to Dr. Samuel T. Mayo, who in the capacity of an adviser, has so generously and wisely shared his broad knowledge and erudite experience in directing this study. To Dr. John Wozniak, Dr. Max Engelhart, Dr. Henry Malecki, and Dr. Jasper Valenti, the members of the doctoral committee, a sincere expression of thanks is extended for the guidance and helpful suggestions in the organization of this study.

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CHAPTER I

INTRODUCTION

The present crisis in education, in which rising school enrollments and the demands for greater expansion of knowledge and higher educational requirements are far surpassing the capacity to provide adequate teaching personnel, has challenged educators and psychologists to seek new ways among the modern educational media to increase the effectiveness of the teaching-learning process. They have recently discovered from studies in the behavioral sciences that one excellent way to accomplish this task is through the use of the latest technological innovation, the teaching machine. In the past few years, this device, a product of the psychology laboratory, has been steadily gaining a prominent place among the newer media as a potential force in increasing the efficiency and scope of education. As Hively infers:

\[\text{It proves to be surprisingly effective in teaching... by its carefully arranged sequence of stimuli and its automatically reinforced responses to each stimulus. The use of the machine may eliminate some of the undesirable aspects of present classroom learning and free the teacher to work toward goals that are best achieved through personal, human interchange between teachers and students.}\]

Although still in its state of infancy, the teaching machine has already exerted a tremendous impact upon American education.

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1 Wells Hively, "Implications for the Classroom of B.F. Skinner's Analysis of Behavior," Harvard Educational Review, XXI (Winter, 1959), 37. (Editor's Note.)
Educators throughout the country are seriously concerned about the possible role it might play in improving the quality and effectiveness of teaching and learning and in resolving some of today's critical educational problems. In a recent doctoral study, Fry describes teaching machines as effective teaching devices that:

... are ideally suited to individual differences. They act as a private tutor in many ways, yet do not require personal attention of a human teacher. The immediate knowledge of results has been found to be rewarding and when this is combined with rate flexibility and properly programmed curriculum material, the result is often a highly motivated teaching situation.²

Educators, psychologists, and technologists have displayed more interest and curiosity in this new educational innovation than in any other single development. This is probably due to: (1) its emergence from the psychology laboratory as an effective medium of instruction which provides a major break in traditional classroom procedures; (2) its new approach to individualized instruction as opposed to mass instructional education; and (3) the great promise it holds "for qualitative improvement of learning combined with quantitative savings of teaching."³


Throughout the report of this investigation, the term "teaching machine" is defined as a device (hardware or non-hardware) which can present programmed material in sequential steps while making use of reinforcement. In other words, it possesses facilities for displaying the program, provides some method for making a response and for showing whether the response is correct or not. Teaching machines are also referred to as teaching devices, auto- or self-instructional devices, and automated teaching devices. A "program" consists of subject-matter broken down into small steps and arranged sequentially in order to lead the student step-by-step to an understanding of the concepts basic to the course or unit. "Automated teaching," sometimes referred to as programmed learning, programmed instruction, auto-instruction, or teaching-machine instruction, is defined as the method or technique of instruction associated with the use of some auto-instructional device. Other terms used differently from those in the ordinary sense are defined at the time used.

THE TEACHING-MACHINE MOVEMENT

Development of the Teaching Machine as a Device

Pressey's Devices. Like all other useful machines, the teaching machine "developed slowly from the need to do a job more effectively than it could be done otherwise." Historically, the teaching machine

as a device is not new. While patent records indicate a device by Halcyon Skinner in 1866, and other devices even earlier, which might be termed teaching machines, Dr. Sidney L. Pressey of Ohio State University is credited with the invention of the first educational teaching machine which he described in School and Society in 1926. Originally, his simple mechanical apparatus was more of a testing device than a teaching machine; however, its properties for self-instruction soon became evident. Dr. Pressey saw in this simple device which provided immediate knowledge of results a useful tool for performing certain routine functions of a teacher particularly in drill work and recitation. Immediate knowledge of results could afford a more effective means of teaching than commonly used classroom procedures. It seemed evident to Pressey that learning with this new device could implement some of the laws of effective learning. In 1927, Pressey incorporated a mechanism into his device which eliminated correctly answered items from the series and allowed only the missed items to reappear. This interesting feature may be found in a number of the more expensive modern teaching machines.

Pressey and his students continued to develop additional teaching devices with which they conducted numerous experiments in college teaching. In each case, learning proved to be more effective and much...


time was saved. These claims were firmly supported both by Pressey and his collaborators, as reported by Fattu:

They claimed that learning was more efficient because the learner was actively at work, his errors were immediately indicated, and practice was focused upon correcting his own errors. Students liked to work with the devices and the devices saved considerable time and drudgery for the teachers.7

Despite Pressey's enthusiasm and optimism and the educational promise resident in these simple, labor-saving devices, he was forced to abandon his project in 1932. Apparently, educators and researchers were not prepared to accept this advanced concept of teaching. Skinner, in a recent article on teaching machines, offers the following reasons for their failure to attract the attention of the educational world:

Cultural inertia aside, Pressey's machines had limitations that probably contributed to their failure. They were mainly testing devices to be used after some amount of learning had already taken place elsewhere. They did not use the principles of programming that later emerged from the study of operant reinforcement.8

Automated teaching, consequently, did not take root; the teaching-machine movement as an educational enterprise remained at a standstill.

Even though Pressey's early teaching devices did not receive public recognition at this time, nevertheless, his inventive ideas provided the foundation and incentive for further development of the teaching-machine movement. Pressey hoped that enough had been done


8Skinner, op. cit., 95.
to stimulate other workers, so that this fascinating field might be rapidly developed.  

Military Training Aids. No further progress in the teaching-machine movement occurred until 1942. Mechanization of instruction developed rapidly among the Army, Navy, and Air Force personnel during World War II. A shortage of qualified instructors and the pressure of time necessitated the utilization of new methods and devices for making military training as effective as possible in the briefest possible time. Thus, numerous training aids, or training devices were employed by the instructor. As wartime pressures increased, more and more training aids were utilized. To the instructor-centered audio-visual aids was added a variety of electronic, mechanical, electrical, visual, and auditory devices. With pressures mounting still higher, it was discovered that the trainee's inferior performance was due primarily to poor training. Instructors soon realized that active participation in learning situations resulted in superior performance. As a result, the customary training aids were supplemented with mockups, or models, which "required the active participation of the learner as well as the

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instructor."\(^12\) By 1945, the mockup had evolved into the simulator which had begun as an instructor-centered device, but soon advanced to provide a complete learning environment without much human intervention.\(^13\) Training aids had thus become learner-centered devices as distinguished from the former instructor-centered aids.

Business and industry quickly adopted the training experiences of World War II to their training programs. Application to education, however, was extremely slow; "the learner-centered simulator remained pretty much as a military training device and as an education curiosity."\(^14\)

**Skinner's Revival of Teaching Machines.** A revitalization, leading to the current interest in the teaching machine occurred as a result of laboratory research done by Dr. Burrhus F. Skinner at Harvard University. Skinner improved upon Pressey's ideas and devised a number of teaching machines which were characterized by self-pacing and immediate reinforcement of responses. In two provocative and challenging articles published in 1954 and in 1958, Skinner described the nature of his teaching machine and the theory underlying automated teaching which he called "programed learning."\(^15,16\)

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\(^14\) Levine and Silvern, *op. cit.*, 8.


laboratory experiments with lower organisms, he gained knowledge concerning the functional analysis and control of behavior which led to a sweeping revision of educational practices. Skinner believes:

... that his machines, which present material in such small steps that correct responding is virtually assured, can provide a new and better source of motivation than the "aversive methods" currently employed to stimulate learning.

Skinner devised about five distinct types of teaching machines, all of which duplicated certain features and functions of Pressey's early devices. His unique contribution, however, was not in the hardware, but rather in the programing of content for shaping responses—a direct outgrowth of the theories and techniques which he developed from studies with pigeons and white rats in the psychology laboratory.

**Development of the Automated Teaching Method**

The Socratic Method and Automated Teaching. Application of the principles basic to the technique of automated teaching, or programed learning, may be traced back to the tutorial, or dialectical method, used by the early Greek philosophers in ancient times. Socrates (400 B.C.) might be considered a kind of impromptu programmer. Through careful questioning, he guided the individual student to make intellectual discoveries for himself. His genius lay in his ability to probe, to pursue, and to cross-examine the student. As in present-day

17 Gene C. Fusco, "Technology in the Classroom Challenges to the School Administrator," *School Life*, (March-May, 1960), 5. (Reprint.)

programing, the Socratic method represented a type of automated teaching which followed a slow, but steady, progress toward a teaching objective. The subject matter was broken down into small parts and reinforcement of learning took place through a series of questions related to each other. In contrast to modern programing, the Socratic approach was not concerned with new information, but made use of facts already known to the student. It pursued a line of inquiry designed to bring about enlightenment through the mistakes and faulty reasoning of the student. Modern programmed instruction, on the other hand, is based upon a series of rewards, or successes.

In simple terms, this new approach to learning is an auto-instructional method which is a blending of the time-honored Socratic method of teaching by asking questions, the Cartesian idea of analyzing a learning problem into its smallest parts, and the application of Thorndike's modified law of effect. It is surprising that systematic application of these simple ancient principles to the learning process has taken so long to develop.

Skinner's Contributions. The impetus to the present-day technique of automated instruction, or programmed learning, was provided by Burrhus F. Skinner in 1954. In the Harvard University psychology laboratory he achieved remarkable results from his experiments with pigeons and other lower organisms. He succeeded in shaping the behavior of animals by one-step-at-a-time teaching followed by immediate

19 Ibid.
reinforcement of each correct response. As a result of these conditioning experiments with lower animals, the usefulness of reinforcement principles in the practical control of human learning was discovered. To control the process of learning, Skinner recommended the use of some type of instrumentation, such as a teaching machine, "to equip students with large repertoires of verbal and nonverbal behavior." 20

In 1957, Skinner designed the first program—a Harvard course in psychology on the analysis of behavior—which emphasized the possibility of more direct application to education of concepts developed in the psychology laboratory. Following Skinner's lead, numerous programs have been prepared, and others are being prepared by scholars throughout the country in various curricular areas:

... ranging from ... arithmetic to calculus, from modern behaviorism to the Old Testament, from spelling and English grammar to many modern languages, from biology and physics to medical—school courses, and in hundreds of fields of industrial education. 21

The years 1957-58 mark the beginning of the period in which an upsurge of interest in teaching machines and its technique of automated teaching for more effective teaching was initiated. Ramo in 1957 re-opened the possibility of automated techniques for classroom use. His arguments served as a forceful attempt to alert educators to the needs and requirements for automation in education. 22

Skinner's continued interest and advances in the experimental analysis of behavior have served as a major catalyst in the development of a true technology of education. The recent development of teaching machines and the introduction of the technique of automated teaching predicts a new and constructive relationship between the science of learning and the art of teaching.

Current Trends and Developments

Many different models of teaching machines have been constructed ranging in price from one to five thousand dollars. Despite great variation in the structure of these devices, they possess the following characteristics in common:

1. They present information and require frequent responses by the student.
2. They provide immediate feedback to the student, informing him whether his response is appropriate or not.
3. They allow the student to work individually and to adjust his own rate of progress to his needs and capabilities.23

Growing numbers of colleges and universities are conducting research projects to study the new technique and to determine how it can best be integrated with traditional methods. Harvard University and Earlham, Hamilton and Oberlin, the Universities of Southern California and Loyola (Los Angeles), and numerous other institutions are presently engaged in extensive study programs of this type.

As interest and knowledge grow, more and more elementary and secondary schools are taking part in experimentation either independently

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or in conjunction with college testing and evaluation projects. Many of these studies are sponsored by the Ford Foundation and the United States Office of Education.

Indication of the growing significance of teaching machines and programmed instruction is evidenced by the establishment of the Center for Programed Instruction in New York City. The center, which is an outgrowth of the Collegiate School project, proposes to offer the following services to educational communities:

Consulting with and helping schools interested in carrying on projects in the fields of programmed instruction and teaching machines.

Creating thoroughly tested programs of instruction in all subjects.

Conducting controlled research to investigate programing variables and administrative techniques of implementing programmed instruction.

Supplying experimental programmed learning materials to schools.

Disseminating objective information about programmed instruction and teaching machines.

Conducting in-service workshops in cooperation with school systems, teachers colleges, and universities.24

Other centers with similar purposes have been established throughout the country. Working closely with psychologists, subject matter specialists, and classroom teachers, and drawing on the best practical and theoretical experiences on hand, these centers are producing and testing programmed courses and texts which will soon be available for classroom use.

24"Center for Programed Instruction," Audiovisual Instruction, VI (April, 1961), 151.
Commercial firms are entering the field of teaching machines at "a rate of two per week. One new noncommercial firm gets into the act every four weeks."\(^{25}\)

With this rapid growth of educational automation it seems almost impossible to keep pace with new developments in the field.\(^{26}\)

**Reactions to Automated Teaching**

The current appearance of the teaching machine and teaching-machine programs on the educational scene in the early 1960's has evoked a host of favorable, and not too favorable, reactions which educators generally expect from every new educational device. "As the products of twentieth-century technology find their way into the classrooms, they are sometimes met with murmurings of 'gadgetry' and 'automated teaching'!" Some educators see the teaching machine as a serious threat to the teacher;\(^{27}\) others claim it will dehumanize the teaching-learning process; still others feel it will completely eliminate the teacher. Fears of such a nature are unwarranted. In a recent article, Skinner states in simple terms the purpose of teaching machines in education:

... to teach rapidly, thoroughly, and expeditiously a large part of what we now teach slowly, incompletely and with waste effort on the part of both students and teacher. Some of the machines also hold the promise of teaching behavior of a kind and subtlety that until now has seemed beyond the reach of explicit teaching methods.\(^{29}\)


\(^{26}\) Ibid.


\(^{29}\) Ibid.
Despite the fact that teaching machines have met strong resistance, nevertheless, the last few years have witnessed successful utilization of a variety of teaching devices on an experimental basis in classrooms throughout the country. "The potentialities of the teaching machine technique are being realized as more creative teachers explore and implement their ideas and desires." Many diligent efforts have been made to determine ways in which this new medium can be used constructively for upgrading the quality of the teaching-learning process. Much has been learned from studies conducted; but much more remains to be learned.

Need for Further Investigation

With the emergence of this new and promising device, it is imperative, therefore, in this period of educational crisis to investigate more fully the true potential effectiveness of the teaching machine and its related technique in classroom situations in order to place it in proper perspective to other successful media. It is likewise necessary to determine how this new teaching device can be utilized to optimal advantage for greater teaching and learning efficiency.

THE PROBLEM

Statement of the Problem

The present study is concerned with the effectiveness of the automated technique of teaching high school science. The basic problem was to determine the relative effect on the learning of space biology

by means of a simple teaching machine with and without a self-trainer which provided immediate knowledge of results. To accomplish this purpose, the study was designed to compare the efficiency of four methods of instruction for acquiring and retaining knowledge of subject matter related to the human factors involved in space flight. Each of four comparable groups of science students was taught a unit in space biology by one of the following methods:

Method I - Teaching Machine,* Films and Filmstrips.
Method III - Programed Lecture,* Films and Filmstrips.
Method IV - Programed Lecture, Note-Taking, Films and Filmstrips.

In the course of the investigation answers were sought to the following questions:

1. What is the relative effect on learning of the automated and programed lecture methods in terms of the acquisition and retention of subject matter knowledge of space biology?
2. Does automated teaching produce more effective learning results in students of high, average, or low ability? in ninth- or tenth-grade science students?
3. What specific increment in learning is attributed to the use of a self-trainer which gives the students immediate knowledge of results?
4. What differences in learning accrue from the fact that students take notes during the programed lecture?
5. What is the attitude and reaction of the students toward the methods used in this study?
6. How does the role of the teacher change in automated teaching?
7. Did the program in space biology achieve the objectives proposed?
8. What recommendations and suggestions may be offered for the optimal use of a simple teaching machine and a self-trainer in the science classroom?

* A complete description is given in Chapter III.
The particular unit of instruction selected for study in this experiment was space biology, or the human factors and problems involved in space flight. The levels at which the experiment was performed were the ninth- and tenth-grade science classes of two Catholic coeducational high schools (School A and School B) in the Chicago area. Approximately four hundred students participated in the study which extended over a period of two-and-a-half weeks in School B and three-and-a-half in School A. Differences in the duration of the experiment were attributed to different time schedules in the schools. The experiment in School A was an exact replication of the experiment in School B. A methods-by-levels-analysis of variance experimental design was used. The four treatments, or methods, described previously were assigned at random to separate groups of ninth- and tenth-grade students, previously ranked on the basis of initial intelligence scores and arranged into three ability levels. The experiment was replicated twice in each of the two schools. Each replication constituted a complete experiment. All lecture classes were conducted by the investigator; other groups were proctored by the regular teacher. The films and filmstrips and minor details were the same in all classes. Thirty-six simple teaching machines were used by the students in Groups I and II to present the 500-frame program in space biology.

Relative gains in learning were measured by a pretest administered three times and a post-test administered twice to all participating students. Students in Group II used a self-trainer in connection with the first administration of the pretest and post-test. Data
concerning students' attitudes and reactions to teaching machines, films and filmstrips, and other parts of the study were gathered by means of structured statements of an opinionnaire and free comments. The space biology program was evaluated by means of a detailed analysis of errors. A complete description of the experiment and devices used follows in Chapter III.

Significance of the Problem

During the past decade considerable attention has been focused on the quality-quantity problem of secondary science education. To many science educators and teachers the improvement of science teaching has been a matter of deep concern. Recent discoveries in the potential use of the teaching machine and its related technique have alerted science teachers to consider the feasibility of employing this instrument developed by science to bring about more effective science instruction. If science is to be taught to an ever-increasing number of students, it will need competent science teachers and the very best methods so that schools may more effectively prepare students for life in the science-dominated world of the future.\(^\text{31}\) As Anderson states: "For the schools of America to ignore this challenge would be folly, indeed."\(^\text{32}\)


\(^{32}\)Ibid.
In another place he asserts the following:

Science teachers should, by the very nature of their training, be producers of the finest types of educational research and possess at the moment the best methods of teaching.33

If the goals of science can be achieved through teaching-machine instruction as effectively as through other methods, or more effectively and in less time, then it is incumbent upon science educators to examine this possibility with great care. If automated teaching can make the process of learning science more effective and satisfying, then certainly its full educational value and place in the science curriculum should be investigated by science educators through classroom research and experimentation.

This study is unique insofar as it is primarily concerned with the effectiveness of automated teaching in the high school science classroom. It would seem that any method which tends to increase the strength of science teaching and to provide more and better science learning for more students in less time is worthy of investigation in view of the present national emergency. This study also offers an example of the effectiveness of utilizing several media in combination. Research studies in this phase of automated teaching are scarce. Studies of this nature are further required in order to overcome prejudice and bias in the use of this new technique in classroom learning. Teachers need to develop confidence, understanding, and skill in using teaching machines in the regular course of the classroom schedule.

33 "Improving Science Teaching through Realistic Research," Science Education, XXXVII (February, 1953), 59.
Throughout this study it is assumed that teaching machines and their programs can teach effectively. However, the investigator advances the premise that no device can replace the teacher completely but can only aid him to accomplish his all too many tasks more effectively.

It was with this idea in mind—the need for improving the teaching and learning of science through the use of the teaching machine technique—that the present study was conceived.

SUMMARY

This chapter has been concerned with a summary of the development of the teaching machine movement, with the statement, definition, and significance of the problem, and definitions of terms. Chapter II presents a summary of research relevant to the problem. In Chapter III the experimental data collected for this study are reported in detail. Chapter IV presents the statistical analysis of the data using methods—by-levels analysis of variance. Chapter V includes an analysis of the space biology program and student reactions. In Chapter VI are given the summary and conclusions derived from this study with recommendations for further research in the field.
CHAPTER II

REVIEW OF PREVIOUS LITERATURE

A growing awareness of the potential importance to education of the teaching machine and its related technique is reflected in the notable increase in the published literature on the subject. Fry, Bryan, and Rigney report that prior to 1948 there were only six references on teaching machines, whereas through 1959 the number had gone far beyond the fiftieth mark.\(^1\) Today, this rapidly expanding field has literally mushroomed to such an extent that it is difficult to keep abreast of new developments in this area.

Much of the early research in the field of teaching machines has been oriented in terms of the effectiveness of the teaching machine when used in conjunction with conventional teaching methods—the Drossey approach. The main concern in research using this approach has been with the implementation of knowledge of results following some previous learning experience.\(^2\) More recently, there has developed a growing interest in the use of the teaching machine as the sole source of instruction—the Skinner approach.\(^3\) The history of research indicates


\(^3\)Ibid., p. 117.
that many investigations utilizing the teaching machine under both approaches have already been undertaken. The number of such studies, however, is still limited, and the resultant findings are more provocative than definitive.4

This chapter contains a review of the previous and related literature and research on the teaching machine and its technique using the Pressey approach, as well as literature and selected classroom studies using the Skinner approach. Included also in this review are:
(a) several important reference sources on teaching machines which have aided the investigator in surveying the literature; and (b) a summary of the points contributed by the literature to the present study.

The literature is replete with research conducted by the Army, Navy, and Air Force particularly during World War II when qualified teaching and training personnel was wanting. These military studies have amassed a great deal of information regarding the effective use of training aids. The importance and value of the results obtained are not denied. However, since this study was primarily concerned with the effectiveness of automated instruction in classroom situations, only a few military studies were considered relevant to the present experiment.

Reference Sources

The first published survey on mechanical teaching aids was Porter's critical review of the literature which appeared in 1957.

In this work, Porter describes teaching machines and devices other than teaching machines; he also reviews and evaluates several early experimental studies. The review is particularly valuable: (1) for its classification of devices into stimulus, response, and stimulus-response devices; (2) for the similarities and differences between Pressey's early teaching-testing devices and Skinner's teaching machines; and (3) for presentation of Skinner's two important innovations in this area, namely the use of constructed responses versus Pressey's multiple-choice response mode, and the carefully organized programing of subject matter content. 5 Due to numerous advances in the field of automated teaching since 1957, Porter's review was somewhat incomplete as far as the present study was concerned.

One of the most complete and authoritative sources of research on teaching machines is the annotated bibliography by Fry, Bryan, and Rigney which appeared in 1960. 6 It is a comprehensive reference designed "to show the scope of the relatively new field that is variously referred to, as 'teaching machines' or 'automated instruction'." 7 In addition to the annotations to articles and reports on research studies found in Part III, the 80-page publication also includes tabular summaries of


6 Fry, Bryan, and Rigney, op. cit., 1-80.

7 Ibid., 5.
experimental studies and teaching machine development, a summary of teaching machine devices, and a bibliography of commercially developed teaching machines. This extensive bibliography purports to save the research worker many hours of library research.

Another excellent source of information for one interested in programmed learning and teaching machines is the recently published source book—Teaching Machines and Programmed Learning. This comprehensive text brings together widely scattered literature dating from 1926 to 1960, and makes it conveniently available in a single volume. Many unpublished papers not accessible through the usual sources are abstracted or annotated in the Appendix of the book. This makes the book a highly resourceful publication and a "must" for all research workers in the teaching-machine field.

A survey of teaching-machine programs and programming techniques, as they appeared in 1960, is reported in Current Teaching-Machine Programs and Programming Techniques. The aim of this survey may be best expressed in the words of the authors:

The object of the report is to present an overview for the many individuals who have a need to know about programming and programs. ...It is an interpretative and descriptive report rather than a survey of the research literature....It describes the types of programs now available in terms of content and educational level. It defines some common terms in the field and summarizes some programming rules and techniques. It presents an outline of the

educational content in which programmed learning must find a place. And finally it presents samples of 31 current programs.9

Stolurow's recent monograph, Teaching by Machine, contains a wealth of information on types of teaching machines, machine systems, techniques and concepts of programming, the impact of teaching machines on the learner, research findings, and implications for education. The purpose of this monograph is "to examine the potentialities of auto-instruction or automated teaching as a possible solution to some of today's critical problems in education."10

The Pressey Approach

As early as 1926, Sidney L. Pressey of Ohio State University described the first educational teaching machine as "a simple device which gives tests and scores and teaches." This paper was the first major article published in the field of teaching machines. Pressey described this machine as a device which presented multiple-choice questions on a drum, and the student responded by pressing one of four buttons. The machine kept an error count and would not permit the student to proceed until the right button was pressed.

A major advantage of the device was that it provided the student with immediate information regarding the correctness of his responses. That the device made efficient learning possible in a very interesting


manner is evidenced by the following paragraph:

The somewhat astounding way in which the functioning of the apparatus seems to fit in with the so-called "laws of learning" deserves mention in this connection. The "law of recency" operates to establish the correct answer in the mind of the subject, since it is always the last answer which is the right one. The "law of frequency" also cooperates; by chance, the right response tends to be made most often, since it is the only response by which the subject can go on to the next question. Further,..., the apparatus will present the subject with a... reward upon his making any given score for which the experimenter may have set the device; that is, the "law of effect" also can be made automatically, to aid in the establishing of the right answer.11

The following year Pressey reported an effort to develop a machine for teaching drill material. "The important feature...," Pressey reports, "is the exemplification of the fact that machines can be built which meet, automatically, certain very important requirements of efficient teaching."12

In a third paper Pressey predicted the possibility of an "industrial revolution" in education during which new instruments and materials for extensive research would appear. No experimental studies with these early devices have been reported by Pressey at this time.13

James K. Little, under Pressey's influence at Ohio State University, reported the first systematic use of teaching machines

in regular college classes to present items in educational psychology in 1934.

In this experiment, Little used Pressey's drill machine and test machine. Results of the study indicated that both experimental groups performed significantly better than the control group. One of the most interesting findings was that the slower students benefited most from the use of teaching machines. In spite of the crude methods used, this experiment revealed surprising results which demonstrated the feasibility of utilizing mechanical aids in classes in education and favored their use in contrast to regular classroom techniques. 14

In 1950, Pressey conducted a major study with college students using the punchboard which gave immediate knowledge of results. The findings of this investigation indicated better learning performance on the part of the experimental groups. Pressey confirmed his belief in the efficacy of mechanical aids in the classroom. Research results proved them to be in harmony with the laws of learning proposed by Thorndike.

Some of the most significant findings of this study are pointed out in the following statements:

1. The punchboard is a simple device which facilitates learning by combining test-taking, scoring, and immediate knowledge of results.

2. The punchboard is useful and effective in transforming testing into a systematically directed self-instructional program.

14James K. Little, "Results of Use of Machines for Testing and for Drill upon Learning in Educational Psychology," Journal of Experimental Education, III (September, 1934), 45-49.
3. The punchboard when properly used results in an increase in students' understanding of the subject matter.

4. Immediate knowledge of results provided by the punchboard enhances the learning of a variety of school subjects and is an important factor in learning.  

Studies conducted by other investigators likewise supported the claim that knowledge of results provided by punchboards and other simple devices is a key factor in maximizing the efficiency of the teaching-learning process.

Angell and Troyer reported favorable results in a college chemistry study using the punchboard. Angell investigated the effect of immediate and delayed knowledge of quiz results on the acquisition of knowledge and on quantitative problems in freshman college chemistry. The experimental group received immediate knowledge of quiz results from the Angell and Troyer punchboard; delayed knowledge of results was obtained through the use of IBM answer sheets which were scored and discussed at the following class meeting. The criterion of improvement was the final examination score which was statistically significant in favor of the experimental group.

In his doctoral investigation, Briggs developed and appraised two procedures for facilitating the work of college students in an

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educational psychology course. Of the 300 students participating, thirty superior students were assigned to an accelerated seminar which required out of class work, including the use of punchboards with instructional tests. Results favored the use of self-instructional methods for superior students. In another part of the study, Briggs experimented with a four-week proficiency examination program for very superior and responsible students. Achievement test scores were again significantly higher when compared with control groups.¹⁸

Jensen's experiment with superior college students who completed an educational psychology course in five weeks in an independent-study laboratory without formal teaching, resulted in better grades, gain in capacity for independent study, and economy of time. Pressey's punchboard and practice tests were made available to the experimental groups for self-testing, review, and discussion. Knowledge of results was provided in each case.¹⁹

Dowell conducted a large scale evaluation study of trainer-testers with military trainees. The experimental population consisted of four matched groups in basic electronics. Results of the study revealed the following: (a) experimental group one, using both equipment

¹⁸Leslie J. Briggs, "The Development and Appraisal of Special Procedures for Superior Students and an Analysis of the Effects of 'Knowledge of Results'" (unpublished Ph.D. dissertation, Ohio State University, Columbus, 1949).

and trainer-testers, produced the highest average scores on the criterion measure; (b) the control group was significantly higher than the pretest group, but not as high as group one; (c) experimental group two, using only trainer-testers, was not superior to the pretest group that had no practice whatsoever in trouble-shooting.

Analysis of the student questionnaires disclosed strong interest in the trainer-tester and a significant help in learning trouble-shooting. Teacher questionnaires revealed that most instructors felt that trainer-testers could augment student motivation, improve attitudes, teach skills and increase or implement knowledge.

Cantor and Brown, in a military study, investigated the relative effectiveness of three methods of teaching trouble-shooting to Basic Electronics trainees at the U.S. Naval Training Center, Great Lakes. One method, which was essentially that in current use by the Navy, involved trouble-shooting training with actual equipment. The other two methods differed from this conventional method in that part of the laboratory work with equipment was replaced by practice with paper-and-pencil trouble-shooting training aids—the trainer-tester and the punchboard tutor. Results from achievement test scores proved that the trainer-tester and punchboard-tutor groups were superior to the equipment only group. These differences were statistically significant in intellectual aspects. The equipment-only group was superior in equipment usage.

In a follow-up study, it was discovered that trainees who used the training aids in Basic Electronics similarly produced superior results in Advanced Radar Training—a laboratory course. Results indicated that training devices can be used successfully as partial replacements for actual equipment in trouble-shooting training. Their value as training aids lies in their low-cost and their ability to teach the intellectual aspects of trouble-shooting. Their high motivational value for students proved to be an important asset to training. 21

In a more recent experiment, Freeman using an electric version of the Pressey punchboard in two experimental versus control-group-studies confirmed the need for integration of reinforced practice in instruction. This study revealed that under typical conditions of classroom testing, the casual use of reinforced practice has little effect upon performance. 22

Other interesting issues which emerged from Freeman's investigations were:

1. Frequent short quizzes produce better results than fewer long ones.
2. Rapid gains in learning do not necessarily mean better retention.
3. Effectiveness of knowledge of results may depend upon programming of content.

4. The type of test used to determine retention and the amount of reinforcement may affect the results obtained.23

Stephens, in a doctoral study, compared the achievement of an experimental group in educational psychology using two devices, a punchboard and a drum tutor for immediate knowledge of results with a control group using no device. Results favored the experimental group. Stephens asserts without doubt "... that a clear knowledge of how well one is doing has a definite effect on performance ..."24 In another part of the study, he reported equally good performance by students with the drum tutor versus others using the punchboard. Students preferred working with the drum tutor.

Stephens also made a comparison of the effects produced by immediate knowledge of results provided early in learning by means of the drum tutor with the same results provided after learning under other conditions (with the punchboard). These data suggest that learning is more effective if knowledge of results is given early. Stephens' findings further suggest that significantly better performance could be obtained from the combined use of knowledge of results during learning and after learning.

The Skinner Approach

The foregoing review of the literature has been concerned with the use of teaching machines in the context of a course, that is, as a


component of the instructional program. In the review that follows, emphasis is placed on literature and selected classroom studies which deal with the effectiveness of the teaching machine as the sole source of instruction, independent of conventional teaching methods.

Characteristic Functions of Teaching Machines

Despite great variation in the complexity of the teaching machines used in the studies reviewed, they all represent "a form of tutorial instruction using the Socratic method, carried out with a level of control quite impossible under standard live instruction." Teaching machines differ from other audio-visual media because of the following important functional properties:

1. A teaching machine presents information either as statements followed by questions, or as paired sets of abstract symbols to be associated together with incomplete associations for testing purposes. (Presentation function).

2. A teaching machine requires an overt and measurable response. (Response function).

3. A teaching machine compares, or permits the learner to compare his response to a predetermined correct response. (Comparator function).

4. A teaching machine provides knowledge of results and possesses the potential for doing this after each response. (Feedback function).

5. A teaching machine programs information according to a set of rules that are capable of being made explicit. (Programming function).


7. A teaching machine combines learning and its measurement into a single set of coordinated operations. (Collator function).

25 Stolurow and West, op. cit., 16.
8. A teaching machine automatically rejects the correctly-responded-to items so that the learner uses a small number of items from trial to trial. (Selective function).

Although the teaching devices used in the classroom studies reviewed do not possess all of the above properties, nevertheless, they represent a method of providing systematically programmed material while making efficient use of reinforcement. In other words, they offer facilities for displaying the material, for making a response, and for showing the correctness of the response.

**Skinner's Papers**

The first proposals for teaching machines and their techniques along the lines employed today date back to 1954, when Professor Skinner of Harvard University in a provocative and challenging paper reintroduced the concept of educational automation. Since then Skinner has displayed an active interest in the recent advances in the experimental analysis of behavior which may lead to the development of a true technology of education. His studies with rats and pigeons in the psychology laboratory have revealed interesting data concerning knowledge about behavior which he found applicable to the understanding and improvement of the teaching-learning process. Skinner's greatest contribution to education, as evidenced from his writings, is the beginning of an effective partnership between the science of learning and the technology of

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education through the use of appropriate instrumentation in the form of mechanical devices. 27

In another major article which appeared in Science in 1958, Skinner further reported the need for present-day mechanization of instruction. This paper is responsible for the current interest and expansion of activity in teaching machines. 28 Lumsdaine and Glaser emphasized the fact that Skinner's paper "... also focused attention on the programming of detailed, carefully ordered learning sequences by which complex behavioral repertoires may be shamed through successive approximations." 29

After the publication of these two famous articles, other Skinner papers characterized by the same persuasiveness appeared in the form of unpublished reports many of which are abstracted in Teaching Machines and Programmed Learning. 30

Classroom Studies

The initial classroom study to which Skinner's principles of programmed learning were applied was conducted by Ferster and Sapon in 1958. They attempted to teach a college course in German by means of a simple cardboard mask. The device consisted of a cardboard folder

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29 Lumsdaine and Glaser, op. cit., p. 96.
containing mimeographed material which exposed one line at a time. The
student, after writing his response on a separate sheet of paper, ad-
vanced the paper in the mask, thereby exposing the correct response.
The device gave immediate reinforcement for small units. Motivation was
not hindered by frequent failure since the material was presented in
small steps.

According to the authors, "... the conformance of the student's
written German with the materials he uncovers on the second line is the
reinforcement that maintains the study behavior."31

The instructional material in the form of a program was adminis-
tered to 28 adult subjects, none of whom had had any previous knowledge
of German. Of the 28 subjects, only six finished the lessons. Their
mastery of German composition was determined by their performance in
several tests. The mean time for the six subjects was 47.5 hours; the
amount of German learned was comparable to that learned in a one-semester
course.

Another published study carried out by Porter, reports the ef-
fec ts of teaching-machine instruction in the elementary classroom. This
experiment under the sponsorship of the U.S. Office of Education was con-
ducted during the academic year 1957-58 in the teaching of spelling to
second- and sixth-grade level students. Porter used a write-in type of
teaching machine of "maximum simplicity." As the author described it:

31 Charles R. Perster and Stanley M. Sapon, "An Application of
Recent Developments in Psychology to the Teaching of German," Lumsdaine
and Glaser, op. cit., p. 176.
"The sole mechanical functions of the machine are to provide immediate response confirmation, prevent cheating, and keep subjects from having access to any but the current teaching items."32

An interesting aspect of the experimental program was that no spoken instruction was given to the students. All necessary directions and instructional procedures were provided by the program. Results measured on standardized achievement test scores were significantly superior for the experimental group.

Porter also reported no significant relationship between intelligence scores and achievement in the experimental group; however, a significant positive relationship was noted in the control group. Other interesting findings in this study indicated: (1) positive relationship between the number of responses per lesson required of subjects and subsequent achievement; (2) no relationship between the number of errors per lesson and achievement; (3) the experimental group spent only one-fourth as much time studying as did the control group; (4) 20 percent of the second grade pupils and 10 percent of the sixth grade pupils could not match their answers with the answers given in the machine; (5) no relationship existed in either group with respect to sex, or whether or not students liked this new instructional procedure; (6) a

check on the "novelty" factor of the new method by comparing first-half and second-half machine scores indicated no differences. 33

A study utilizing teaching devices in a class setting reported by Keislar, explored the possibility of using multiple-choice items on a kodachrome filmstrip to develop understanding of elementary arithmetic concepts. The Film Rater, a modification of a device employed by the Navy during World War II, was the teaching machine used in the experiment with fourteen elementary school children; fourteen others served as controls. These were matched on the basis of intelligence, sex, reading ability, and pretest scores. Results proved that automated devices can promote understanding of arithmetical concepts. A wide range of individual differences was noted even among children of similar intelligence and reading ability. An analysis of the test results revealed that the group was significantly better at the one percent level than the matched control group. On the whole, the program appeared to be more appropriate for the brighter children. In a part of the report, Keislar discusses principles of programing and the necessity for early revision of a program in terms of student performance. 34

In a classroom study at Santa Monica City Junior College, Coulson and Silberman investigated the question of multiple-choice versus constructed response mode. Eighty psychology students were

33 Ibid., pp. 85-90.
subjected to an experimental training session using simulated teaching machines. Eight groups were formed; each group being taught by a different mode of teaching-machine operation. The three independent variables were: (1) student response mode; (2) size of steps; (3) branching versus no branching.

A criterion test was administered to all subjects immediately after the training session and a retention test three weeks later. The same written criterion test was given to the control group students who received no instruction of any kind.

In their analysis of the results, Coulson and Silberman reported that:

1. The multiple-choice response mode took significantly less time than the constructed response mode; no significant difference was obtained between response modes on the criterion test.

2. Use of the simulated teaching machines resulted in superior learning performance as compared with the control group.

3. Small item steps required significantly more time, but yielded significantly higher scores than large steps on the constructed-response criterion test.

4. Branching conditions required less training than non-branching but were not significantly different on the criterion test.35

Another classroom study which attempted to determine which of the two response modes (multiple-choice or constructed response) promotes more efficient learning was conducted by Fry with 153 ninth-grade students enrolled in a Spanish course. A simple cardboard folder teaching device which could handle both types of responses was used by the students.

Both response modes were used in the same classroom at the same time with the following three conditions being imposed on each group: (1) groups worked to a criterion of mastery; (2) limited working time was allotted to the groups; and (3) both time and number of repetitions were controlled. The evaluation test used both multiple-choice and constructed responses.

Results were as follows:

1. The constructed response method was significantly superior to the multiple-choice method, but required more time for mastery.
2. When time was controlled, the constructed response was again significantly superior.
3. With time and number of repetitions controlled the constructed response was significantly superior.

Fry concluded that if recall is the criterion for learning then constructed responses are more effective, given conditions similar to the experiment. 36

A classroom study with first-grade pupils investigated the efficacy of an instructional program to give scientific explanations of physical phenomena by means of the Videosonic Tutor. The following results were reported:

1. All but one of the 13 experimental children showed higher post-test scores than did the controls, a difference which is statistically significant.
2. Success on the post-test was significantly related to the number of errors during the instructional program (the better the performance on the program, the better the performance on the post-test.)

3. There was some evidence that the program was more appropriate for children with a high reading readiness and effective study habits.

4. All of the children, when asked if they would like to continue learning new things in this fashion, indicated that they would. Their classroom teacher reported that they looked forward to the program each day.37

A recent doctoral investigation with "intellectually superior" elementary school pupils of the fifth and sixth grades resulted in no statistical significance between students being taught advanced mathematics through the conventional method or through a programed text. However, twenty percent time saving was reported for the experimental groups.38

A classroom investigation on the effects of negative reinforcement on programed instruction was undertaken by Melaragno with 28 subjects from freshman mathematics classes of a junior college. Subjects were randomly assigned to three groups. A comparison of the results of the three groups indicated that:

1. There was no significant difference between the group receiving all positive reinforcement and the group receiving spaced negative reinforcement.

2. The scores of the groups receiving all positive reinforcement and spaced negative reinforcement were significantly greater than those of the massed negative reinforcement group.

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Melaragno concluded that the presence of some spaced negative reinforcement within a program does not hinder a student's learning. Too many negatively reinforcing items appearing one after another have a tendency to reduce learning efficiency.\textsuperscript{39}

An extensive classroom investigation on the relative effectiveness of teaching machines and programmed textbooks and the influence of grade level on learning achievement by means of these automated teaching methods was conducted under the direction of Eigen and Komoiski. This study is frequently referred to as the Automated Teaching Project. A total of 74 male high school students from the Collegiate School in New York City (25 ninth-, 23 tenth-, and 26 eleventh-grade students) with a mean Otis IQ of 126.8 participated in the study. No low-ability students were included in the experiment.

The machines used were the Skinner-type write-in, and the program was Sets, Relations and Functions, a 707-frame sequence by Lewis D. Eigen. Machine and programmed textbook groups were matched on the basis of intelligence scores for each grade level. Upon completion of the program two tests were taken: a post-test on material specifically taught in the program and a transfer test comprised of items not specifically taught. The three measures available for each subject were:

1. a post-test score; (2) a transfer test score; and (3) the amount of time needed to complete the program.

\textsuperscript{39}R. J. Melaragno, "Results of Experiment on Negative Reinforcement in Automated Teaching" (Santa Monica: System Development Corporation, 1960). (Mimeo-graphed.)
The following results were reported:

1. There was no significant effect of grade level on learning.
2. There was a significant effect upon the subject's ability to transfer the material.
3. No significant effect of grade level upon the length of time needed to learn was discovered.
4. Some students found difficulty in handling the machines.

The authors concluded that the usual contention that materials are best taught at a given grade level requires further research. They further concluded that since grade level is positively correlated with transfer, the most suitable grade level for particular subject matter should be based on transfer ability. The study opens the question of grade placement of material to research by programing. 40

D. J. Klaus, in collaboration with Lumsdaine, at the American Institute for Research in Pittsburgh conducted a project to assess the contribution of self-instructional materials used in conjunction with televised physics lessons in the EBF Harvey White series. The program consisted of approximately 3000 separate question-and-answer frames. Test results for experimental classes in which self-instructional materials were made available to supplement the televised physics course were compared with those of control classes which did not receive self-instructional materials. The test results demonstrated that the use of

the materials made a significant contribution to the average level of achievement by the students. 41

A current classroom study by Feldhusen investigated students' reactions to self-instructional devices and programs with both structured and open type questions. College students enrolled in general and educational psychology were used as subjects. Simple manila-folder self-instructional devices and a 37-frame program on teaching machines and programming were used by the students. Thus, the students were provided with a standard background experience on teaching machine and programming before their reactions were measured. Upon completion of the program which aimed to teach seven concepts on automated teaching, each student was given a questionnaire to answer.

Results obtained from responses on questionnaires indicated favorable reactions of students to self-instructional devices and programs. Both advantages and disadvantages were perceived. 42

Lawson, Burmester, and Nelson reported a college study in which five experimental sections of the natural-science course at Michigan State University using a semi-automated teaching device called a "scrambled book," were compared with five control sections on an objective test in genetics. Difference in performance was significant at the


one percent level in favor of the experimental group. Results of a
questionnaire revealed that the number of students who accepted the
scrambled book and found it enhancing to learning far outnumbered those
who rejected or disfavored it. Comments from the staff were likewise
favorable.

Description of the scrambled book used, writing and programing
problems, and "scrambling problems" form a large part of the study. In
a section of the study on the effectiveness of the scrambled book as an
aid to learning, the authors state:

The scrambled book was developed as a possible means of handling
more students per staff member by placing greater responsibility
for their own learning upon the students themselves. To be accept­
able for this purpose the scrambled book would have to meet three
criteria:

(1) It should be almost completely self-administering, thereby not
increasing the work-load of the individual staff member . . .
(2) It must not result in a deterioration of quality of learning
on the part of the student.
(3) It must not be regarded by a majority of both the students and
staff members as a genuinely useful and stimulating aid to
learning and not as a mere novelty.

Hoemer and Nolan in a comparative study with military students
sought to analyze the results obtained from the use of a scrambled book
versus traditional classroom teaching. Two experimental and two control
groups were involved in the experiment. Results showed that students
using the scrambled book finished in much less time and gained a compara­
ble amount of academic learning as the control students. No major

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43 C. A. Lawson, M. A. Burmester, and C. H. Nelson, "Developing
a Scrambled Book and Measuring Its Effectiveness as an Aid to Learning
differences between groups on the end-of-instruction retention test and on student achievement by general aptitude were revealed. Slow-learning students learned just as much as the fast learners. The end result indicated "that students learn effectively in less time by the scrambled book self-instructional device." 44

Hughes compared the effectiveness of programed and conventional instruction with 112 men enrolled in an IBM company course in customer engineering.

The following results were reported:

1. Students with programed textbooks completed their work in less time.
2. Mean score of students with programs was higher than that of conventional group.
3. Attitude questionnaire indicated a favorable reaction toward programed instruction. 45

Classroom Studies in Progress

A number of experimental classroom studies on various aspects of automated teaching are presently in progress at various universities and centers throughout the country. Information regarding such studies has been reported in current issues of AID and Programmed Instruction. Several of these studies are reported below:


The division of Academic Research and Service of the Pennsylvania State University is presently engaged in a comparative study with groups of students receiving instruction in mathematics and English by means of: (1) programed booklets, (2) teaching machines, (3) closed-circuit television, and (4) conventional methods. 46

The Division of Educational Research at the University of Virginia is testing its programs in elementary mathematics with 850 fourth-grade pupils. A current issue of AID offers the following information:

Comparisons are being made between control and experimental groups and between programed textbooks and teaching machines in relative maintenance of motivation over a period of time and relative efficacy of programed materials at different levels of ability. 47

A recent doctoral dissertation, "An Experimental Comparison of Two Approaches to Teaching Multiplication of Fractions," by Jack W. Miller has been completed at The Graduate School of George Peabody College. Results are not yet available, however, the author has reported that:

Comparative data were obtained from the results of teaching sixth-grade children by the usual method, which involved development of understanding and computational skills through use of a textbook and teacher's manual, and a method employing demonstrations, discussions, visual aids, and computational practice on a teaching machine. 48


Coulson reports a study supported by Title VII of the National Defense Education Act which involves a comparison of different methods of item construction. Its purpose is to determine the effects of automated materials on informational and conceptual learning by under-achieving, normal, and over-achieving high school students.49

SUMMARY OF THE FINDINGS

Studies reviewed in this chapter indicate that the teaching machine when wisely used, either according to the Pressey or Skinner approach, possesses distinct pedagogical values. The findings, however, present such a wide range that one must agree with the statement that "the usefulness of any . . . aid varies with every topic or project."50 Experimentation also shows that results vary considerably with different groups at different age or grade levels.

On the basis of the literature reviewed, resultant findings of research studies utilizing the Pressey approach have followed a rather consistent trend. In general, the simple teaching devices, as well as the more complex teaching machines, have enhanced, facilitated, and accelerated learning in students of varying levels of ability and with a variety of subjects. By testing and teaching at the same time, teaching machines have provided a way to relieve the teacher of many time-consuming tasks. In addition, immediate knowledge of the correctness of


responses has resulted in significant increments in learning. Pressey, Little, Jensen, and others have confirmed the efficacy of mechanical devices and the importance of knowledge of results in the teaching-learning process. 51, 52, 53

Stephens and Angell have reported more effective results from knowledge of results provided early in learning than from delayed results. 54, 55 Stephens, however, predicts better performance through the combined use of knowledge of results during and after learning. This suggestion has been investigated in the present study.

Military trainees have displayed strong interest in training devices as aids in learning the intellectual aspects of certain skills. 56, 57, 58 Instructors and students have reacted favorably to the use of automated teaching devices; some students, however, found difficulty in manipulating the mechanical devices. 59, 60 The present study has attempted to investigate the effective use of a very simple, versatile device which could be handled equally well by all students.

51 Pressey (1950), op. cit.
52 Little, op. cit.
53 Jensen, op. cit.
54 Stephens, op. cit.
55 Angell, op. cit.
56 Cantor and Brown, op. cit.
57 Dowell, op. cit.
58 Hosmer, op. cit.
59 Porter (1959), op. cit.
60 Eigen and Komoski, op. cit.
The Eigen and Kemoski and Keislar studies have revealed effective results from the use of teaching machines with brighter students; Porter's study seemed to indicate that such devices could be used effectively with all ability levels. The investigator of the present study has explored the effectiveness of teaching machines with students at three ability ranges.

While Coulson and Silberman found little difference between the constructed versus multiple-choice response modes, Fry's study indicated superior results with constructed responses.

There was evidence suggesting that it may not always be desirable to minimize errors in a program. Keislar and Stolow, on the otherhand, recommended a "minimum difficulty level."

In spite of the many benefits that have accrued from research studies with teaching machines, nevertheless, inadequacies and limitations are evident. Since most of the studies reviewed have used only relatively small samples, one may question the generality of the findings. In most cases, adult learners in colleges and universities acted as subjects. Relatively few comparative classroom studies with larger samples have been conducted on the elementary and secondary school levels.

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61 Ibid.
62 Keislar, op. cit.
63 Porter, op. cit.
64 Coulson and Silberman, op. cit.
65 Fry, op. cit.
66 Porter, op. cit.
67 Melaragno, op. cit.
68 Keislar, op. cit.
69 Stolow, op. cit.
great deal of research with teaching machines in actual classroom situations is presently underway, consequently, only meager conclusive evidence regarding their effectiveness has been established. Comparatively few studies in automated teaching have been conducted in science instruction at the secondary school level. None of these experiments has investigated the effectiveness of a simple teaching machine in a normal classroom situation, nor have they attempted to determine the combined effect of the teaching machine and a self-trainer. These aspects of the automated teaching problem have been investigated by the author.

In planning the setup of the present study, every effort was made to maintain a normal classroom situation. The extent to which this attempt has been successful can best be judged from the following chapters.
CHAPTER III

PRESENTATION OF THE EXPERIMENTAL DATA

This investigation was conducted during the spring of 1961 using the data from two Catholic coeducational high schools in the Chicago area. The study was principally designed to test the relative effectiveness of automated teaching of space biology at three levels of intelligence in the high school science classroom. Learning resulting from the use of simple teaching machines, with and without a self-trainer, was compared with that resulting from programmed lecture instruction, with and without note-taking. The experiment also attempted to obtain evidence concerning the changing role of the teacher and student reactions to teaching-machine instruction and other phases of the experimental study.

In the chapter that follows the experimental design, the sample, the devices, tests, instructional unit, procedures, methods, and other experimental data are presented and described.

DESIGN OF THE STUDY

The Sample

The sample for the experiment consisted of ninth- and tenth-grade students enrolled in biology, general science, and health classes at two Catholic coeducational high schools. For convenience of reference in this report, the two schools are designated as School A and School B. The schools were selected for purposes of experimentation for several reasons:
(1) They were similar in size, purpose, and socio-economic background;
(2) They were easily accessible to the investigator;
(3) The administration expressed a willingness to participate in the experiment; and
(4) They had administrative and teaching conditions which made it possible to fit them into the plan of the present experiment.

The school districts in which the students lived included well-established residential areas and relatively well-industrialized areas; the socio-economic status ranged from average to relatively high.

A total of 416 students participated in the study. However, twelve students for whom complete test data were not obtained due to absenteeism, or to random deletion in order to maintain proportional subgroups for the multiple analysis of variance were dropped from consideration in the final analysis. Thus, the total sample was reduced to 404 students. School A contributed 180 students—88 tenth-grade biology students and 92 ninth-grade general science students. In School B, the participating classes consisted of 116 biology students and 108 health students—a total of 224. For purposes of convenience, these grade groups are referred to as A-9, A-10, B-9, and B-10. The actual balancing of groups was not performed until all the testing had been completed at the end of the experimental period. The students for whom complete test data were lacking, or who were statistically deleted from the final analysis, were not physically barred from participating in the experiment, but were permitted to proceed along with their fellow students.
METHODS-BY-LEVELS-ANALYSIS OF VARIANCE DESIGN

The experimental design employed in this experiment was the methods-by-levels-analysis of variance. This design is essentially the application of the technique of analysis of variance to groups organized by the experimenter on the basis of some initial measure highly related to the criterion. In this particular experiment four method groups were matched on the basis of intelligence quotients obtained from the Henmon-Nelson Test of Mental Ability. Each method group was then divided into three levels of ability. A complete description of the procedure used in equating the groups and in arranging the levels follows under the next major heading.

The principal purpose of the methods-by-levels design is to determine if the methods "have different average effects on the members of the specified population." The null hypothesis to be tested is that the population mean is the same for all methods. Another purpose of experiments of this type is to determine whether or not there is any interaction of methods and levels. The corresponding hypothesis to be tested is that the differences among corresponding method population means are the same for all levels.

This design offers greater precision and efficiency to the experiment than the simple-randomized design. Among other advantages, it

yields valuable information regarding interaction between methods and levels; it minimizes systematic differences from one method subgroup to another due to extraneous factors; and the assumptions underlying the test of significance of the methods effect are much less restrictive and more likely to be valid than in any other design.²

PROCEDURES USED IN THE STUDY

Intelligence Testing

Two weeks prior to the experiment, the Henmon-Nelson Test of Mental Ability - Form A for Grades 9-12 was administered to all participating students in each of the two schools. The test results yielded information regarding the initial mental ability which was used as a basis for equating the students. This test is "designed to measure those aspects of mental ability which are important for success in academic work and in similar endeavors outside the classroom."³ It consists of 90 test items arranged in order of increasing difficulty. The investigator selected this test, rather than any other, for the following reasons: (1) It is simple to administer; (2) easy and rapid to score due to its self-marking qualities; and (3) its testing time does not exceed thirty minutes. The administration and faculty in both schools administered, scored, and recorded the data for the test.

²Ibid., pp. 147-148

Frequency distributions of the Herman-Nelson intelligence quotients for the four separate grade groups, A-9, A-10, B-9, and B-10 were tallied and are reported in Tables I and II. Graphic presentation of the intelligence quotients are shown in Figure 1. The average class results corresponded very closely with the intelligence scores available in the records of the two schools. All means and standard deviations were computed from ungrouped data with the aid of the Underwood Olivetti Divisumma 24 electric calculator. One can note from Figure 1 and Tables I and II that only slight differences in the mean intelligence quotients were found between the same grade groups in the two schools. Between the total IQ means of A-9 (109.4) and B-9 (109.1) there was merely a difference of .3. The Mean IQ of A-10 (107.4) was 1.2 points higher than that of B-10 (106.2). In both schools the mean IQ’s of the freshman groups (A-9 and B-9) were slightly higher than those of the sophomore groups (A-10 and B-10).

**Equateing the Groups**

In each school the name of the student, grade, and intelligence quotient were entered on 3 x 5 index cards—one for each student. The cards were separated into ninth- and tenth-grade students and were arranged in rank order from highest to lowest. The cards of each grade group were then divided into three ability levels according to the following plan:

- **Level I** - students with intelligence quotients of 110 and above;
- **Level 2** - students with intelligence quotients of 101 to 109;
- **Level 3** - students with intelligence quotients of 100 and below.
TABLE I
HENMON-NELSON INTELLIGENCE QUOTIENTS

<table>
<thead>
<tr>
<th>Class Interval</th>
<th>SCHOOL A-9 Method</th>
<th>SCHOOL A-10 Method</th>
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<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>150-154</td>
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<td></td>
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<tr>
<td>145-149</td>
<td></td>
<td></td>
</tr>
<tr>
<td>140-144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>135-139</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>130-134</td>
<td></td>
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<td>125-129</td>
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<td>115-119</td>
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<td>105-109</td>
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<td></td>
</tr>
<tr>
<td>N</td>
<td>23</td>
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Grade N 92
Total Mean 109.4

N 88
Mean 107.4
### TABLE II

**HENMON-NELSON INTELLIGENCE QUOTIENTS**

<table>
<thead>
<tr>
<th>Class Interval</th>
<th>School B-9 Method</th>
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<th></th>
<th></th>
<th>School B-10 Method</th>
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<th></th>
<th></th>
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<tbody>
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<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>I</td>
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**Grade**

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<tr>
<th>N</th>
<th>108</th>
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<tr>
<td>Total Mean</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Total Mean</td>
<td>106.2</td>
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</tbody>
</table>


FIGURE 2
DISTRIBUTIONS AND MEANS OF INTELLIGENCE SCORES IN SCHOOLS A AND B
With four experimental conditions, or methods, the first four subjects with the highest scores were assigned one subject to each of the four undetermined experimental conditions. Thus, the first row consisted of subjects of comparable levels on the Henmon-Nelson Test of Mental Ability. Similarly, the next four subjects were assigned one to each of the four experimental conditions, or methods. The second row also consisted of subjects of comparable levels on the initial test. This process was repeated until all of the subjects in each grade group had been placed. The specific experimental conditions, or methods, were then randomly assigned to each of the four groups. Tables III, IV, V, and VI indicate the arrangement and number of students in each of the grade groups according to the methods-by-levels experimental design. For ease in computation, the same number of students was maintained in each of the four cells on the same level.

**TABLE III**

THE ARRANGEMENT AND NUMBER OF SCHOOL A-9 STUDENTS IN THE CELLS ACCORDING TO METHODS AND LEVELS

<table>
<thead>
<tr>
<th>Levels</th>
<th>Methods</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>L₁</td>
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<td>4</td>
</tr>
<tr>
<td>N</td>
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<td>23</td>
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</tbody>
</table>

Code: \( L₁ = \) IQ 110 and above; \( L₂ = 101-109; \) \( L₃ = 100-below \)
### TABLE IV

**THE ARRANGEMENT AND NUMBER OF SCHOOL A-10 STUDENTS IN THE CELLS ACCORDING TO METHODS AND LEVELS**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Methods</th>
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<th>II</th>
<th>III</th>
<th>IV</th>
<th>Total</th>
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<td>9</td>
<td>9</td>
<td>9</td>
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<td>7</td>
<td>7</td>
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<td>28</td>
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<tr>
<td>L₃</td>
<td></td>
<td>6</td>
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<td>6</td>
<td>6</td>
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<td>22</td>
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<td>88</td>
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</tbody>
</table>

**CODE:**  
L₁ = IQ 110 and above; L₂ = 101-100; L₃ = 100-below

### TABLE V

**THE ARRANGEMENT AND NUMBER OF SCHOOL B-9 STUDENTS IN THE CELLS ACCORDING TO METHODS AND LEVELS**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Methods</th>
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<th>II</th>
<th>III</th>
<th>IV</th>
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</thead>
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<td>27</td>
<td>27</td>
<td>108</td>
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</tbody>
</table>

**CODE:**  
L₁ = IQ 110 and above; L₂ = 101-109; L₃ = 100-below
TABLE VI

THE ARRANGEMENT AND NUMBER OF SCHOOL B-10 STUDENTS IN THE CELLS ACCORDING TO METHODS AND LEVELS

<table>
<thead>
<tr>
<th>Levels</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>L₁</td>
<td>11</td>
</tr>
<tr>
<td>L₂</td>
<td>10</td>
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<tr>
<td>L₃</td>
<td>8</td>
</tr>
<tr>
<td>N</td>
<td>29</td>
</tr>
</tbody>
</table>

CODE: \( L₁ = \text{IQ 110 and above; } L₂ = 101-109; \) \( L₃ = 100\)-below

DESCRIPTION OF THE DEVICES USED

The Teaching Machines

Thirty Vertimask and six Slide-a-mask teaching machines were used in this experiment by 202 students in Method Groups I and II to present the 500-frame teaching-machine program in Space Biology. Both of these devices were products of the Dyna-Slide Company, Chicago, Illinois. Brief descriptions of the devices follow:

The Vertimask is a teaching machine reduced to minimum essentials. It has a rigid plastic base and a flexible opaque masking curtain kept in horizontal alignment by a concealed slider-in-track arrangement. Three notches are provided to engage the rings of a notebook. This simple, compact, portable device does just what the more complicated teaching
machines do: (1) it presents a question or statement; (2) it allows the student to write his answer, and (3) it reveals the correct answer. An added advantage is that neither question nor answer size is restricted to the size of a fixed window. Pictures and diagrams of almost any shape and size may also be used. Programs can be printed or mimeographed on 8½ x 11 paper.

Program sheets used with the Vertimask employ aligning marks at the left hand side. With the mask at the top of the page, these marks are visible and indicate stopping places for the mask in its downward travel. When a page has been completed, the mask is returned to the top; and the page is easily turned with the mask in place—preventing accidental seeing of answers on the new unworked page.

The Vertimask has many advantages for business and industrial training. It has been especially adopted for use in home study courses. Its high price of $10.75, however, has prevented it from being adopted for extensive classroom use.

The Slide-a-mask, the other teaching machine used in this study, is a less expensive device characterized by maximum simplicity and compactness. It is a single piece of formed sheet vinyl plastic which accomplishes masking in exactly the same manner as the Vertimask. It maintains horizontal alignment by using the left hand edge of the program for a guide. In both devices, pages may be easily turned with the mask covering the page.
Photostats of the Vertimask and Slide-a-mask may be found on the next page. Directions for the use of these two devices are included in Appendix A and Appendix B.

The Self-Trainer

The Multiple-Purpose Self-Trainer, X-0 Form (24 items), used in this experiment is a product of Management Research Associates, Chesterton, Indiana. It is actually a modern punchboard which combines the values of the conventional test with advantages in new areas of immediate training and stimulation. The students in Method Group II used the self-trainer before learning in connection with the space biology pre-test and after learning with the post-test. Instead of an answer sheet the students had a self-trainer. By pulling tabs they were immediately informed about the correctness of their responses. If there was an "X" under the tab, the answer was correct; if an "0" appeared the answer was incorrect. Further information regarding the use of the self-trainer will be given in connection with the testing instruments used in this experiment.

THE INSTRUCTIONAL MATERIAL

The instructional material chosen for this experiment was space biology for ninth- and tenth-grade science students. The reason for selection of this particular instructional material was mainly that the material had not been covered previous to the experiment, nor did the regular teachers plan to include it in the year's work. Other reasons for its selection are included in the objectives of the unit.
PLATE I

PHOTOSTATS OF TEACHING MACHINES USED IN THE STUDY

Figure 1. - THE VERTIMASK

Figure 2. - THE SLIDE-A-MASK
(1) To develop in the students an awareness of the responsibility of man's place in space.
(2) To acquaint the students with the physiological, psychological and physical problems of human space flight.
(3) To acquire general knowledge of the human factors involved in space travel.

The material to be covered in the experimental unit was organized around the points of interest indicated by the following outline:

OUTLINE OF UNIT OF INSTRUCTION

1. The necessity of operating in a virtual vacuum
2. Weightlessness, the result of operating under zero gravity
3. Protection against nuclear radiation
4. Adjustment to high acceleration and deceleration
5. Vision and hearing in space
6. The air, food, and elimination problems

The Teaching-Machine Program

The subject matter to be utilized in the experiment was programmed in small steps by the investigator. An effort was made to word and sequence the items in such a way to enable the student to proceed from one item to the next with little difficulty. Student responses followed the Skinnerian constructed-response mode.

A portion of the space biology program used in the study may be found in Appendix E. Analysis of the error rate and a complete description of the program follows in Chapter IV.

The Programmed Lectures

The subject matter of the space biology unit was presented by the investigator to the students in Groups III and IV in the form of programmed lectures. These lectures covered the same content as that found
in the space biology program used by the students in Groups I and II. Since the teaching-machine program was composed by the experimenter, presentation of the same material in the form of a lecture did not create a problem. Following the programmed lecture, a certain amount of time was allotted to a discussion period. The procedure followed was similar to that of the conventional lecture method, except that the lecturer had to adhere rather rigidly to the content covered by the teaching-machine program.

Films and Filmstrips

The field of available sound motion pictures and filmstrips was surveyed in an attempt to obtain current, up-to-date films and filmstrips which would serve the purposes of the experiment. Since the subject matter of space biology was relatively new to the student, it was necessary to select such visual and audio-visual instructional aids that would provide the students with background material necessary for better acquisition of subject matter knowledge of the human factors involved in space flight. The main purpose for the use of the films and filmstrips was to offer greater incentive and vitalization to the teaching-learning process. Since the films and filmstrips were shown in all of the method groups, changes in learning behavior resulting from their use could not be measured.

*Man in Space*---a Walt Disney film---and *Trip to the Moon* were the two 16 millimeter films selected for use in this study. Both films were shown after completion of the instructional unit. They served the purpose of presenting and summarizing the most recent aerospace developments.
and concepts and of providing an up-to-date analysis of space travel today. The films were obtained through the courtesy of the Chicago Public Library, Visual Aids Center.

Four color filmstrips of the Space and Space Travel series from the Society for Visual Education were also included in the experiment. In general, they supplied up-to-date timely information on recent space explorations and concepts. The series consisted of the following filmstrips:

1. **Leaving the World**--41 frames. Pictures man-made satellites--information recently launched. Shows how rockets developed. Explains rocket power and thrust, speed of release. Defines perigee, apogee, period, and ellipse.


3. **Man in Space**--47 frames. Shows how men are being trained for outer-space trip. Obstacles to be overcome--weightlessness, acceleration, temperature extremes, radiation. Discusses future manned space stations.

4. **Space Travel A.D. 2000**--52 frames. Emphasizes nature of space, facts of astronomy. Shows relationship of time and distance to space travel. What other worlds might be like. New forms of power being
considered. Discusses atomic engines, plasma and photon power, ion propulsion. 4

**Measuring Instruments**

The problem was one of testing which method produced superior results in measured subject matter knowledge of *Space Biology* during the experimental period: Method I, Method II, Method III, or Method IV. The design adopted required that differences which might occur in performance of the four groups were to be tested for significance by assumption of the null hypothesis.

In order to secure necessary data as a basis for a statistical test of the null hypothesis, the following tests were administered:

1. **Pretest**--before instruction--to determine the students' initial knowledge of space biology.
2. **Post-test I** (same as pretest)--after instruction--to measure the amount of gain from pretest to post-test.
3. **Post-test II**--after instruction--to test recall.
4. **Retention test I**--one week after experimental period to measure retention from pretest to retention test I.
5. **Retention test II**--to measure retention from post-test II to retention test II.

As no space biology tests were available which would adequately measure subject matter knowledge, two tests were constructed especially for the purpose of the experiment. The pretest, a true-false test of 120 items, was administered to the students before instruction as a pretest, after instruction as post-test I, and one week after completion of the experimental study as retention test I. Similarly, post-test II,

---

a 100-item (true-false) test, was used twice—after instruction as post-test II and one week later as retention test II. Both tests were designed to measure subject matter knowledge of space biology. The calculated coefficient of correlation between the two tests—pretest and post-test II—was .84.

Since the students in all four Method Groups were given the same tests, it was necessary to construct the tests so that they conformed with the X's and 0's under the tabs of Nelson's Multiple-Purpose Self-Trainer. The students in Method Groups I, III, and IV wrote their answers on conventional test papers, while those in Group II received immediate knowledge of results through the use of the Self-Trainer.

Photostat appears on next page. See Appendix C and Appendix D for tests.

All tests were scored by the investigator and the regular classroom teachers whose educational experience enabled them to perform this task with a minimum of error. The accuracy of scoring was further insured by one scorer checking another.

Coefficients of reliability were computed for the tests. In this computation, a random selection of one hundred test papers was made for each test. The coefficients of reliability follow.

<table>
<thead>
<tr>
<th>Test</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
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</tr>
<tr>
<td>Post-Test I</td>
<td>.89</td>
</tr>
<tr>
<td>Retention Test I</td>
<td>.87</td>
</tr>
<tr>
<td>Post-Test II</td>
<td>.84</td>
</tr>
<tr>
<td>Retention Test II</td>
<td>.89</td>
</tr>
</tbody>
</table>

5The coefficients of reliability were computed by correlating the odd items with the even items and applying the Spearman-Brown prophecy formula \( r_{nm} = \frac{nr}{1+(n-1)r} \).
## The Multiple Purpose Self-Trainer

**Example**

<table>
<thead>
<tr>
<th></th>
<th>a.</th>
<th>b.</th>
<th>c.</th>
<th>d.</th>
<th>e.</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<td>a.</td>
<td>b.</td>
<td>c.</td>
<td>d.</td>
<td>e.</td>
</tr>
</tbody>
</table>

### Score Table

- **X** = Correct
- **O** = Incorrect
- **Possible X Score** = 60

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**Figure 1**

**The Multiple Purpose Self-Trainer**
Distribution of pretest scores, post-test I and II scores, and retention test I and II scores for the combined method groups in each grade group are reported in Figures 2, 3, 4, 5, and 6. Means and standard deviations were machine calculated from ungrouped data. Analysis of the results of these data are considered in Chapter IV.

**Student Opinionnaire**

Apart from the measuring instruments described above, the attitudes and opinions of individual subjects of each grade group were investigated with respect to method of instruction and the experimental study at large. Twenty-one statements or items relating to the instructional unit, teaching machine instruction, note taking, films and filmstrips, the devices used, and the programmed lecture were presented to the students with instructions to indicate by numbers ranging from 1 to 5 their position of agreement or disagreement toward each statement. In addition to the structured opinionnaire, the students' personal reactions to the study were gathered by means of free comments. Analyses of the students' responses to the opinionnaire and their free comments are discussed in Chapter V.

**METHOD GROUPS**

The students in each of the four grade groups, A-9, A-10, B-9, and B-10 were arranged on the basis of intelligence scores into three ability levels, and were randomly assigned a particular method—I, II, III, or IV.
FIGURE 2

DISTRIBUTION OF PRETEST SCORES, MEANS, AND STANDARD DEVIATIONS FOR COMBINED METHOD GROUPS

SCHOOL A-9
MEAN = 73.73
S.D. = 6.28
N = 92

SCHOOL A-10
MEAN = 72.38
S.D. = 7.01
N = 88

SCHOOL B-9
MEAN = 67.94
S.D. = 6.28
N = 108

SCHOOL B-10
MEAN = 70.80
S.D. = 6.66
N = 116
FIGURE 3

DISTRIBUTION OF POST-TEST I SCORES, MEANS, AND STANDARD DEVIATIONS FOR COMBINED METHOD GROUPS

SCHOOL A-9
MEAN = 84.45
S.D. = 6.69
N = 92

SCHOOL A-10
MEAN = 84.50
S.D. = 5.13
N = 88

SCHOOL B-9
MEAN = 80.88
S.D. = 5.68
N = 108

SCHOOL B-10
MEAN = 81.60
S.D. = 5.39
N = 116
SCHOOL A-9
MEAN = 84.01
S.D. = 6.70
N = 92

SCHOOL A-10
MEAN = 85.14
S.D. = 5.67
N = 88

SCHOOL B-9
MEAN = 81.21
S.D. = 5.63
N = 108

SCHOOL B-10
MEAN = 80.91
S.D. = 4.96
N = 116

FIGURE 4
DISTRIBUTION OF POST-TEST II SCORES, MEANS, AND STANDARD DEVIATIONS FOR COMBINED METHOD GROUPS
SCHOOL A-9
MEAN = 83.50
S.D. = 6.64
N = 92

SCHOOL A-10
MEAN = 87.68
S.D. = 4.73
N = 88

SCHOOL B-9
MEAN = 83.16
S.D. = 5.42
N = 108

SCHOOL B-10
MEAN = 84.40
S.D. = 5.44
N = 116

FIGURE 5
DISTRIBUTION OF RETENTION TEST I SCORES, MEANS, AND STANDARD DEVIATIONS FOR COMBINED METHOD GROUPS
SCHOOL A-9
MEANS = 83.46
S.D. = 5.84
N = 92

SCHOOL A-10
MEANS = 84.65
S.D. = 4.94
N = 88

SCHOOL B-9
MEANS = 81.32
S.D. = 5.06
N = 108

SCHOOL B-10
MEANS = 81.03
S.D. = 5.00
N = 116

FIGURE 6

DISTRIBUTION OF RETENTION TEST II SCORES, MEANS, AND STANDARD DEVIATIONS FOR COMBINED METHOD GROUPS
A description of the method of instruction followed in each method group is presented below.

(a) **Method Group I**, commonly referred to as the teaching-machine group, was taught space biology by means of a 500-frame program which covered subject matter knowledge of the factors involved in human space flight. Each day the students gathered in adjacent science classrooms to work on a portion of the space biology program. These groups were proctored by the regular science teachers. No verbal instruction was offered.

(b) **Method Group II**, also a teaching-machine group, received instruction by means of the same program as Method Group I. The only difference between the two groups was the addition of a self-trainer at the time of pretesting and post-testing. The students in this group received immediate knowledge of results before instruction through the self-trainer, during instruction by means of the teaching-machine program and again after instruction with the self-trainer.

(c) **Method Group III** was taught by means of programmed lectures followed by discussion. The programmed lectures covered the same subject matter as the teaching-machine program. The students in this group were not permitted to take notes during the lectures.

(d) **Method Group IV** was also taught by the programmed lecture, but note-taking was mandatory. Since high school students normally take notes during classroom lectures, this group might be designated as a special control group placed in an experimental situation.
Throughout the conduct of this investigation every effort was made to avoid any condition which might interfere with the teaching situation. The students were aware of the fact that they were participating in an experiment. The administration and teachers showed splendid cooperation without becoming unduly concerned about the outcomes of the study.

Great care was exercised to prevent any condition which might favor one particular method of instruction. The four method groups were treated alike in that all lecture classes were taught by the investigator; the teaching-machine groups were proctored by the regular science teachers. All classes met the same number of times, that is, five days a week. School A had 45-minute class periods and School B, 55-minute periods; however, caution was taken to devote the same amount of time in terms of clock hours to all classes in both schools. Any variation from the usual program found necessary for one class was observed in all classes. No textbooks were used in any of the classes; no homework or outside readings were assigned. All learning took place during the class periods. The same films and filmstrips were shown at the same intervals to all groups. The tests administered before and after instruction were also identical. Particular stress was placed upon the necessity of keeping the work of the four method groups as nearly identical as possible during the experimental period.

In order to satisfy the standards of modern experimental design and statistical analysis, the requirements of randomization, replication,
and local control were carefully met in this investigation. Random assignment of methods to the four groups arranged according to mental ability fulfilled the requirement of randomization; replication was provided by conducting four independent experiments in two schools; local control was satisfied since one method group in each experiment served as a control group.

Statistical analysis and interpretation of the data follow in the next chapter.
CHAPTER IV

STATISTICAL ANALYSIS AND INTERPRETATION OF THE DATA

The foregoing chapters have dealt with the proposed problem of investigation, a review of the literature in the field, and presentation of the data. This chapter is concerned with the analysis and interpretation of the data which were gathered as a result of comparing the effectiveness of the teaching machine, with and without a self-trainer, versus the programmed lecture, with and without note-taking.

The data collected from each grade group in School A and School B were subjected to methods-by-levels-analysis of variance. The method, as indicated in the previous chapter, is an application of the analysis of variance technique to groups matched on the basis of some initial test score. "Its advantage over the classic matched group technique," as Koppa states in his dissertation, "is that it provides a means of determining whether or not the relative effectiveness of the compared methods of instruction is related to the initial levels of ability of the students." 1 In this experiment, methods-by-levels-analyses were made with each grade group in separate schools--School A and School B--using the distributions of intelligence quotients matched for the four

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method groups, I, II, III, and IV and divided into three levels of ability. Similar analyses were made with the grade groups 9 and 10 combined in each school. The purpose of the analyses with the IQ scores was to determine whether the expected significant differences between levels within subgroups would appear as a result of previous matching and division of the groups into levels. Analyses of variance (24 in all) were also made using the pretest scores; gains between pretest and posttest I scores; delayed retention between the pretest and retention test I; and finally delayed retention between post-test II and retention test II. These analyses were made with the groups divided into levels in A-9, A-10, B-9, and B-10, respectively, and then with the combined grade groups A-9 and 10 and B-9 and 10 without levels. At no time were the data of both schools pooled for statistical analysis. In each case the schools were treated separately.

ASSUMPTIONS BASIC TO THE ANALYSIS OF VARIANCE

Underlying the application of the analysis of variance to any data are several assumptions upon which the development of the method is based. Johnson indicates that whenever the analysis of variance is used the following assumptions must be met:

1. All groups of a certain criterion . . . should be randomly chosen from the subpopulations. . . . This assumption is the keystone of the analysis-of-variance technique. Failure to fulfill this assumption gives biased results.
2. The population distribution should be normal.
3. The subgroups under investigation should have the same variability.

---

The extent to which the first assumption of randomness, or representative sample, is satisfied lies completely within the control of the investigator. In the methods-by-levels design used in the present study, the methods were randomly assigned to the groups matched on the basis of the intelligence quotients of the subjects.

As far as the second assumption is concerned, the requirement of normality is in general more likely to be satisfied in this type of design than in any other. The distributions of test scores in Figures 2, 3, 4, 5, and 6 in Chapter III indicate that, except for the pretest scores, the departure from normality is not too marked.

With reference to the assumption of the homogeneity of variance in the methods-by-levels design, differences among the means may vary from one method to another, but the variance within subgroups remain more or less the same.

In a discussion on the assumptions underlying the analysis of variance in the methods-by-levels design, Lindquist states:

In any event, a considerable departure, either from normality in the criterion distribution, or from homogeneity of variance among cells of the table, is permissible; yet the sampling distribution of the ratio of mean squares for treatments and within-cells will remain essentially the same.

Accordingly, in his report on the Norton study, the same author asserts:

The results of the Norton study should be extremely gratifying to anyone who . . . contemplates using the F-test of analysis of

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variance in experimental situations in which there is serious doubt about the underlying assumptions of normality and homogeneity of variance. Apparently, . . . one need be concerned hardly at all about lack of symmetry in the distribution of criterion measures, so long as this distribution is homogeneous in both form and variance for the various treatment populations. . . . In general, the F-distribution seems so insensitive to the form of the distribution of the criterion measure that it hardly seems worthwhile to apply any statistical test to the data to detect non-normality, even though such tests are available.4

With reference to heterogeneity of variance, Norton's findings, according to Lindquist, indicate that:

. . . the heterogeneity must be quite extreme to be of any serious consequence. While statistical tests of heterogeneity of variance are available . . . , there will be relatively few situations in which any such test is required.5

Since the data gathered from the two schools were treated separately, the statistical tests available for determining whether or not the assumptions underlying the analysis of variance were satisfied, were not made. Wert, Neidt, and Ahmann in a section on the analysis of variance state that . . . "it is becoming more apparent that the analysis of variance technique is sufficiently satisfactory even when there is considerable departure from the strict fulfillment of the assumptions."6

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4 Ibid., p. 86

5 Ibid.

RESULTS OF THE STATISTICAL ANALYSIS

Three separate measures of the relative effectiveness of the four teaching methods were available: (1) scores on post-test I for comparison with pretest performance to measure gain; (2) scores on retention test I for comparison with pretest performance to measure delayed retention, and (3) scores on post-test II for comparison with retention test II, likewise, to measure delayed retention. The mean and standard deviation of the five tests were calculated for each method group and then for the entire grade group. The distributions of scores, means, and standard deviations of pretest, post-test I, post-test II, retention test I, and retention test II for the entire grade group are presented in Figures 2, 3, 4, 5, and 6 found in Chapter III.

Tables VII and VIII present a summary of the means and standard deviations for each method group in School A and School B, respectively. A considerable difference in variability from method to method can be noted by the size of the standard deviation in only a few of the method groups. The means likewise indicate slight differences among the methods and grade groups. As the results indicate, no outstanding merit between the methods seems apparent.

Figures 2, 3, 4, 5, and 6 on pages 72 to 76 provide a graphic presentation of the respective test results showing the variability and frequency of the test scores in each grade group. A great amount of peakedness and skewness in the distribution of pretest scores may be observed, particularly in School B-9 represented by Figure 2 on page 72.
<table>
<thead>
<tr>
<th>Test</th>
<th>Grade</th>
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<th>II</th>
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<tr>
<td>Pretest</td>
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<td>73.52</td>
<td>74.87</td>
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<td>73.82</td>
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<tr>
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<td>9</td>
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<td>86.00</td>
<td>83.63</td>
<td>85.87</td>
<td>84.45</td>
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<td></td>
<td>10</td>
<td></td>
<td>84.09</td>
<td>86.36</td>
<td>82.73</td>
<td>84.82</td>
<td>84.50</td>
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<tr>
<td>Post-Test II</td>
<td>9</td>
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<td>85.59</td>
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<td>9</td>
<td></td>
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<td>84.57</td>
<td>83.39</td>
<td>85.52</td>
<td>83.50</td>
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<td></td>
<td>10</td>
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<td>86.41</td>
<td>88.64</td>
<td>87.59</td>
<td>88.09</td>
<td>87.68</td>
</tr>
<tr>
<td>Retention Test II</td>
<td>9</td>
<td></td>
<td>82.39</td>
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<td>83.17</td>
<td>84.04</td>
<td>83.46</td>
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<td>10</td>
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<td>86.36</td>
<td>83.50</td>
<td>85.36</td>
<td>84.65</td>
</tr>
<tr>
<td>Test</td>
<td>Grade</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>Average</td>
<td></td>
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<tr>
<td>------------</td>
<td>-------</td>
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<td>------</td>
<td>------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>9</td>
<td>M = 67.37</td>
<td>69.22</td>
<td>68.48</td>
<td>66.70</td>
<td>67.94</td>
<td></td>
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<tr>
<td></td>
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<td>S.D. = 5.75</td>
<td>7.81</td>
<td>6.16</td>
<td>5.41</td>
<td>6.28</td>
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</tr>
<tr>
<td></td>
<td>10</td>
<td>M = 68.52</td>
<td>70.90</td>
<td>72.86</td>
<td>70.93</td>
<td>70.80</td>
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</tr>
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<td></td>
<td>S.D. = 7.15</td>
<td>6.86</td>
<td>6.99</td>
<td>6.23</td>
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</tr>
<tr>
<td>Post-Test I</td>
<td>9</td>
<td>M = 80.37</td>
<td>81.93</td>
<td>80.70</td>
<td>80.52</td>
<td>80.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.54</td>
<td>5.32</td>
<td>6.63</td>
<td>5.23</td>
<td>5.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>M = 80.76</td>
<td>83.31</td>
<td>81.69</td>
<td>80.62</td>
<td>81.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.39</td>
<td>5.60</td>
<td>5.64</td>
<td>4.92</td>
<td>5.39</td>
<td></td>
</tr>
<tr>
<td>Post-Test II</td>
<td>9</td>
<td>M = 80.37</td>
<td>81.44</td>
<td>81.41</td>
<td>81.63</td>
<td>81.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.47</td>
<td>4.96</td>
<td>6.89</td>
<td>5.18</td>
<td>5.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>M = 78.83</td>
<td>82.48</td>
<td>82.10</td>
<td>80.24</td>
<td>80.91</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 4.71</td>
<td>4.62</td>
<td>4.74</td>
<td>5.77</td>
<td>4.96</td>
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</tr>
<tr>
<td>Retention Test I</td>
<td>9</td>
<td>M = 82.81</td>
<td>83.78</td>
<td>82.33</td>
<td>83.70</td>
<td>83.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.07</td>
<td>5.07</td>
<td>6.89</td>
<td>4.65</td>
<td>5.42</td>
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</tr>
<tr>
<td></td>
<td>10</td>
<td>M = 82.00</td>
<td>85.62</td>
<td>85.59</td>
<td>85.97</td>
<td>84.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.74</td>
<td>5.92</td>
<td>4.98</td>
<td>5.11</td>
<td>5.44</td>
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<tr>
<td>Retention Test II</td>
<td>9</td>
<td>M = 80.37</td>
<td>80.74</td>
<td>82.00</td>
<td>82.15</td>
<td>81.32</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.17</td>
<td>5.51</td>
<td>6.28</td>
<td>4.25</td>
<td>5.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>M = 78.69</td>
<td>82.21</td>
<td>82.34</td>
<td>80.89</td>
<td>81.03</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>S.D. = 5.78</td>
<td>4.79</td>
<td>4.51</td>
<td>4.93</td>
<td>5.00</td>
<td></td>
</tr>
</tbody>
</table>
This departure from normality might be due to lack of initial knowledge of the subject matter of space biology possessed by the students. To many students, the content was completely foreign at the time of pretest administration. Careful observation of the pretest data in Figure 2 also indicates lower scores for School B-9. This might be attributed to the fact that these were students from Health rather than from General Science classes. The lower pretest mean in B-10 could be due to failure and carelessness on the part of some of the students to answer all of the 120 test items in the pretest.

Close comparisons of Figures 2 and 3, 2 and 5, and 3 and 6 reveal the progress in learning achievement that had resulted from the experimental study. The mean gains between pretest and post-test I scores are presented in Table IX.

<table>
<thead>
<tr>
<th>TABLE IX</th>
<th>MEAN GAINS BETWEEN PRETEST AND POST-TEST I FOR METHOD GROUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>A-9</td>
<td>10.44</td>
</tr>
<tr>
<td>A-10</td>
<td>10.27</td>
</tr>
<tr>
<td>B-9</td>
<td>13.00</td>
</tr>
<tr>
<td>B-10</td>
<td>12.24</td>
</tr>
</tbody>
</table>
As shown in Table IX, very little differences can be noted in the means for A-9 from method to method; for A-10 the mean gain of Method II is slightly higher than that of I; and Method IV mean exceeds that of III. For B-9 the differences are also slight, but the B-10 means for Methods I and II are somewhat higher than for Methods III and IV. Table X presents, in summary form, the mean amount of subject matter knowledge retained from pretest to retention test I, administered one week after completion of the experimental study. Table XI indicates the mean amount of retention from post-test II to retention test II.

**TABLE X**

MEAN MEASURES OF RETENTION FROM PRETEST TO RETENTION TEST I

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-9</td>
<td>9.87</td>
<td>9.70</td>
<td>9.87</td>
<td>10.65</td>
</tr>
<tr>
<td>A-10</td>
<td>12.59</td>
<td>16.14</td>
<td>15.36</td>
<td>17.14</td>
</tr>
<tr>
<td>B-9</td>
<td>15.44</td>
<td>14.56</td>
<td>13.85</td>
<td>17.00</td>
</tr>
<tr>
<td>B-10</td>
<td>13.48</td>
<td>14.72</td>
<td>12.73</td>
<td>15.04</td>
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</tbody>
</table>

**TABLE XI**

MEAN MEASURES OF RETENTION FROM POST-TEST II TO RETENTION TEST II

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-9</td>
<td>-.87</td>
<td>.22</td>
<td>-.44</td>
<td>-1.13</td>
</tr>
<tr>
<td>A-10</td>
<td>-.73</td>
<td>-.55</td>
<td>-.45</td>
<td>-.23</td>
</tr>
<tr>
<td>B-9</td>
<td>.00</td>
<td>-.70</td>
<td>.59</td>
<td>.52</td>
</tr>
<tr>
<td>B-10</td>
<td>-.14</td>
<td>-.28</td>
<td>.34</td>
<td>.66</td>
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</tbody>
</table>
RESULTS OF THE ANALYSES OF VARIANCE

Separate tests of the analysis of variance were made using the IQ scores, pretest scores, gain between pretest and post-test I, retention between pretest and retention test I, and retention between post-test II and retention test II. Results and interpretation of the analyses follow.

Intelligence Test Analysis

As previously indicated, analyses of variance were made with the intelligence quotients of each grade group to determine whether the expected statistical significance for between levels would be obtained for all four grade groups. Results of the analyses with the expected between levels significance are shown in Tables XII, XIII, XIV, and XV.

TABLE XII

ANALYSIS OF VARIANCE RESULTS
FOR INTELLIGENCE QUOTIENTS
SCHOOL A-9

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>7.05</td>
<td>3</td>
<td>2.55</td>
<td>0.10</td>
</tr>
<tr>
<td>Levels</td>
<td>6618.36</td>
<td>2</td>
<td>3309.13</td>
<td>134.31**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>13.54</td>
<td>6</td>
<td>2.26</td>
<td>.092</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>1970.36</td>
<td>80</td>
<td>24.63</td>
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</tr>
<tr>
<td>Total</td>
<td>8609.91</td>
<td>91</td>
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<td></td>
</tr>
</tbody>
</table>

** Significant at 1% level
### TABLE XIII

**ANALYSIS OF VARIANCE RESULTS FOR INTELLIGENCE QUOTIENTS**
**SCHOOL A-10**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>9.77</td>
<td>3</td>
<td>3.26</td>
<td>.049</td>
</tr>
<tr>
<td>Levels</td>
<td>7188.38</td>
<td>2</td>
<td>3594.19</td>
<td>54.09**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>2.27</td>
<td>6</td>
<td>0.38</td>
<td>.006</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>5049.30</td>
<td>76</td>
<td>66.44</td>
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<tr>
<td>Total</td>
<td>12249.72</td>
<td>87</td>
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<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level**

### TABLE XIV

**ANALYSIS OF VARIANCE RESULTS FOR INTELLIGENCE QUOTIENTS**
**SCHOOL B-9**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>15.77</td>
<td>3</td>
<td>5.26</td>
<td>.08</td>
</tr>
<tr>
<td>Levels</td>
<td>12110.85</td>
<td>2</td>
<td>6055.43</td>
<td>94.77**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>71.52</td>
<td>6</td>
<td>11.92</td>
<td>0.19</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>6133.27</td>
<td>96</td>
<td>63.89</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18331.41</td>
<td>107</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level.**
The results of the methods-by-levels-analysis of variance with the intelligence quotients matched showed that there were no significant differences between the method means. In addition, the analysis in all four groups also showed that the interaction variance was not significant. The significant F-values for levels in all four analyses confirmed the evidence that the differences in level means could not reasonably be attributed to fluctuations in random sampling, since the levels were pre-arranged by the experimenter.

Results of the methods-by-grades-analyses using the IQ scores of A 9-10 in one analysis and B 9-10 in another, however, yielded no significant F-values for methods or grades. Non-significant F-values have not been included in tabular form in this report.
Since statistical significance for levels in the analysis of variance with the IQ's was expected as a result of pre-arrangement of the groups on the basis of three levels of mental ability, t-tests were not made with the IQ data.

Pretest Results

A methods-by-levels analysis using the initial pretest scores of each grade group was also made. Results of these data appear in Tables XVI, XVII, XVIII, and XIX.

TABLE XVI

ANALYSIS OF VARIANCE RESULTS FOR PRETEST SCORES
SCHOOL A-9

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>160.03</td>
<td>3</td>
<td>54.34</td>
<td>1.41</td>
</tr>
<tr>
<td>Levels</td>
<td>904.00</td>
<td>2</td>
<td>452.00</td>
<td>11.92**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>190.75</td>
<td>6</td>
<td>31.79</td>
<td>0.84</td>
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<td>Within Subgroups</td>
<td>3031.43</td>
<td>80</td>
<td>37.89</td>
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<tr>
<td>Total</td>
<td>4286.21</td>
<td>91</td>
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</tbody>
</table>

**Significant at 1% level**
### TABLE XVII
ANALYSIS OF VARIANCE RESULTS FOR PRETEST SCORES
SCHOOL A-10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>91.03</td>
<td>3</td>
<td>30.34</td>
<td>1.04</td>
</tr>
<tr>
<td>Levels</td>
<td>1388.80</td>
<td>2</td>
<td>694.40</td>
<td>23.91**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>317.95</td>
<td>6</td>
<td>52.99</td>
<td>1.82</td>
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<tr>
<td>Within Subgroups</td>
<td>2206.84</td>
<td>76</td>
<td>29.04</td>
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</tr>
<tr>
<td>Total</td>
<td>4004.02</td>
<td>87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level

### TABLE XVIII
ANALYSIS OF VARIANCE RESULTS FOR PRETEST SCORES
SCHOOL B-9

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>102.33</td>
<td>3</td>
<td>34.11</td>
<td>0.97</td>
</tr>
<tr>
<td>Levels</td>
<td>475.07</td>
<td>2</td>
<td>237.53</td>
<td>6.78**</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>156.42</td>
<td>6</td>
<td>26.07</td>
<td>0.74</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>3363.85</td>
<td>96</td>
<td>35.04</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4097.67</td>
<td>107</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level
It is interesting to note from the above tables that in the results of the analyses, a significant F-value for levels appeared in each grade group. These results, however, were anticipated, since previous research has indicated a positive relationship between intelligence and achievement. To determine the degree of relationship between the IQ's and the pretest scores a correlation was made with a random sample of 100 scores. The correlation coefficient computed was a moderately high .82.

No significant differences between methods were found among the A-9, A-10, or B-9 groups; however, as indicated in Table XIX, a significant F-value at the 5% level was obtained for methods in the B-10 group.
Subsequent to the analysis of variance, a series of t-tests for the difference between means were applied to discover where the difference existed. The standard t-formula for the difference between two means was used:

\[ t = \frac{M_1 - M_2}{\sqrt{V \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}} \]

where \( \sigma \text{ diff.} = \sqrt{V \left( \frac{1}{n_1} + \frac{1}{n_2} \right)} \)

\( V \) stands for the within subgroups variance and \( n \) represents the number of cases in the cells on the same level.

Substitutions were made in the equation which was solved to determine what difference in means was necessary to obtain significance at the 5% level. For 104 degrees of freedom a t-value of 1.98 is required for significance. From Table XIX, the variance within subgroups is 33.53 and the \( n \) value, or number of cases in each cell at level 1, is 11. Substituting into the standard t-formula above,

\[ 1.98 = \frac{M_1 - M_2}{\sqrt{33.53 \left( \frac{1}{11} + \frac{1}{11} \right)}} \]

Solving for \( M_1 - M_2 \), a value of 4.87 is necessary to give a difference between means which would be significant at the 5% level. Since there was a difference of 6.17 between the means of Methods I and III, which exceeded the required 4.87, it may be concluded that there were differences between these two methods at level 1. The differences between the means at level 2 were not this large; the differences between the means of Methods I and III, and I and IV at level 3, however, exceeded the required t-value of 5.90. Hence, these differences were
significant at the 5% level. It may be concluded, then, that in B-10 the initial amount of subject-matter knowledge of space biology possessed by the students in Method Group III at levels 1 and 3 was greater than that of Method Group I. Likewise, Method Group IV initially possessed significantly more knowledge of the subject than the students in Method Group I.

Similar analyses of variance were run with the pretest scores of the combined A 9-10 and B 9-10 groups. Since the F-values for methods, grades, or methods-by-grades in A 9-10 appeared insignificant, the results of these data are not tabulated here. In the B 9-10 group, however, an F-value of 10.72, significant at the 1% level, appeared between grades. The results of the analysis of variance for this combined group are reported in Table XX.

**TABLE XX**

ANALYSIS OF VARIANCE RESULTS
FOR PRETEST SCORES
SCHOOL B 9 AND 10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>258.37</td>
<td>3</td>
<td>88.12</td>
<td>2.02</td>
</tr>
<tr>
<td>Grades</td>
<td>456.60</td>
<td>1</td>
<td>456.60</td>
<td>10.72**</td>
</tr>
<tr>
<td>Methods x Grades</td>
<td>119.16</td>
<td>3</td>
<td>39.72</td>
<td>0.93</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>9198.58</td>
<td>216</td>
<td>42.59</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10032.71</td>
<td>223</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level**
Results of successive t-tests performed revealed no significant differences between the grade means of School B. For 216 degrees of freedom a t-value of 4.50 was required for significance. Differences between the grade means in Method III reached a very close 4.38; while between the means of Method IV a difference of 4.23. It may be concluded that in this sample there were no differences in the amount of initial knowledge of space biology between Grades 9 and 10 as revealed by the pretest scores.

In a series of analyses to measure the gain in subject matter knowledge from pretest to post-test I, a number of significant F-values appeared. In the School A-10 analysis an F-value of 3.87, with significance at the 5% level was obtained, while School B-10 produced a value of 4.81 which was significant at the 1% level. In School A 9 and 10, significant F-values for both methods and grades were obtained, whereas the School B-9 and 10 analysis resulted in a value of 11.67 for grades significant at the 1% level.

Results of the analyses of the gain from pretest to post-test I are shown in Tables XXI, XXII, XXIII, and XXIV. The t-test results for the significant values are recorded under each table.
TABLE XXI
ANALYSIS OF VARIANCE RESULTS
FOR PRETEST TO POST-TEST I
SCHOOL A-10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>266.59</td>
<td>3</td>
<td>88.86</td>
<td>3.87*</td>
</tr>
<tr>
<td>Levels</td>
<td>132.15</td>
<td>2</td>
<td>66.07</td>
<td>2.88</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>187.22</td>
<td>6</td>
<td>31.20</td>
<td>1.36</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>1745.67</td>
<td>76</td>
<td>22.97</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2331.63</td>
<td>87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at 5% level

1. Required value to give a difference between method means which would be significant at the 5% level for level 1 = 4.49. Differences between method means did not exceed this value; therefore, there were no differences between the method means on the gain from pretest to post-test I.

2. No significant differences between means were obtained at level 2.

3. At level 3, a value of 5.49 is required as the difference between means. This value was exceeded by significant differences at the 5% level between the means of:
   a. Methods I and II, in favor of II.
   b. Methods I and IV, in favor of IV.
   c. Methods II and III, in favor of II.
   d. Methods III and IV, in favor of IV.
The number of cases in each cell at this level was 6. It is questionable whether one can draw a valid conclusion to the effect that the students in level 3 achieved greater significant gains from pretest to post-test I as a result of superiority of the method.

TABLE XXII

ANALYSIS OF VARIANCE RESULTS
FOR PRETEST TO POST-TEST I
SCHOOL B-10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>284.33</td>
<td>3</td>
<td>94.77</td>
<td>4.81**</td>
</tr>
<tr>
<td>Levels</td>
<td>25.67</td>
<td>2</td>
<td>12.84</td>
<td>0.65</td>
</tr>
<tr>
<td>Methods x Levels</td>
<td>94.05</td>
<td>6</td>
<td>15.68</td>
<td>0.80</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>2048.98</td>
<td>104</td>
<td>19.70</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2453.03</td>
<td>115</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level

Since an F-value significant at the 1% level was obtained for methods in School B-10, t-tests for the differences between means were made. For the degrees of freedom listed in Table XXII, a t-value of 1.96 is significant at the 5% level and a t of 2.63 is significant at the 1% level. Results of the t-tests indicated that at the highest level the mean of Method I differed from that of III at the 5% level, in favor of the Method I group; at the same level differences between the means of II and III were significant at the 5% level, in favor of Method II.
At the lowest level Method I mean differed from III, in favor of I, and II differed from IV, in favor of II at the 5% level. There was also a significant difference between the I and IV groups, in favor of I, at the 1% level.

TABLE XXIII
ANALYSIS OF VARIANCE RESULTS
FOR PRETEST TO POST-TEST I
SCHOOL A 9 AND 10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>190.28</td>
<td>3</td>
<td>65.43</td>
<td>3.02*</td>
</tr>
<tr>
<td>Grades</td>
<td>89.11</td>
<td>1</td>
<td>89.11</td>
<td>4.25*</td>
</tr>
<tr>
<td>Methods x Grades</td>
<td>87.83</td>
<td>3</td>
<td>29.28</td>
<td>1.40</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>3988.17</td>
<td>172</td>
<td>20.97</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3973.39</td>
<td>179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at 5% level

No significant differences were found between the method means of Grade 9. In Grade 10, however, significant differences between the means of Methods I and II, in favor of II; I and IV, in favor of IV; II and III, in favor of II; and III and IV, in favor of IV, were obtained as a result of the t-tests. The first two were significant at the 1% level and the last two at the 5% level.

Since a significant F-value of 4.25 was obtained for grades in Table XXIII, t-tests were made to detect in which method groups significant differences between the two grade means might be found. Results of the t-tests showed that no differences were found between the means
of grades 9 and 10 in Method I and in Method III, however, significant differences were noted in II, in favor of Grade 10 and in IV, also favoring Grade 10. This would seem to support the inference that there were significant differences between the mean gains from method to method within Grade 10 group, and likewise that some differences could be found in the method mean gains between the grades, in favor of Grade 10.

Table XXIV indicates that mean differences between the grades in each method have also been present in the B 9 and 10 group in the analysis of the results from pretest to post-test I. Following the significant F-value for grades, t-tests were made of the differences between means of Grade 9 and Grade 10 in each method. The t-test indicated no significant differences between grade means in Methods I and II, but significant differences were found in Methods III and IV at the 1% and 5% levels, respectively.

TABLE XXIV
ANALYSIS OF VARIANCE RESULTS
FOR PRETEST TO POST-TEST I
SCHOOL B 9 AND 10

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sums of Squares</th>
<th>Degrees of Freedom</th>
<th>Variance</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>168.87</td>
<td>3</td>
<td>56.29</td>
<td>2.56</td>
</tr>
<tr>
<td>Grades</td>
<td>256.63</td>
<td>1</td>
<td>256.63</td>
<td>11.67**</td>
</tr>
<tr>
<td>Methods x Grades</td>
<td>151.63</td>
<td>3</td>
<td>50.54</td>
<td>2.30</td>
</tr>
<tr>
<td>Within Subgroups</td>
<td>4749.08</td>
<td>216</td>
<td>21.99</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6326.21</td>
<td>223</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at 1% level
Since no significant F-values were obtained in the analyses of variance using the remaining test data for methods, levels, methods-by-levels, or methods-by-grades, the hypothesis that the means were equal was accepted and no further tests were necessary.

**SUMMARY OF THE ANALYSIS OF VARIANCE**

Results of the analyses that produced one or more significant F-values were presented in detailed tabular form. From these tables (XII through XXIV) the following summarization has been made:

1. There were no statistical differences between the IQ means from method to method in all four grade groups; there were differences between the level means. These results indicated that Method Groups I, II, III, and IV were comparable with respect to mental ability, but that the IQ level means within each group differed due to organization of the groups into a methods-by-levels design before the experiment.

2. The analyses with the pretest scores indicated no significant differences between method means for either A-0, A-10, or B-9. Students in these groups possessed an equal amount of subject matter knowledge of space biology before instruction. The students in B-10 Method III, levels 1 and 3, performed better on the pretest than those assigned to Method I; Method Group IV at the same levels (1 and 3) possessed a greater knowledge than Method Group I. Differences between level means were discerned in all of the groups. A positive correlation between IQ and achievement obviously was present.
That there were no statistical differences between the Grade 9 and 10 means from method to method indicates equal performance on the pretest by ninth- and tenth-grade students.

3. In the analyses which measured gain from pretest to post-test 1, the following results were indicated:

a. The students at levels 1 and 2 in A-9 gained an equal amount of subject matter knowledge in all four Method Groups. At level 3, however, the students in II, who were taught by the teaching-machine program and used a self-trainer before and after learning, achieved better results than those in I who used the teaching machine, but did not receive immediate knowledge of results at testing time. At the same level, the programed lecture method with note-taking (IV) produced better results than the teaching machine (I) method. Method II students also surpassed the students in III (programed-lecture without note-taking). Method IV (with note-taking) also at level 3 was superior to III (without note-taking). These results indicated that the students in the lower level in A-9 were affected by the method of instruction.

b. Similar statistical differences between mean gain occurred in B-10. At the highest level, the students in I (teaching machine group without self-trainer) and in II (teaching machine with self-trainer) achieved a greater amount of subject matter knowledge as measured by the mean gain from pretest to post-test 1 than III, (the programed lecture group without note-taking) at the same level. Group I also performed better than III at level 3; and Groups I and II both surpassed Group IV
(programed lecture with note-taking) at level 3. Since no significant F-value at level 2 was obtained, we may infer that the students gained an equal amount of knowledge of the subject from method to method.

c. In the analysis with gain from pretest to post-test I in A 9 and 10, results obtained indicate that:

(1) All students in A-9 gained an equal amount of knowledge of space biology.

(2) In A-10, several significant F-values indicated that Group II (teaching machine with self-trainer) gained more than I (teaching machine without self-trainer) and III (programed lecture without note-taking). Group IV (programed lecture with note-taking) did better than I and III.

(3) In comparing means between Grades 9 and 10 in the analysis, the latter achieved significantly higher means for Method II (teaching machine with self-trainer) and Method IV (programed lecture with note-taking).

(4) In B 9 and 10, no significant differences between methods occurred, but there were differences in grade means for Method III, (programed lecture without note-taking) and for Method IV (programed lecture with note-taking), in favor of Grade 9.
CHAPTER V

ANALYSIS OF THE STUDENT OPINIONNAIRE
AND THE SPACE BIOLOGY PROGRAM

ANALYSIS OF THE ITEM RESPONSES OF THE STUDENT OPINIONNAIRE

In addition to the subject matter test items, all students (404) were required to indicate by numbers, 1 to 5, their position of disagreement or agreement with six items concerning the experimental unit. The teaching-machine students (202) responded to thirteen additional items concerning their disagreement or agreement with items about teaching machine instruction. The teaching-machine plus self-trainer students (101) responded to two extra items on the use of the self-trainer. The percents of each type of response to the items are summarized in Tables XXV to XXVII.

All of the students agreed that their knowledge of space biology had increased a great deal through the experimental unit. Likewise, there was almost full agreement that the information imparted was interesting and challenging. A low 3.2% remained neutral.

The responses to the benefits of note-taking—Item 23—were divided among all five categories with a greater percentage of agreement than disagreement.

It is interesting to note the consistency of the students in response to Item 24 that: "High school students should not have to take notes during classroom lectures." A high percentage of the students
disagreed with this statement. The distribution of Item 24 responses among the five categories was approximately the same as Item 23 except that it was in the reverse.

Over 95% of all the students believed that the films and filmstrips aided in providing background knowledge of space biology.

Close to 50% of the students considered the lecture method the best instructional method; about one-fourth remained neutral; and another one-fourth were in disagreement.

Items 27 to 39 were answered by all teaching-machine students. It is revealing to note the students' reactions to Item 27. More than 50% of these students indicated that teaching-machine instruction was better organized than the conventional lecture method.

Again films and filmstrips received a highly favorable response, this time concerning their effectiveness as an incentive to learning. A low 1.5% disagreed and 5% neither agreed nor disagreed.

A total of 86.6% of the students felt that teaching-machine instruction would be more effective if followed by a weekly question and answer session or a discussion period. A very low percentage was in disagreement.

Approximately 89% were in assent as to the advantages of frequent review frames in the teaching-machine program. Of the remaining 11%, a small 3.5% did not believe that such review frames helped to prevent tedious memorization; 0.5% disagreed strongly on this point, and 7.4% expressed neither agreement nor disagreement.
There was almost general (94%) agreement to Item 31 that "Self-correction of errors and immediate knowledge of results are very satisfying and rewarding to the student."

Responses to Item 32 concerning "a minimum of distraction with this method" were distributed in five categories as follows:

- Strongly disagree: 9.9%
- Disagree: 22.8%
- Neither agree nor disagree: 7.9%
- Agree: 30.6%
- Strongly agree: 19.8%

With the first two categories combined, 32.7% indicated disagreement; with the last two combined 50.4% expressed agreement.

About three-fourths of the teaching-machine students reported that teaching-machine instruction is adapted for both slow and fast learners. A little over 13% disagreed with this point, and 5% strongly disagreed.

That "information is logically organized and easily found when back references are necessary" met with approximately 87% agreement. About 5.9% remained neutral, and the remaining 6.4% disagreed with the statement.

Twenty-six percent of the teaching-machine students did not think that teaching-machine instruction was "more interesting than lecture instruction;" 58% considered teaching-machine instruction more interesting and over 15% were not sure of their feelings.

The students overwhelmingly—88.6%—agreed that teaching-machine instruction teaches one "how to concentrate during the learning process."
About 7% were of the opinion that it did not possess this advantage; and about 5% remained neutral.

In response to Item 37 that "Teaching machines will soon replace the teacher. . . .", close to 70% of the students disagreed—with 49.0% of these disagreeing strongly; 12.4% believed that teaching machines will take the place of the teacher in the classroom; almost 10% were not sure about this.

Practically all of the students—93%—agreed that the "Space Biology program was organized in small enough steps to ease the learning process;" 1% strongly disagreed; 2% disagreed; and 4.0% of the students neither agreed nor disagreed.

More than three-fourths of the students favored the use of the Vertimask and Slide-a-mask in Item 39; over 11% disagreed with this statement; and 16% of the students were not sure about the effectiveness of these non-mechanical teaching machines.

The remaining two items—Items 40 and 41—were answered only by those students who used the self-trainer.

It is significant that 93% of these students agreed with Item 40 that the self-trainer, through its provision for immediate knowledge of results, contributes reinforcement to the learning process. One percent disagreed strongly with this item; 2% disagreed, and 4% of the students expressed neither agreement nor disagreement.

With a high percent of 83.2, the self-trainer students believed that this device brings about more effective learning; about 7% disagreed, and 9.9% were not sure about this in Item 41.
### TABLE XXV

**PERCENT OF RESPONSES OF ALL STUDENTS TO ITEMS 21-26 OF STUDENT OPINIONNAIRE**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Student Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>köläss of space biology has increased a great deal through this unit.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>21</td>
<td>My knowledge of space biology has increased a great deal through this unit.</td>
<td>37.4 62.6</td>
</tr>
<tr>
<td>22</td>
<td>The information presented was extremely interesting and challenging.</td>
<td>3.2 41.8 55.0</td>
</tr>
<tr>
<td>23</td>
<td>High school students benefit much from taking classroom notes.</td>
<td>1.5 11.6 18.6 40.6 27.7</td>
</tr>
<tr>
<td>24</td>
<td>High school students should not have to take notes during classroom lectures.</td>
<td>22.2 45.5 15.3 11.6 5.4</td>
</tr>
<tr>
<td>25</td>
<td>The films and filmstrips have added much to my background knowledge of space biology.</td>
<td>0.5 3.7 45.8 50.0</td>
</tr>
<tr>
<td>26</td>
<td>In my opinion, the lecture method is the best method of instruction.</td>
<td>8.7 18.8 25.5 24.2 22.8</td>
</tr>
</tbody>
</table>

**Total Number of Respondents = 404**

**CODE:** 1 Strongly disagree; 2 Disagree; 3 Neither agree nor disagree; 4 Agree; 5 Strongly agree
<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Student Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Teaching-machine instruction is a better organized method of instruction than the conventional lecture method.</td>
<td>5.9 14.4 16.8 26.2 36.7</td>
</tr>
<tr>
<td>28</td>
<td>The films and filmstrips served as an excellent incentive to learning.</td>
<td>1.5 5.0 46.5 47.0</td>
</tr>
<tr>
<td>29</td>
<td>Teaching-machine instruction would be more effective if followed by a weekly question and answer session, or a discussion session.</td>
<td>2.0 5.9 5.5 39.1 47.5</td>
</tr>
<tr>
<td>30</td>
<td>Through frequent review frames, knowledge of subject matter is acquired without tedious memorization.</td>
<td>0.5 3.5 7.4 42.1 46.5</td>
</tr>
<tr>
<td>31</td>
<td>Self-correction of errors and immediate knowledge of results are very satisfying and rewarding to the student.</td>
<td>0.3 5.0 37.6 56.9</td>
</tr>
<tr>
<td>32</td>
<td>There is a minimum of distraction with this method.</td>
<td>9.9 22.8 7.9 39.6 19.8</td>
</tr>
<tr>
<td>33</td>
<td>Teaching-machine instruction is excellent for slow- as well as for fast-working students.</td>
<td>5.0 13.4 7.4 36.1 38.1</td>
</tr>
<tr>
<td>34</td>
<td>Information is logically organized and easily found when back references are necessary</td>
<td>0.5 5.9 5.9 53.5 34.2</td>
</tr>
</tbody>
</table>

TABLE XXVI

PERCENT OF RESPONSES OF TEACHING MACHINE STUDENTS TO ITEMS 27-39 OF STUDENT OPINIONNAIRE
TABLE XXVI (continued)

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Student Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>35</td>
<td>Teaching-machine instruction is more interesting than lecture instruction.</td>
<td>9.4</td>
</tr>
<tr>
<td>36</td>
<td>Teaching-machine instruction teaches the student how to concentrate during the learning process.</td>
<td>2.4</td>
</tr>
<tr>
<td>37</td>
<td>Teaching machines will soon replace the teacher in the classroom.</td>
<td>49.0</td>
</tr>
<tr>
<td>38</td>
<td>The space biology program was organised in small enough steps to ease the learning process.</td>
<td>1.0</td>
</tr>
<tr>
<td>39</td>
<td>The Vertimask and Slide-a-mask are excellent non-mechanical teaching machines.</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Total Number of Respondents = 202

CODE: 1 Strongly disagree; 2 Disagree; 3 Neither agree nor disagree; 4 Agree; 5 Strongly agree
TABLE XXVII
PRECENT OF RESPONSES OF SELF-TRAINER STUDENTS TO ITEMS 40-41 OF STUDENT OPINIONNAIRE

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Student Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>The self-trainer which provides immediate knowledge of results adds proper reinforcement to the learning process.</td>
<td>1.0 2.0 4.0 62.3 30.7</td>
</tr>
<tr>
<td>41</td>
<td>The use of this device makes learning more effective</td>
<td>6.9 9.9 24.8 58.4</td>
</tr>
</tbody>
</table>

Total Number of Respondents = 101

CODE: 1 Strongly disagree; 2 Disagree; 3 Neither agree nor disagree; 4 Agree; 5 Strongly agree
COMMENTS MADE BY STUDENTS REGARDING THE EXPERIMENTAL STUDY

In addition to the structured responses to the Opinionnaire, free comments were given by the students concerning what they liked or disliked about teaching-machine instruction and other phases of the experimental study.

Many remarks relative to the effectiveness and advantages of the teaching machine were made:

Each student can make progress at his own rate of speed.

Teaching-machine instruction gives you an opportunity to think out the answer for yourself.

I learned much more through frequent repetition than I would through conventional lectures.

Teaching machines eliminate distractions common to a regular class.

One is apt to remember constantly repeated items.

Seeing your mistakes and knowing at once the correct answer are very helpful.

Through immediate knowledge of the correctness of my answers, I knew how well I was learning.

I liked the teaching device method very much. I never knew it was so easy to teach myself.

The teaching machine permits us to see the statements in writing so that when we see these same statements in a test, they are not new to us.

Automated teaching is a unique way of teaching. It is a test of learning and mastering subject matter and a test of honesty, because you have the answers right on the paper.

On the other hand, some students voiced a preference for the personal contact of a teacher.
I would rather have a teacher who talks to me as an individual, not through a machine.

I think teaching-machine instruction is impersonal; the teacher does not have good contact with the students.

I would get greater understanding from a teacher. The teaching machine, however, is a good device for reviews before tests.

I think the old way of teaching is the best way.

I do believe there is no substitute for a teacher. One cannot ask a piece of paper a question.

Who wouldn't rather listen to an interesting lecture than read and write, and read and write... Teaching-machine instruction would become monotonous and boring. No machine can replace a teacher.

The teaching machine is very boring when you keep at it for a long period of time. You don't get a chance to discuss the material.

The teaching machine put strain on my eyes. I missed the personal comments of the teacher.

In regard to the lecture method, most students expressed a positive reaction to taking notes during the lecture:

I feel more secure when I take notes.

Notes are useful for future reference.

It is better to take notes, because some day they will be of help to us.

Writing something down helps me to remember it better.

Notes make facts stick.

I would remember more if I could have taken notes.

Not being able to take notes was an obstacle rather than a benefit. I can't remember much without repetition.

Notes are a beneficial reference in preparing for a test or a quiz.
I prefer taking notes because you have help right in front of you.

I was happy to take notes especially when I knew we were to have a test.

However, a few individuals found satisfaction in listening to a lecture without the necessity of taking notes.

While I write down one idea in class, I miss another more important one.

I'm glad I did not have to take notes. I get all confused.

I was afraid I might miss something while I was taking notes.

I liked not taking notes, because when a person is listening and not writing, he gets more out of it. In the process of note-taking one might miss an important statement.

Commenting on the use of films and filmstrips, the students indicated a general overtone of satisfaction.

I enjoyed the films and filmstrips immensely. Seeing is the best way to learn.

The films prepared us for the material given later on. When Sister was talking, you could just visualize everything.

The filmstrips were very interesting and also profitable.

The movies were the best because you could see everything that happens in space.

Pictures give a clear idea of what is being taught. The films and filmstrips were helpful in presenting many pictures on space.

These free comments, as well as the item responses of the structured opinionnaire, indicate that the students reacted quite favorably to teaching-machine instruction. Many found this new method of automated teaching a novel experience—in some instances even, an exciting and enjoyable one. Despite the consensus of opinion that machine teaching can be profitable, particularly before testing periods, students
nevertheless judiciously preferred the direct personal approach of an instructor. In regard to note-taking, both positive and negative opinions in terms of advantages and disadvantages have been cited. The necessity for further research in this and other areas of automated teaching becomes more and more evident.

ERROR ANALYSIS AND EVALUATION OF THE SPACE BIOLOGY PROGRAM

Description of the Program

The space biology program used in this investigation consisted of 500 frames and was divided into five sections. Essentially, it was a Skinner-type program which employed comparatively small sequential steps and required constructed responses. Feedback and immediate knowledge of results were provided through the response frames which enabled the student to recognize the correct answer after writing each response. It is obvious that with this kind of feedback there is a tendency for even the best students to glance ahead at an answer as soon as they are uncertain about a response.

The items, or frames, of the program were written by the investigator during the summer of 1960, at a time when only meager knowledge about the art of programming was available. The program was given an initial trial on approximately 10 subjects, not included in the study, and after an analysis of the difficulty of the items, was revised. The item analysis led to the addition of 150 frames to the original 350, thus increasing the total to 500 frames, as used in this study. Since some frames contained more than one blank, the total number of responses in the program was 850.
Objectives

Several educational objectives which the investigator felt the students should attain during the instructional period were formulated before writing the program. These objectives were listed in Chapter III under the heading, The Instructional Material, and are re-listed here for convenient reference.

(1) To develop in the students an awareness of the responsibility of man's place in space.
(2) To acquaint the students with the physiological, psychological, and physical problems of human space flight.
(3) To acquire general knowledge of the factors related to human space travel.

Error Rate and Analysis

At present, there are no formal criteria for evaluating the efficiency of a teaching-machine program. In many instances the quality of a program has been determined, or measured, by analysis of students' responses reduced to a numerical "error rate". Some authorities in programming consider an "error rate" of not more than 10% indicative of a good program. The "error rate" itself, however, does not offer sufficient evidence of quality, since it is possible to have low error rates and teach little.

The individual programs completed by the students in this study were subjected to an intensive error analysis. The errors made in the program by each student were recorded and the error percentage was found by dividing the number of errors in each student's program by 850 (the total number of response blanks in the entire program).
The total sum of the errors made by all students on a given level in a particular grade group was calculated. From this, the mean error number per student per level was computed; and finally the mean error percent per level. In the end, the total error percent of all four grade groups on each level was calculated. Table XXVIII presents the results of the error analysis of the space biology program. The total error percent of the program was 3.97.

Close examination of this table indicates that considerable differences in the error rate may be discerned among the grade groups in each level. The highest total error percent, as shown in the final column of the table, was made by the students in level 3; the next highest by level 2; and the lowest percent by level 1.

Until definite criteria for the evaluation of teaching-machine programs are discovered, one must approach all proposed measures of evaluation, including that of "error rate", with caution. A low error rate, then, indicates nothing more than that the student made a few errors in the program. The important issue is whether or not he has learned anything; whether or not he has attained the objectives set down by the program.

The results of the statistical analysis of the test data which attempted to measure subject matter knowledge of space biology, indicated that automated teaching proved to be either as effective, or better than, the programed lecture method. Attainment of the objectives of the program as evidenced by the results of the tests and favorable responses to the
TABLE XXVIII
ERROR ANALYSIS OF THE TEACHING-MACHINE PROGRAM

<table>
<thead>
<tr>
<th>SCHOOL</th>
<th>Grade</th>
<th>Level</th>
<th>Number of Students</th>
<th>Total No. of Errors</th>
<th>Mean Error No. per Student</th>
<th>Mean Error Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9</td>
<td>1</td>
<td>24</td>
<td>1007</td>
<td>41.96</td>
<td>5.1</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>1</td>
<td>24</td>
<td>467</td>
<td>19.46</td>
<td>2.3</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>1</td>
<td>18</td>
<td>459</td>
<td>25.50</td>
<td>3.0</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>1</td>
<td>22</td>
<td>336</td>
<td>15.27</td>
<td>1.8</td>
</tr>
<tr>
<td>A</td>
<td>9</td>
<td>2</td>
<td>14</td>
<td>876</td>
<td>62.57</td>
<td>7.3</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>2</td>
<td>16</td>
<td>370</td>
<td>23.13</td>
<td>2.7</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>2</td>
<td>14</td>
<td>532</td>
<td>38.00</td>
<td>4.4</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>451</td>
<td>22.55</td>
<td>2.6</td>
</tr>
<tr>
<td>A</td>
<td>9</td>
<td>3</td>
<td>8</td>
<td>472</td>
<td>59.00</td>
<td>6.9</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>3</td>
<td>14</td>
<td>429</td>
<td>30.64</td>
<td>3.6</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>3</td>
<td>12</td>
<td>458</td>
<td>38.17</td>
<td>4.4</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>3</td>
<td>16</td>
<td>482</td>
<td>30.13</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Total Number of Responses in Entire Program = 850
Number of Frames = 500
student opinionnaire, may for the present, serve as valid evaluative instruments in determining the quality and efficiency of the teaching-machine program.

To obtain a critical review of the program, the investigator submitted a portion of the space biology program to a reputable publishing company. The following general criticisms were offered:

1. Inadequate cues or prompts. The student is not always prepared for the proper response.
2. Too many "trivial" responses, which add nothing to the student's learning.
3. Too many frames in which the response comes early, and the student has little incentive to concentrate on the remainder of the frame.
4. Difficulty in discerning a logical sequence of ideas.

The publishing company recommended that the opinion and evaluation of other agencies be sought, since "... no one can claim to have definitive answers in a field as new and untried as programing, but nevertheless, some guide lines are beginning to emerge."
CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The principal purpose of this investigation was to determine the relative effectiveness of automated teaching of space biology at three levels of intelligence in ninth- and tenth-grade science classes. More specifically, learning of subject matter knowledge related to the human factors in space flight, resulting from the use of simple teaching machines, with and without a self-trainer during the testing period, was compared with that of learning from programmed lecture instruction, with and without note-taking. The study also attempted to obtain evidence concerning the changing role of the teacher in automated teaching, and student reactions to teaching-machine instruction and other phases of the investigation.

The subjects in the experiment were 404 high school science students (ninth- and tenth-grades) from two Catholic coeducational high schools in Chicago. The two participating schools were designated in this report as School A and School B and the individual grades groups as A-9, A-10, B-9, and B-10.

A methods-by-levels-analysis of variance design which provides for direct control of inter-subject variations was employed. Four methods were administered randomly to students who were matched on the basis of intelligence scores obtained from the 

Henmon-Nelson Test of Mental
Ability, Form A. The experiment was replicated twice in each of the two schools—with A-9, A-10, B-9, and B-10 groups.

The unit selected for study was space biology, or the human factors involved in space flight. Each of the four comparable groups of science students was taught this unit by one of the following methods:

Method I—Teaching Machine
Method II—Teaching Machine, Self-Trainer
Method III—Programmed Lecture
Method IV—Programmed Lecture, Notes-taking

Films and filmdips pertinent to the subject were shown in all of the above method groups.

The learning of the participating students in each grade group was measured by two objective tests, which were designed to measure the acquisition and retention of subject matter knowledge of the human factors involved in space flight. Tests 1 and 2 consisted of 120 and 100 true-and-false items, respectively, and were patterned after the multiple purpose self-trainer used by the students in Method Group II. Test 1 was used as a pretest, post-test I, and retention test I; test 2 was used as post-test II and retention test II. The five tests from which the data were gathered were administered in the following order:

1. Pretest—before instruction, to measure initial knowledge of subject matter.
2. Post-test I—(same as pretest)—to measure gain after instruction.
3. Post-test II—after instruction
4. Retention test I—to measure delayed retention after interval of one week.
5. Retention test II—same as post-test II—to measure delayed retention one week after completion of the experiment.
The scores of the participating students on mental ability tests and pretest; the gain from pretest to post-test I; the measure of retention from pretest I to retention test I; the measure of retention from post-test II to retention test II were used as the basis for the statistical analysis. The significance of the differences between means of the groups was tested by Fisher's t-test following the application of the analysis of variance technique. The data in each school were treated separately at all times.

Data concerning the reactions and opinions of the students toward the methods of instruction were gathered by means of a structured Student Opinionnaire and from free comments of the students. The teaching-machine program on space biology was evaluated by means of a detailed analysis of errors. The changing role of the teacher in automated teaching, together with suggested recommendations resulting from the study are treated at length in this chapter.

SUMMARY OF THE FINDINGS

On the bases of the analyses of variance results using the test data, the item responses to the student opinionnaire and student comments, analysis of the teaching-machine program, the following summary of the findings is presented:

**Analyses of Variance**

1. There were no significant differences between the method means of the Iq scores; there were differences between the level means. All four grade groups were equally matched with respect to methods and levels.
2. Using the pretest results in A-9 and B-9, there were no significant differences between any of the means from method to method on the same level. Students on similar levels possessed an equal amount of initial subject matter knowledge of space biology. There was a correlation of .62 between the IQ and the pretest scores. The significant differences among the level means confirmed this correlation between mental ability and achievement.

3. In the B-10 group there were significant differences between the method means. The t-tests revealed greater amounts of initial knowledge possessed by students in Method Groups III and IV than in I at levels 1 and 3.

4. All students in the combined A-9 and 10 group and in the combined B-9 and 10 group performed equally well on the pretest and consequently, possessed equal amounts of subject matter knowledge.

5. In the analyses using the differences between pretest to posttest I scores to determine the amount of subject matter knowledge of space biology gained after instruction, the following summary has been made:

a. There were no significant differences between method means in A-9 and B-9. All students in these two groups gained an equal amount of subject matter knowledge of space biology.

b. There were no significant differences between method means of A-10 and B-10 at the middle level. It would seem then that the average level group in both schools achieved equal amounts of knowledge of space
biology, as revealed by the absence of significant differences between the method means.

e. There were no significant differences at level 1 at A-10, but in the B-10 group at the same level, there were significant differences between: (1) the teaching machine method mean (I) versus the programmed lecture mean (III), in favor of I; (2) the teaching-machine self-trainer mean (II) versus the programmed lecture mean (III), in favor of II.

d. At level 3, there were significant differences in A-10 and B-10, which revealed that in A-10, the teaching-machine self-trainer group (II) achieved better results than the teaching-machine group I without the self-trainer. Similarly, the note-taking group (IV) gained more than the programmed lecture group without note-taking (III). Likewise, in B-10 at the same level, significantly better results were attained by the teaching-machine groups I and II than by III and IV, the programmed lecture groups.

e. In the combined grade groups there were significant differences between method means of Grade 10 in the A 9-10 group. The method mean of II was significantly greater than that of I and III; students in IV gained more knowledge than those in I and III of Grade 10.

f. There were no significant differences between the method means of Grade 9 in the combined A 9-10 group.

g. In both combined groups, significant differences were noted in the grade means. In A 9 and 10, the Grade 10 means in Method II and IV were higher than those of Grade 9. From these results, we may infer that
the significant gain in knowledge of the Grade 10 students who were subjected to teaching-machine instruction plus the self-trainer (II), and programed lecture plus note-taking (IV) might be attributed to a greater amount of educational maturity on the part of these students. It would seem that the older student is able to benefit more from self-instruction preceded and followed by immediate knowledge of results provided by the self-trainer than the younger Grade 9 student. Likewise, note-taking seemed to produce better learning in the Grade 10 than in Grade 9 students. On the otherhand, in B 9 and 10, differences in the means of Methods III and IV were found in favor of Grade 9. From these data we may infer that the Grade 9 students taught by Methods III and IV gained more knowledge than Grade 10 students taught by the same methods. It would seem that the Grade 9 student performed significantly better when taught by more conventional methods. Adjustment to a new method of teaching appeared to be easier for students in the higher grade level.

h. There were no significant differences in the means when measuring retention from post-test I to retention test I in any of the groups.

i. No significance was obtained in measuring retention from post-test II to retention test II. All students recalled subject matter knowledge of space biology equally well after a one-week interval.

j. The interaction between methods and levels was insignificant at all times. There was no interaction between intelligence level (or grade) and method of instruction. The appropriateness of the instructional method for different levels of intellectual ability could not be
determined. From the absence of interaction between methods and levels, one may infer that no single method was superior for a particular grade or ability level. The usual contention that materials are best taught at a given grade level requires further research.

THE STUDENT OPINIONNAIRE

The data collected through the Student Opinionnaire reflected the student's reactions to the experimental study at large, note-taking, teaching-machine instruction, programed lectures, films and filmstrips, and the self-trainer.

The results of the item response analysis indicated highly favorable reactions of students to many phases of the experimental study.

1. Almost all of the students strongly felt that they had increased their knowledge of space biology through this study; they also agreed that the information presented was challenging and interesting.

2. More than 80% of the students recognized the benefits derived from taking notes during classroom lectures and agreed that high school students should be required to take notes.

3. Approximately 95% of the students were aware of the value of the films and filmstrips in providing the background knowledge necessary for better understanding of the human factors involved in space flight.

4. All of the students were not in agreement that the lecture was the best method of instruction. About twenty-five percent were not sure about this.
In general, majority of the students in the teaching-machine groups indicated highly favorable responses to this new method of instruction, as evidenced by the following summary of the student responses to Items 27-29 of the Opinionnaire:

1. More than 50% of the students agreed that teaching-machine instruction was a more interesting and better organized method of instruction than the lecture method.

2. The advantages of frequent review frames and immediate knowledge of results were recognised by approximately 88% of the students.

3. A high proportion of the students--75% asserted that teaching-machine instruction should be followed by discussion sessions.

4. More than 80% indicated that teaching-machine instruction teaches the student how to concentrate during the learning process.

5. Close to 33% of the students disagreed with the statement that "There is a minimum of distraction with this method."

6. It is significant that only a low 12% felt that teaching machines would soon replace the teacher; 18% were not sure about this.

7. Over three-fourths of the students liked the Vertimask and Slide-a-mask teaching machines.

8. A high 93% of the students were of the opinion that the program used to convey subject matter knowledge of space biology was organized in small enough steps to make learning easy.

9. In regard to the use of the self-trainer, the students in Group II felt that the immediate knowledge of results afforded reinforcement to the learning process which made learning more effective.
THE FREE COMMENTS

The free comments also indicated favorable reactions to automated teaching as well as to note-taking, films and filmstrips. Between the lines, however, the students seemed to prefer the warmth, understanding, and personal contact of a "live" teacher. Some students felt that teaching-machine instruction would be highly profitable before testing periods. Constant, daily self-instruction by machine, they felt, would be boring and monotonous.

THE SPACE BIOLOGY PROGRAM

Analysis of the program in terms of the number of errors made by the students does not warrant a program of good quality. The simple teaching machines used in the study were versatile, compact, and flexible, but they were not cheat-proof. For this reason alone, the low error rate in the program used is not a valid criterion for evaluation.

Results of the analyses of variance with the test data which attempted to attain the objectives of the program indicated superior performance on the part of students using the program particularly at the lowest level of ability.

The average percentage of errors made by the students at each level varied from group to group, and from level to level. The total error percent of each level, however, indicated that the students at the highest level made the least number of mistakes, while those at the lowest level made the highest percentage of incorrect responses.
THE CHANGING ROLE OF THE TEACHER

While it was not the principal purpose of this study to investi­gate the changing role of the teacher in automated instruction, neverthe­less, active participation in teaching-machine experimentation tends to lead to improved understanding of the teaching-learning process and realization of the changing role of the teacher. The introduction of every new medium into the educational process, in the past, has always been accompanied by changes in something other than the medium of instruction. This has been the case with films, filmstrips, radio, and other media. Every new medium requires the development of new skills, new ideas, and new procedural competencies on the part of the teacher for effective use in the instructional program.

There is no doubt that the use of teaching machines on a wide scale will have considerable influence upon the role of the teacher, the student, and the entire administrative structure. In the paragraphs that follow, consideration is given to the changing role of the teacher in automated instruction.

An increasing number of teachers and educators have recognized that teaching machines when wisely used, possess unparalleled potential for the transmission of certain phases of learning. Research concerning automated instruction, though still premature to speak of definitive findings, has shown that appropriate tasks of varying nature have been successfully taught to persons ranging from low "mental retardates to
gifted graduate students." There is some evidence that teaching by machine may also be a solution to teacher shortages, the population explosion, and other educational problems. However, the contrast between these potential advantages and the reactions that have been expressed in opposition to it, necessitates greater consideration of the relationship of teaching-machine instruction to the changing role of the teacher.

The advent of teaching machines has effected a change in the role of the teacher, and these changes have resulted in a careful re-examination of the teacher's former role. Traditionally, the teacher has been looked upon as a personal guide and master in the teaching-learning process. There is no reason to question the value and need for this role at the present time. With automated teaching, however, there is no personal contact between student and teacher. The programmer is the teacher, and the instruction is completely controlled by him through the program. This fact makes the teaching machine potentially threatening to the status quo in its transfer of control over learning from the classroom teacher to an unknown programmer.

In human terms of the teaching profession then, automated teaching imposes a restriction upon the teacher's instructional freedom to a certain extent; it deprives him of his previous status as the master of the instructional process. The teacher's prerogative to organize, direct, and control learning; to use, or not to use, certain educational media,

may be considerably curtailed. In other words, with the advent of teaching machines the role of the classroom teacher has changed, and a significant reshifting of responsibility for control of the teaching-learning process has occurred. In a sense, the programmer becomes the master teacher and the classroom teacher must develop new ideas; must assume new responsibilities in a new role. Under such conditions, he plays a secondary role.

This changed role, however, need not be as threatening as one might at first believe. The classroom teacher, even under such conditions is really the teacher; since he continues to have personal contact with the students in the classroom. In a normal teaching situation where certain aspects of subjects are taught by means of teaching-machine programs, the teacher's time may be more adequately utilized to be creative, to write or revise programs, or even for professional advancement.

There is reason to believe that teaching-machine instruction will greatly enhance the role of the teacher, and will actually increase his effectiveness. Through knowledge of programming, he will learn to present his lectures in a more logical and sequential order. He will also be released from a certain amount of routine drill work, and thus will be enabled to devote more time to the individual differences of his students. Furthermore, the operational and behavioral approach required by programmed instruction should lead to increased knowledge of the learner during the learning process.

This changing situation, nevertheless, will require the teacher to learn new techniques of instruction. It may force the teacher to place
less emphasis upon his role as a conveyer of knowledge and more emphasis upon his role as a guide, leader, and evaluator of learning experiences. The transmission of knowledge and information may be efficiently accomplished through a teaching machine or some other mechanical aid. These devices, however, can never, as the literature indicates, replace the teacher, when one considers personal contact, warmth, and human understanding. As Edgar Dale remarked in a current publication:

Programed materials will not replace the teacher but will replace him, enable him to return to the basic role of guide, counselor, motivator, briefer of an exploring party, intellectual gadfly.

He can become for the students a model of the thinking man and not the petty administrator of simple learning tasks easily handled by programed teaching materials. He can develop the self-programed, self-instructed student.2

This means that the teaching machine and its related technique may be of use in conveying certain portions of the entire educational program. Such devices assist the teacher; they do not substitute or replace him.

In summary, the teaching machine does not purport to replace the teacher. It is true, that the role of the teacher has changed as a result of the introduction of teaching machines into education. However, just as the textbook has released the teacher from the necessity of conveying verbal knowledge to the students, so, too, do teaching machines attempt to release the teacher for more important, more professional

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tasks in the teaching process. All in all, a knowledge of the learning principles underlying automated instruction should create better teachers for more students.

CONCLUSIONS

This investigation by itself does not provide sufficient evidence to reach definite conclusions concerning the relative effectiveness of teaching machines and the related technique of automated teaching. Limitations of the present study dictate caution in the interpretation of the present results. In the first place, results of a single investigation in a field as new as teaching machines are obviously far from conclusive. A final evaluation of the effectiveness of the new device and technique would be highly imprudent. Secondly, since the experiment was conducted in an actual classroom situation, regardless of the precision and accuracy of the methods-by-levels design, the possibility of uncontrolled extraneous variables operating to affect the data may have been present. Thirdly, the testing instruments and opinionnaire which were used in the investigation to assess student achievement and reactions are subject to certain limitations and are not always considered the best known evaluative criteria. Lastly, the teaching-machine program used in the study was inferior and deficient in quality. With these limitations in mind, the outstanding facts which seem to be disclosed by the findings of this investigation have been drawn:

1. An equal amount of subject matter knowledge of space biology was acquired and retained by students in the two grade groups—A-9 and B-9,
as well as in the combined B 9-10 group. It would seem that learning took place with equal efficiency at all differential levels of ability whether the subject matter was presented by teaching machines, with or without a self-trainer, or by programmed lectures, with or without note-taking.

2. A greater amount of subject matter knowledge was acquired in the different Method Groups by students in A-10 and B-10 at the lowest ability level. Differences in achievement were discerned particularly between the two teaching-machine groups (I and II) and between the two programmed lectures groups (III and IV). Therefore, it would seem that the self-trainer and note-taking were effective in augmenting learning in students at the lowest ability levels.

3. The self-trainer through provision of immediate knowledge of results contributed significantly to learning in tenth-grade students. The successful use of the self-trainer may have required a greater amount of educational maturity on the part of the student.

4. An equal amount of subject matter knowledge of space biology was retained by all students after a one-week interval.

5. Teaching-machine instruction, in the opinion of the students, is a better organized method of instruction than the lecture method.

6. Films and filmstrips acted as incentives to learning and contributed to increased background knowledge of space biology.

7. The over-all error rate of a teaching-machine program is not indicative of a good quality program. The higher level students made fewer errors than the middle and lower levels.
8. A method which emphasizes organization and participation by the learner seems to be more effective for learning for the lower ability student than a more passive method.

9. The learning of the higher ability level student appears to be less affected by method than the lower level student.

10. Any method too long applied may be inadvisable. For this reason, combinational procedures are suggested.

11. As a result of automated teaching, it seems reasonable to predict that the role of the teacher will change as more technological devices find acceptance in classroom situations.

RECOMMENDATIONS

In view of the findings of this investigation, the following recommendations have been suggested:

1. That this experiment be replicated on a larger scale along similar lines over a longer period of time, with other science courses, on other levels and with all types of students.

2. That classroom teachers engage in small-scale investigations with their classes to overcome fear and prejudice and to get the "feel" of automated teaching.

3. That the use of the automated teaching technique be optimized by providing a proper balance between this technique and other compatible methods.

4. That the results of studies with teaching machines be made known to others in a reasonably short period of time.
5. That the basic techniques of programing be made available to all classroom teachers through in-service training programs.

6. That further experimental verification of the rules of programing be made.

7. That the use of teaching machines be geared to the objectives of improving instruction and enhancing learning.

8. That teacher education institutions expand training in the use of teaching machines by introducing courses in programed learning.

9. That workshops and conferences be organized at all educational levels to investigate the application of teaching machines to the curriculum.

10. That the basic learning theories and principles involved in automated teaching be studied more thoroughly.

11. That teachers and principals examine, study, and acquaint themselves with the extensive field of literature on teaching machines.

12. That an analytical attitude which will aid in distinguishing worthwhile procedures in using automated devices be developed.

13. That teachers and principals be given the opportunity to visit schools where programs in automated instruction are in progress.

14. That the need for continued and thorough research and investigation of the potentialities of the teaching machine and programed learning be fully realized and encouraged by educators who have great responsibility for making modern media of education available to schools for instructional use.
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BIBLIOGRAPHY

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D. UNPUBLISHED MATERIALS


APPENDICES
APPENDIX A

HOW TO USE THE VERTIMASK

What is the Vertimask?

The Vertimask is simply a compact device for controlling the vertical movement of a mask. It is for use with program material printed on standard 8½ by 11 paper, in which questions calling for a written response are followed by answers so that an immediate comparison can be made by the student after he has answered each question. Alignment marks are used at the left hand side of all program pages to act as stopping places for the mask in its downward travel. The program sheets may be used in a 3-ring binder, in a workbook with a conventional binding, or in sheafs with sheets hinged at the left.

Whenever the student finds his recall of "learned" material is faulty (as indicated by a wrong answer) he is expected to check previously covered material to reinforce himself. This is actually necessary since later questions will require a complete understanding of all that has gone before.

The student can help himself to avoid seeing advance answers accidentally. Studies have shown that inadvertent glances at advance answers can have the same effect as deliberate peeking; that is, to destroy the challenge which is the whole point of programmed self-instruction.
1. **Inserting the Vertimask**

A program will have a blue cover page or some conspicuous page to show that questions follow. With this page on top, take about 15 pages as a unit in the left hand and slip the white plastic base of the Vertimask under the group letting the mask portion slide over the top. Insert the Vertimask all the way in and slide the mask to its topmost position.

2. **Turning the Page**

Each student will find his preferred way of turning pages; however, in all cases the mask must stay at the top while the pages are being turned. It will be found more convenient to turn a page if the mask is raised up at the left an inch or two. Since all answers are located at the right they will not come into view. After turning the page, align the mask with the first mark on the program page.

3. **Read the question and enter your response in the space provided.**

4. **Move the mask down to the next aligning mark.** The correct answer is now visible and can be compared with the written answer. If the two answers do not agree, return to source material and re-read.

5. **If ready for the next question, again lower the mask to the next aligning mark and proceed as before, reading the question and entering your written answer.**

6. **When the lowermost answer on the page has been compared, raise the mask all the way to the top, turn the page as described in step 2, and proceed with the next question.**

7. **When the last page in the sheaf has been turned, turn it back again to lay on top of the mask so that it becomes the cover page for the next sheaf of 15 pages. Now extract the Vertimask and re-insert as described in step 1.**

Dyna-Slide Company
Chicago, Illinois
What is the Slide-a-mask?

The Slide-a-mask is a simple, rigid mask that can be easily moved up or down on a program page retaining its alignment by using the right hand edge of the program as a guide. It is for use with program material printed on standard 8½ by 11 paper, in which questions calling for a written response are followed by answers so that an immediate comparison can be made by the student after he has answered each question. Alignment marks are used at the left hand side of all program pages to act as stopping places for the mask in its downward travel. The program sheets may be in a looseleaf ring binder, a conventionally bound workbook, or in sheafs hinged at the left.

When the student has begun to adopt proper habits of using the mask he will seldom overshoot the aligning marks and will not see advance answers accidentally due to careless page turning or failure to keep new pages covered when reinserting the mask at intervals. It is of the utmost importance that the student realize that only answers which have not been seen previously can reinforce his learning.

1. Inserting the Slide-a-mask

A program should always be preceded by a cover page alerting the student that questions follow. With this page on top, take about 20 pages as a unit in the left hand and "hook" the mask onto the group. Insert the Slide-a-mask all the way in until the folded edge at right is in contact with the program
sheets. Now slide mask to top so that only the top inch of paper shows.

2. Turning the page

Each student will find his preferred way of turning pages; however, in all cases the mask must stay at the top while the pages are being turned. It will be found more convenient to turn a page if the mask is raised up at the left an inch or two. Since all answers are located at the right they will not come into view. After turning the page, align the mask with the first mark on the program page.

3. Read the question and enter your response in the space provided.

4. Move the mask down to the next aligning mark. The correct answer is now visible and can be compared with the written answer. If the two answers do not agree, return to source material and re-read.

5. If ready for the next question, again lower the mask to the next aligning mark and proceed as before, reading the question and entering your written answer.

6. When the lowermost answer on the page has been compared, raise the mask all the way to the top, turn the page as described in step 2, and proceed with the next question.

7. When there are only two or three sheets left inside the Slide-a-mask, it is time to reinsert the mask to gain more support for the mask during sliding and aligning operations. Before extracting the mask, turn back the previously worked page to lie on the top of the mask so that it becomes the cover page for the next sheaf of 20 pages. Now extract the Slide-a-mask and reinsert as described in step 1.

Dyna-Slide Company
Chicago, Illinois
APPENDIX C

SPACE BIOLOGY - PRE-TEST
(Used also as Post-Test I and Retention Test I)

1. 
(a) On October 4, 1957, the Russians launched into space Sputnik I, the first artificial satellite.
(b) On November 3, 1957, the United States launched the second satellite, Sputnik II.
(c) Sputnik II was a man-made moon that carried a dog into space.
(d) Explorer I, the first American artificial satellite, circled the sun at a height of 1500 miles.
(e) United States and Russia are the only two countries that have launched artificial satellites.

2. Scientists hope to learn many things about the universe through the exploration of space by means of space flight.
(a) They hope to learn everything about the planets that are our farthest neighbors.
(b) They want to learn many things about the planet on which we live and the atmosphere that surrounds it.
(c) They want to learn how to get to the planet Pluto.
(d) They hope to find a cure for cancer on Venus.
(e) They want to gain more knowledge about space from which all mankind can benefit.

3. 
(a) Man's conquest of space began with the launching of the first artificial satellites in 1957.
(b) United States is responsible for ushering in the Space Age.
(c) The Russians launched a manned artificial satellite on October 4, 1957.
(d) Scientists, military men, and engineers hope to gather more information about space through space travel.
(e) The purpose of sending artificial satellites into space is to find room for our expanding population.

4. 
(a) All the problems concerning manned space flight have been solved.
(b) Space Biology is that branch of biology that deals with the human factors involved in space flight.
(c) Space biologists know that life exists on all planets.
(d) Space is a very strange, hostile, and unfriendly environment for man.
(e) The Department of Space Medicine, which is a branch of Aviation Medicine, was created about 50 years ago.
5. (a) The chief responsibility of Space Medicine is to prepare man as completely as possible for space flight.
(b) The problems involved in space travel will be solved solely by space doctors and biologists.
(c) Man, like all living organisms, possesses unlimited physiological and psychological tolerances.
(d) The environment of space is not too different from the environment on earth.
(e) Space travel is a first-rate biological and medical problem.

6. (a) Scientists are certain that the body and mind of man will be able to withstand space flight.
(b) Man will encounter only a few dangers in space.
(c) Manned space flight is necessary because certain tasks require man’s judgment, vision, and ability.
(d) Engineering and space biology have nothing in common.
(e) When man goes into space, he will leave his physiological, psychological and environmental problems on earth.

7. (a) The necessity of operating in an almost complete and perfect vacuum is not an important problem of space flight.
(b) Man will not need protection against solar and nuclear (cosmic) radiation.
(c) It is easy for man to adjust to high acceleration and deceleration.
(d) Man will perish in space unless he takes his earth-like environment with him in a space ship.
(e) Weightlessness is the same as zero gravity or absence of gravity.

8. (a) Man’s ability to survive in space depends completely upon the design of the space ship.
(b) The judgment, skill, and vision of man are needed to achieve the greatest effectiveness in space.
(c) Scientists do not agree on where space begins.
(d) The border of the earth’s atmosphere extends about 600 miles up.
(e) The whole mass of air surrounding the earth is called the earth’s surface.

9. (a) The physiological problems of man begin between two and ten miles up.
(b) About 50 miles up, airplanes can fly since there still is enough air to support the wings of the airplane.
(c) Above 120 miles man is space equivalent and does not need oxygen equipment to remain alive.
(d) To travel safely in space, man must have oxygen for breathing, warmth, air pressure, food, and water.
(e) Food, water, and air are life-sustaining essentials without which man cannot live.

10.
(a) The difference between the environment of space and that of the earth is the absence of an atmospheric medium (air).
(b) There is no air in space therefore it is an almost perfect vacuum.
(c) As a result of the presence of air in space, there is no oxygen for man to breathe.
(d) Sound waves can be heard in space.
(e) The atmosphere of space is capable of meeting man's breathing requirements.

11.
(a) Man can easily adjust himself to very low pressure areas.
(b) Air pressure in space is about 10 pounds per square inch.
(c) The limits of air pressure within which man can survive are narrow.
(d) Normal air pressure measures about 15 pounds per square inch.
(e) About 15,000 feet, the air must be artificially pressurized to allow man to breathe.

12.
(a) No biological system can operate in an almost perfect vacuum.
(b) The problem of longer space trips cannot be solved by man.
(c) Convenient and comfortable space ship temperature should be between 85 and 95 degrees Fahrenheit.
(d) "Humidity" means the amount of water pressure in the air.
(e) The temperature in space is about 100 degrees Fahrenheit.

13.
(a) Blood and body fluids begin to boil at any point above 16,000 feet altitude.
(b) "Bends" is a condition in which nitrogen bubbles form in the blood and body fluids.
(c) To break away from the earth's gravity a space ship must acquire a speed of 25,000 miles an hour.
(d) Gravity is a force that attracts all objects toward the center of the sun.
(e) Pressure which is created by the pull of gravity is measured in units called meters.
14. (a) The escape velocity of the earth is 25,000 miles per hour or 20 miles per second.
(b) Space vehicles travel in orbits at a speed of 18,000 miles per hour.
(c) G forces have the same effect on man as gravity.
(d) Acceleration means speeding up; deceleration means slowing down.
(e) Speed has no observable effect on man's body provided that it is constant.

15. (a) High G-forces produce no effect on the human body.
(b) As a result of too much vibration on take-off, landing, and during flight, man's blood and body fluids tend to coagulate, or clump.
(c) The crushing force of acceleration multiplies the body's weight and impairs circulation.
(d) Man's body cannot easily adjust itself to rapid acceleration and deceleration.
(e) The human body is designed to withstand exaggerated stresses.

16. (a) Many health hazards are created during periods of rapid acceleration and deceleration.
(b) Scientists recommend that the space traveler lie in a vertical position at take-off.
(c) Black-outs are caused by blood accumulating in the head.
(d) A black-out is a loss of consciousness due to accumulation of blood in the head.
(e) A red-out occurs during rapid deceleration, or slowing down.

17. (a) If a potential space traveler shows quick adaptation in early periods of weightlessness, he will do all right during longer periods.
(b) Weightlessness produces dizziness, disorientation, and other body disturbances.
(c) Man's hearing is affected during periods of weightlessness.
(d) Vision, and the senses of smell, taste, and touch continue to function normally during weightlessness.
(e) Man is unable to drink and swallow in an upside-down position.

18. (a) Space travelers will be able to sleep comfortably in their beds during periods of weightlessness.
(b) By rotating the space ship weightlessness may be counteracted.
(c) Man must be shielded from the hazards of radiation in space.
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(d) Powerful radiation will not destroy human tissue cells.
(e) Radiations are divided into two broad groups: Solar radiation and cosmic radiation.

19.
(a) Radio waves have no biological significance.
(b) The moon generates light, heat, x-rays and radio waves.
(c) Solar radiation is beneficial to life on the earth's surface.
(d) Overexposure to strong sunlight may result in a severe sunburn due to ultraviolet rays.
(e) Unprotected man could not endure the full strength of solar radiation.

20.
(a) Scientists know the origin of cosmic rays.
(b) The Van Allen Radiation Belts were discovered 100 years ago.
(c) The danger of being struck by fast moving meteors is another hazard of space travel.
(d) A sudden drop in pressure in a space ship due to a break or rip made by a meteor is called explosive decompression.
(e) A hole made in the hull of a space ship would cause air to escape from the ship and the pressure would rise.

21.
(a) There is a lot of noise in space due to the bouncing of meteors against the space ship.
(b) Sound waves cannot be heard in space due to the absence of air.
(c) In order to survive in space, man must be provided with a portable environment similar to the environment on earth.
(d) The space traveler can survive without oxygen in the space ship.
(e) Man takes in oxygen and gives off carbon-dioxide in the breathing process.

22.
(a) Man will have to take tons and tons of food along with him in the space ship to take care of his nutritional needs.
(b) Green plants cannot make their own food.
(c) Green plants take in oxygen and give off carbon-dioxide during the process of photosynthesis.
(d) Chlorella, a green alga, will provide man with oxygen and food in the space ship.
(e) It will be a simple task to dispose of wastes in space.
23. 
(a) Synthetic liquid nutrients injected into man's body might serve as a good substitute for regular food.
(b) In space day and night become meaningless terms because there is no real day and night.
(c) Disregard for the day and night cycle might lead to a complete nervous breakdown.
(d) Claustrophobia, or a fear of being at high altitudes, is a physiological problem in space.
(e) Man will enjoy the quiet and silence of space.

24. 
(a) Man's greatest enemy in space will be boredom.
(b) To date all the major problems of manned space flight have been solved.
(c) Tests with dogs, monkeys and other animals indicate that man will not be able to survive flights into space.
(d) The unmanned satellite will allow man to test space suits, air-conditioning units, and other equipment.
(e) Space stations which will follow the launching of a manned satellite will serve as a training base for space men.
APPENDIX D

SPACE BIOLOGY - POST-TEST II
(Used also as Retention Test II)

Place an x before the statements that are true; 0 before the statements that are false.

1. The principal biological problems which will confront man in outer space are:
   - a. operating in an almost perfect vacuum
   - b. traveling at a constant speed
   - c. weightlessness and extremes of solar and cosmic radiation
   - d. directing the space ship
   - e. high acceleration and deceleration

2. To travel in space man must have:
   - a. a well-designed airplane
   - b. oxygen, warmth, air pressure
   - c. a degree from a school of medicine
   - d. low blood pressure and body temperature
   - e. food, water, and means for waste disposal

3. Space medicine is an extension or continuation of aviation medicine. The responsibilities of space medicine are:
   - a. to prepare man as completely as possible for space flight
   - b. to provide man with an environment different from the earth environment
   - c. to establish a space medicine station on the moon
   - d. to protect man against the hostile environment of space
   - e. to completely change the environment of outer space

4. As far as man's sensitive body is concerned, space does not begin at 600 miles above the surface of the earth, but:
   - a. at 12 miles up, where man's body fluids would vaporize outside a protected environment
   - b. at 2 to 10 miles up, where man is endangered by lack of oxygen
   - c. at 120 miles, where man is space equivalent
   - d. at approximately 11,000 feet, where oxygen equipment is necessary to remain conscious
   - e. where the atmosphere ends abruptly
5. Man is an earth-bound creature and is well adapted to the following physical environmental conditions of the earth:
   a. moderate temperatures
   b. weightlessness, or zero-gravity
   c. absence of an atmospheric medium
   d. crushing force of 25 G’s
   e. normal air pressure of 15 pounds per square inch

6. Which of the following physical environmental conditions are identified with space?
   a. an atmospheric medium
   b. normal gravity of one G
   c. cosmic and solar radiation
   d. 15 pounds of air pressure per square inch
   e. changes in weather conditions

7. About thirty per cent of the fliers tested under conditions of weightlessness suffer ill effects of some kind. The most frequent complaints are:
   a. inability to hear
   b. loss of vision
   c. inability to smell, taste, and feel
   d. dizziness and disorientation
   e. giddiness, nausea, and disturbances in muscle control

8. The decisive difference between the environment of space and that of the earth is the absence of an atmospheric medium. The chief functions of the earth's atmosphere are:
   a. to provide man with oxygen and air pressure
   b. to protect man from cosmic and solar radiation, and meteors
   c. to support airplanes
   d. to transmit sound waves and light waves
   e. to create tornadoes and hurricanes

9. Which of the following represent scientific cause and effect relationships?
   a. Overexposure to strong sunlight may result in a severe sunburn due to the effect of ultraviolet rays.
   b. A plant's requirements for food cause it to carry on photosynthesis.
   c. Man inhales air because he needs oxygen to survive.
   d. A red-out is a loss of consciousness in rapid descents due to accumulation of blood in the brain as a result of decrease in weight.
   e. The crushing force of acceleration multiplies the body's weight and impairs circulation.
10. The best measures to take in order to prevent black-outs or red-outs is to:
   a. lie in a prone or reclining position at right angle to the direction of flight
   b. position head and heart at about the same level
   c. sit in an upright position with hands close to body
   d. float in the center of the space ship
   e. allow the blood to accumulate in the brain

11. A pull that is as strong as the gravity of the earth is called one G. When a person is subjected to too many G's at take-off or landing, he:
   a. retains good vision
   b. floats in the space ship
   c. develops chest pains
   d. has difficulty in breathing
   e. may become unconscious

12. A definite hazard of space travel is puncture by meteors that travel through space at tremendous speed. Puncture of a space ship would:
   a. provide an exit for air which would reduce the pressure and cause explosive decompression
   b. increase the velocity of the space ship
   c. result in immediate death of the space travelers
   d. not be a serious problem in space travel
   e. bring the space ship back to earth

13. In order to provide a livable atmosphere for man in the space ship:
   a. the temperature should be between 30 and 40 degrees Fahrenheit
   b. the humidity should range between 40 and 60 per cent
   c. the temperature should be within the 50 and 70 degree (Fahrenheit) range.
   d. the air should contain 98% oxygen
   e. the air pressure should be about 5 pounds per square inch

14. Man, like all other living organisms, possesses limited physiological and psychological tolerances. In space man will be faced with the psychological problems of:
   a. difficulty in breathing
   b. change in the day and night cycle
   c. claustrophobia
   d. boredom and monotony
   e. isolation and confinement
15. Chlorella is a fast-growing green alga that may be grown successfully in the space ship to provide man with
   a. helium gas for breathing
   b. a source of food
   c. oxygen for respiration
   d. an absorbing agent for carbon dioxide
   e. compressed liquid oxygen

16. The arrangement of a closed ecological system in the space-ship is a theoretical possibility. Scientists think it can be done
   a. by returning every atom of human waste to the nutrition cycle
   b. by lowering the temperature of the ship
   c. by taking extra food along
   d. by immediate disposal of wastes through an airlock
   e. by growing green algal plants in tanks

17. Which of the following biological principles are true?
   a. Living things, including man, have become adapted to wide ranges of physical conditions.
   b. Plants and animals are dependent on one another in various ways.
   c. Some living things do not carry on the life processes of nutrition, respiration, excretion, sensitivity, and movement.
   d. The environment acts on living things and living things act on their environment.
   e. There is scarcely a region in space where some form of life does not exist.

18. What is being done to get men ready for space?
   a. Only the most handicapped persons will be selected.
   b. Candidates are trained in devices which simulate conditions to be found in space flight.
   c. Simulated space cabins will check response to isolation and boredom.
   d. The selected astronauts will have to gain weight to be able to withstand hunger during space flight.
   e. Space candidates must become used to space suits and to working in them.

19. Which of the following statements are true?
   a. Space medicine and space technology must understand the physiological, psychological and environmental problems of man before sending him into space.
   b. Elimination of waste in space will not create a problem.
   c. Protective adaptations are an aid to survival.
   d. When the environment changes an animal must adjust itself to the change or perish.
   e. Species not fitted to conditions about them will not thrive and finally will become extinct.
20. In space travel, man will perform best physically and mentally if the air he breathes contains about

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>a.</td>
<td>100% oxygen</td>
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<tr>
<td>b.</td>
<td>90% nitrogen</td>
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<tr>
<td>c.</td>
<td>2% carbon-dioxide</td>
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<tr>
<td>d.</td>
<td>40 to 60% moisture</td>
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<tr>
<td>e.</td>
<td>16% rare gases</td>
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</tbody>
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APPENDIX E

SPACE BIOLOGY - PART V
(Portion of Space Biology Program)

Since space lacks the atmosphere and pressure needed to sustain human life, it is necessary that manned space flights be provided with a medically satisfactory, portable environment similar to man's ___ on earth.

---

environment (conditions)

---

The space traveler must carry his own ___ of oxygen, because he could not survive in the vacuum of outer ___ where there is no air, or oxygen supply.

---

supply, space

---

When man leaves the earth to travel in the strange and hostile ___ of space, he will have to enclose himself in a small, earth-like artificial environment in which he will be permitted to eat and breathe, to eliminate wastes, and to survive the known and unknown hazards of ___.

---

environment, space

---

The key to the whole science of space medicine is the artificial environment, made possible largely by specially designed ___ or space capsules.

---

space biology
The answer key to human survival in space is a hermetically sealed pressurized space with its own closed environment in which can live and work efficiently for extended periods of time.

ship, artificial, man

If man leaves the last traces of air behind and cruises into the emptiness of space, the walls of his space ship must take the place of the atmosphere (earth).

atmosphere (earth)

Inside his ship man must be supplied with all the tools of life and be protected against the hostile environment of the void outside.

ship (capsule), environment

Man needs the oxygen in the air for breathing or respiration. Without oxygen man cannot live (breathe, survive).

oxygen, live (breathe, survive)

If there is no air in outer space from which man can obtain the oxygen that he needs for life, tanks of compressed liquid oxygen can replenish the oxygen loss on short trips into space.

oxygen (air)

Man can obtain the air that he needs for respiration from tanks of compressed liquid oxygen which the space traveler must take along on a space trip.

compressed
Only on short trips into space will compressed oxygen take care of man's respiratory needs; on long trips some other system must be devised.

On long trips into space a method of supplying oxygen and getting rid of carbon-dioxide would have to be provided. The gas which man exhales is a waste product of respiration.

Ground experiments indicated that the space man performs best physically and mentally when he can breathe air containing a little less than 2 per cent carbon-dioxide, which is essential to his brain.

Man takes in oxygen and gives off carbon-dioxide in the process of respiration.

In the process of breathing or respiration, oxygen is taken in and carbon-dioxide is released. This gas must be removed from the space vehicle to insure the safety and comfort of the space traveler in the space ship.

In space travel, man will perform best physically and mentally if the air he breathes contains about 2 per cent carbon-dioxide.
Means of circulating and purifying the ___ are also necessary for
the comfort and safety of the space traveler.

air

Since green plants need carbon-dioxide for photosynthesis, it has
been suggested that a fast-growing green algal ___ could be grown
in the space ship.

plant

Photosynthesis is the process by which green plants manufacture
food. Green plants need carbon-dioxide for ___.

photosynthesis (food-making)

In the process of photosynthesis, green plants take in carbon-
dioxide which man ___, and release oxygen.

exhales (gives off)

Man needs oxygen which the green plants give off for ___.

breathing (respiration)

An alga is a simple green, blue-green, red, or brown ___ that lacks
true leaves, stem, and root system. It is one of the simplest kind
of plants in the plant kingdom.

plant

An ___ is a plant that lacks true leaves, stem, and root system.
The plural form of alga is algae.

alga
Algae are simple ___ without roots, stems, and ___.

__________________________

plants, leaves

__________________________

Algae may be green in color, blue-green, brown, or ___.

__________________________

red

__________________________

Chlorella is a green algal ___. Biologists discovered that it is a good oxygen supplier.

__________________________

plant

__________________________

Green plants give off ___ in the process of food-making, or ___.

__________________________

oxygen, photosynthesis

__________________________

Chlorella is considered to be a fast-growing green ___ plant that could be grown successfully in the space ship to provide a source of oxygen supply for man's respiratory needs.

__________________________

algal

__________________________

Green plants need carbon-dioxide gas for making ___. Green plants take in ___ gas and give off oxygen in the process of making food (Photosynthesis).

__________________________

food, carbon-dioxide

__________________________

Chlorella, a green alga, would not only supply man with the needed ___ but it would also absorb the ___ exhaled by man in breathing.

__________________________

oxygen, carbon-dioxide
The task of providing air, food, and water in space is one which can be solved in principle even now. Man's food requirements would be much reduced under zero gravity or in a state of ___.

weightlessness

The necessary oxygen to replenish the air would be carried in the liquid state. Tanks of compressed liquid ___ can be taken along in the space ship on short trips into space.

liquid, oxygen

Green plants need ___ gas for food-making. Another word for food-making is ___.

carbon-dioxide, photosynthesis

During the process of ___ the green plant Chlorella, an alga, takes in carbon-dioxide and gives off oxygen as a by-product. This oxygen would supply the space traveler in the space ship with his respiratory needs.

photosynthesis

The green algal plant ___ , not only gives promise of absorbing carbon-dioxide and supplying oxygen, but it can also be cultured in flight and thus serve as a possible source of food for ___.

Chlorella, man

A fast-growing plant, like ___ , would serve as a source of food, an oxygen-supplier, as well as for the absorption of carbon-dioxide gas, a waste product of man's ___.

Chlorella, breathing (respiratory)
Chlorella would then help to set up a carbon-dioxide oxygen cycle in the space, this cycle would be similar to the one that nature provides for man on earth.

In addition to the use of Chlorella as a possible source of oxygen and food for man, compressed and concentrated food might be taken along, provided these are not too heavy.

Compressed and concentrated foods, provided they are light in weight, and Chlorella would help to solve the food problem for man on short and long space trips.

A one-celled green alga which is a very efficient oxygen supplier and food-producer is Chlorella.

There is a plant, Chlorella, a green alga, which possibly could provide man with food and oxygen. It would also absorb the carbon-dioxide gas from the space ship.

The problem, however, is to make a small ecological system in the space, similar to the one that nature provides for man on earth.
The green alga, ___, shows more promise than any other plant as a supplier of ___ and food for man in space, and also for disposal of his wastes.

Chlorella, oxygen

Many more experiments with the green algal plant, ___, must be continued to prove its effectiveness in a small, closed ecological system.

Chlorella

Biologists are now at work developing a substance which could eliminate the need for a person to eat, drink, or breathe in the normal way. The substance is a synthetic nutrient, or food, which will contain all the elements required by the human ___ for nutrition and respiration.

body

are trying to develop a synthetic ___ which will serve as a substitute for food.

Biologists, nutrient

This synthetic nutrient, which will be a ___ substitute, will contain all the elements needed by the human ___.

food, body

The synthetic food substitute or nutrient which ___ are now working on will be in ___ form. It will be injected into the bodies of men on long space flights.

biologists, liquid
If the tests with this ___ nutrient succeed, hundreds of pounds of food, water, oxygen and the equipment to contain and preserve them will no longer be necessary on space ___.

synthetic, trips

The space ship will be much lighter in weight if the ___ succeed in perfecting synthetic nutrients that will eliminate the need for a person to eat, drink, or breathe in the normal way.

biologists

Food, water, and disposal of wastes in space flights will present difficult problems. Food is a problem for one primary reason -- weight. The green alga, ___, will help to supply man with the ___ that he needs to sustain life.

Chlorella, food

Science hopes to arrange a closed ecological system in the space ship similar to the carbon-dioxide-oxygen cycle found in nature on ___.

earth

The very nature of our earthly carbon-___-oxygen cycle may help to solve man's problem of keeping the space travelers alive in the ___ ___.

dioxide, space ship

Green plants in the presence of solar energy (the sun) make food from ___-dioxide and water and give off ___ which man and other animals use for breathing.

carbon, oxygen
This process of making food is called ___. Green plants are able to produce food for themselves and for ___.

_________ ' ' __________

photosynthesis, man (animals)

Experiments have been performed in laboratories in which the very cycle of life on our planet has been reenacted. These experiments demonstrate the possibility of arranging a closed ecological ___ aboard space ships.

________

system

It is believed that human wastes could be processed for food for the plants (algae) and that, in turn, part of the ___ could actually be processed as human ___.

_____________ ' ' __________

algae, food

It might be possible to operate a closed ___ system which would absorb the space traveler's exhaled ___ and wastes, be nourished by those, and in turn produce oxygen for ___, and food.

_____________ ' ' __________

ecological, carbon-dioxide, breathing

The arrangement of a closed ___ in the space ship is a theoretical possibility today. Scientists think it can be done.

__________ ' ' __________

ecological system

A closed ecological system which would return every atom of human waste to the nutrition cycle has become a ___ possibility today.

________________
theoretical
For relatively brief excursions into outer space, the problems of food, ___ , and waste are not really critical.

Space travelers will simply carry their full requirements of ___ for drinking and concentrated or compressed ___. Liquid waste, (urine) could be stored in a compartment of the space suit for discharge after landing.

For long-duration flights a completely ____ system will be an absolute requirement.

Elimination of body wastes will be a serious ____ in a closed environment such as a space ship.

Chief wastes are exhaled ___, sweat, salt, urine, and feces.

Air may be handled by the closed ecological system; some of the water transmitted to the space ship may also be handled by the ____ system.

Exhaled, closed ecological

Urine, or human liquid waste, on short trips may be stored in a part of the ____ suit.
On longer trips human liquid waste, called \( \textit{urine} \), may be removed by distillation. The water may be re-used. The salt crystals that remain, however, are useless and toxic.

\( \textit{urine} \)

The disposal of such human waste as \( \textit{urine} \) (liquid waste) is a very serious problem in a closed \( \textit{system} \) such as the space ship.

\( \textit{urine, system} \)

Food, water and \( \textit{urine} \) of human wastes will present difficult \( \textit{problem} \) in the space ship.

\( \textit{disposal (elimination, removal), problem} \)

As manned space technology becomes more advanced, there will be need for man to venture outside his \( \textit{space} \) ship for landings on our closest neighbor, the \( \textit{moon} \), and on other planets.

\( \textit{space, moon} \)

In order for man to survive on the \( \textit{moon} \) and on other planets, outside of the space vehicle, he will need equipment -- a space suit, containing practically all the protective elements already built into the space vehicle.

\( \textit{moon} \)

To move about on the high-vacuum surface of the \( \textit{moon} \), men will have to wear \( \textit{space suits} \), which will provide them with \( \textit{air} \) to breathe and pressure, yet allowing them enough mobility to work with tools.
Man can carry on normal body functions reasonably well at a pressure of only 10 pounds per square inch rather than the normal sea level pressure of ___ pounds per square inch.

The dangers of very low ___ in outer space can be reduced by the use of specially developed pressurized suits.

The purpose of such a space ___ is to supply pressure to make up for that which space lacks. Man can do well with a pressure lower than that of 15 pounds per square inch.

The chief problem, however, is the invention of a flexible ___ capable of withstanding an internal ___ close to 10 or 15 pounds per square inch.

In addition to supplying man with the proper kind of air ___, space suits will also contain a supply of ___ for breathing purposes, devices for controlling temperature and a radio-communication system.

The basic design of the ___ has been worked out by the United States Navy and Air Force. The suits will be pressurized, that is, they will use compressed air to maintain at least in part the ___ pressure that exists on ___.

---
Transparent helmets will be worn to protect man from ultraviolet rays and to allow man to see.

The space man, floating freely in space in his space suit, feels strangely unable to control his motions. The center of gravity of his body stays put, no matter how he moves his limbs.

Because of this strange feeling of inability to control his motions (movements, limbs), the space traveler will generally have to rely on cords or cables connecting him to the space ship.

The problem of weightlessness will continue to give man trouble in the space ship. It will give him a constant feeling of falling, which could result in serious mental effects.

There is nothing, however, that can be done about himself. He cannot make any radical changes in his own man, body. Men, after all, are adapted for living in a condition of weight.

Some strange things that man, floating, magnetized will encounter in the space ship due to an absence of gravity are: Tools and eating utensils would have to be magnetized to prevent them from away from man. Even man's shoes would have to be magnetized.
Hair and clothing would not stay down. Anything not fastened in place would be free to drift about. Even liquids would not remain in a container.

Bathing would also be a problem in the spaceship, but with careful planning it could be managed.

Man would have to bathe by using sponges. This would have to be done inside some type of plastic bag or else in a strong stream of air, to keep drops of water from floating around.

Bathing would be a big problem, but it could be accomplished by using carefully dampened sponges.

On earth "down" always means toward the center of gravity, and "up" means and feels the opposite.

It is hard to imagine living without an "up" or "down." Hot air could not rise by itself, since the word "rise" applies only when there is an "up."
Fortunately, most problems regarding the lack of can be met by our bodies. We can swallow without ; we can even swallow when upside down.

weight (gravity), weight

On space trips, will undergo severe psychological stresses of isolation, confinement, boredom, and a new cycle of day and night.

long, man

A peculiar feature, or problem, of space flight is that there is no day and night. In space and night become meaningless terms.

day

The reason why there is no and in space is due to the fact that periods of light and darkness succeed each other in a matter of hours or less.

day, night

Periods of light and succeed each other so quickly because the space ship in ellipse passes a number of times each chronological day through the shadow cast by the earth for a depth of 860,000 miles.

darkness

The shadow which the casts into space for 860,000 miles is a zone of darkness.

earth
For health and efficiency ___ is adjusted, or accustomed, to a regular daily cycle of wakefulness and activity, as well as of rest and sleep.

It will be difficult for man in space to ___ himself to a new cycle of day and night.

To keep ___ and be efficient man must have a daily cycle of wakefulness and ___, of rest and ___.

Humans are so strongly adapted psychologically to the ___ and ___ cycle, that it is regarded as a biological law.

Disregard for the day and night ___ for extended or prolonged periods of time, might lead to a complete nervous breakdown.

Rapid succession of periods of ___ and darkness in space flight tends to disrupt the normal day and ___ cycle.

Complete disregard for the day and night cycle could lead to a nervous ___.

---
Psychologically, man is strongly \___ to the day and night cycle. 
Man's adaptation to this \___ is regarded as a biological \___.
adapted (adjusted), cycle, law

Much research is still needed in order to find a pattern for work, recreation, and sleep for the man in \___.
space

Claustrophobia, or a fear of being in closed rooms or narrow spaces, is another psychological problem concerning \___ in space that must be solved.
man

The abnormal fear of being confined to narrow places or closed rooms is called \___.
claustraphobia

By nature, man is a social creature who seeks the company of his fellows. Solitary confinement to a \___ capsule, or ship, with little or no opportunity to move is a psychological and physiological problem that Space \___ has yet to solve.
space, Medicine

One of the greatest psychological problems that man will encounter in space is boredom. Man's greatest enemy in space may be \___.
boredom
Man is accustomed to meaningful activity which frees him from monotony. __ often leads to carelessness. Success of space flight depends upon solving this problem of boredom.

Boredom

Since man has limited physiological and psychological tolerances, it will be difficult for him to survive travel in this totally new environment for a number of reasons: (1) he must endure for several minutes the strain of violent launch acceleration that will increase his weight many times; (2) he must enter the strange world of __ due to reduced or zero gravity; (3) he must eat, sleep, breathe, and perform life functions in a ship or capsule which is surrounded by an almost perfect __ which could cause his blood to boil; (4) he must be able to work for extended periods in a heavily automated ship with fellow workers under equal stresses.

Will Man's body and __ be able to take space flight? Time will tell.

__________ weightlessness, vacuum, mind

OFF TO SPACE!
The dissertation submitted by Sister Mary Stephanetta Kolanowski, C.S.S.F. has been read and approved by five members of the Department of Education.

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the dissertation is now given final approval with reference to content, form, and mechanical accuracy.

The dissertation is therefore accepted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.