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IN THE HIGH SCHOOL CURRICULUM.

The Ohio State University, Ph.D., 1962
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1963

THE EFFECTIVENESS OF A UNIFIED SCIENCE
IN THE HIGH SCHOOL CURRICULUM

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Irwin Leonard Slesnick, B. A., B. S., M. S.

The Ohio State University
1962

Approved by

Adviser
Department of Education

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CHAPTER I

INTRODUCTION

The responsibility of the school has been to introduce to students the fundamental cultural interests and concerns of the society that supports the school. In our modern culture these interests are reflected in the disciplines or broad groupings of disciplines consistently identified as: the natural sciences, mathematics, social sciences and the humanities. The successful teaching of these areas results in informed individuals competent in using an intellectual heritage for the further progress of society.

The product of the school must therefore be broadly prepared to meet the intellectual challenges that have been created for him. He must have a perspective of the vast intellectual resources which he will utilize in becoming a purposeful member of society. He must know these resources and be experienced in their use for the solutions of problems that are real, practical, meaningful and challenging.

An individual prepared for life achieves ideally to his capacity the ability to adjust emotionally and mentally to the dynamic environment with which he interacts. The extent to which this ideal is realized is a measure of his integration. That integration is a goal of education is not an issue; the means for achieving integration has long been an educational issue.

What man has learned about the natural world and his interaction with it, about himself and the interaction among men, has been translated into two approaches to the selection and teaching of curriculum content. Historically the older in the American public school is a subject-centered organization where individual attention is given by teacher and student to the organized knowledge of discrete fields. The student is required to synthesize his learnings into integrative action when life problem situations later arise. The second general curriculum design is a problem-centered organization where real life problem situations are the foci of study and the content and methods of disciplines are borrowed wherever and whenever needed. Foshay has pointed out that neither organization is wholly satisfactory.

The difficulty with a problem-centered approach used as the only approach to the selection of curriculum content is that the problems as they come are not disciplined, nor do they ordinarily lead us to an understanding of the disciplines through which human truth is developed or discovered. An approach through one discipline at a time would not be adequate, since practice in problem solving is also necessary. We have to have it both ways--both problem-centered and discipline centered, . . . if we are to hope to produce students who at the same time they think, are fully aware of the intellectual processes that they themselves are using.¹

To be both problem-centered and subject-centered the various fields of study must be fitted into a curriculum pattern that provides a large measure of coherence and relatedness for the school program as a whole. Science, social studies, humanities and mathematics can no longer be satisfactorily taught at general education levels as series of

¹Arthur W. Foshay, "Knowledge and the Structure of the Disciplines: The Use of the Disciplines as Curriculum Content" (Paper read at University of Wisconsin at Milwaukee School of Education Conference, November 16-18, 1961).

isolated subjects, nor can a curriculum pattern disregard the value of depth experience in the domain, method and tradition of the disciplines.

A current trend in secondary education is the organization of content around themes that transcend component compartments within a specialized field of study, to the end that the student acquires a core of understanding through the "method of discovery" unique to that field. Yet, even in science where the greatest efforts appear to have been made, new courses in biology, chemistry and physics show little or no relationship to each other. Similarly, a project in economics was developed in disregard to its relationship with the other social sciences. Only in mathematics has there been an effort to view the broad field as whole but even here study was limited to only the highest levels of scholarship.²

There is a need to develop general education programs in the broad fields of study that present the most significant content in such a manner that the student is led to perceive the unity of the field, the relations of the field to other broad fields, and is taught to apply the methods of inquiry and the generalizations of that field to problems of life.

Science educators have long recognized that a program in secondary school science can be of value to all students. Many believe that a science program should be unified at each level to follow sequentially and logically from one grade to the next. A few have believed that the

²Arno A. Bellack, "Conceptions of Knowledge: Their Significance for the Curriculum" (Paper read at the University of Wisconsin at Milwaukee School of Education Conference, November 16-18, 1961).

offerings of science for the majority of students should be effectively presented in a problem of living approach. Currently the most common approach to the teaching of science is subject centered, with biology, earth science, chemistry and physics the dominant subjects.

I. The Problem

The purpose of this study has been (1) to develop a sequential course in Unified Science for grades nine through twelve that utilizes themes or "big ideas" of science in disregard for specialized subject matter boundaries; (2) to identify one objective of science teaching common to a unified science and science subject-centered approach; (3) to develop an instrument that would measure the realization of the above objective; and (4) to design and carry out an experiment that would ascertain the comparative effectiveness of unified science and subject-centered science in realizing the objective.

The Unified Science curriculum planned and effected at The Ohio State University School since 1958 claims in its rationale to be able to provide more cogently for the science education needs of adolescents and society than can the currently compartmentalized science curricula. Many of the virtues of Unified Science asserted in Chapter II do not lend themselves well to quantitative testing; tests for the realization of other objectives must await the full completion of the program, the spread of the spirit of science content integration and the growth of the number of products of such a sequential program.

However, this investigator believed that the program had been in operation long enough (three years) to test for the realization of at

least one objective of Unified Science. This objective concerns the image of the physical world perceived by the adolescent, and is referred to as a rational universe image. It is contended that formal study in science should yield a rational awareness of a dynamic universe, composed of matter, energy, and life bonded by interconnecting generalizations. The breadth and depth of understanding and ability to apply these learnings to problem situations of everyday living is a measure of scientific literacy.

Unified science claims to provide the individual with a more complete rational image of the physical world than can traditional science. It does this not by providing more subject matter but rather by using the same content as the traditional courses reweven into a fabric that reflects the real world more truly than can a series of separate subject studies.

Hypothesis

The rational universe images of students who have experienced Unified Science are broader, deeper and more integrated than those of students matched in all controllable factors except organization of content.

II. Importance of Study

Ideas, recommendations, and practices concerning the unification of science content for general education are by no means new. Ever since the early 1900's there has been a general trend throughout the junior high school, senior high school and junior college to develop general courses designed to meet the needs of the common users of

science. Yet, a review of the literature has revealed that although General Science, Biology and Physical Science in varying degrees qualify as fused or integrated courses or course sequences, a broadly unified high school science sequence organized about the interconnecting big ideas of the scientific enterprise has not been developed for testing.

The frequency of calling for an integrated approach to the teaching of science to adolescents at all levels of ability has not been diminishing. In making curricular recommendations for the academically talented secondary school pupil in science, a committee of scientists and educators said:

For the near future, a two-year integrated course in physics and chemistry is advocated and, at a somewhat later date, a three-year integrated course in physics, chemistry and biology seems advisable.³

After analyzing the curricular experience available to students who will not pursue formal science study beyond high school levels and the future scientists who study separately and in depth astronomy, biology, chemistry, geology, meteorology and physics, Renner concludes:

. . . the traditional subject-matter division should be abandoned and a six-year program in science (for secondary schools) be developed which integrates the six major areas of science.⁴

The mere establishment of a course is not enough. Curricular innovations must be evaluated in terms of the objectives they have been

³ National Education Association, The Identification and Education of the Academically Talented Student in the American Secondary School, The Conference Report, Washington: National Education Association, 1958, p. 111.

⁴ John W. Renner, "Do We Dare to Be Different" (Randolph, Wisconsin Educators Progress Service), p. 7 (pamphlet).

hypothesized to realize. To be successful they must be proven more effective than the course(s) they are intended to supplant. In general education courses it seems rather purposeless to compare the quantity of factual knowledge acquired by students in a fused course with the quantity acquired by students in the subject-centered course--as some investigators have been wont to do. Rather, there is a need to investigate the long-term values to the students of various types of subject matter content in general education science courses.⁵

The evaluations of Unified Science dare not wait until after its rejection or acceptance by the teaching profession. The purpose of this research was to enable designers to adjust the pilot program in accordance with the findings. Hurd must not be permitted to include program development in Unified Science if he again writes ". . . the greatest volume of opinionated literature precedes new education practice, research upon the issue follows the practice."⁶

The rational universe image is revealed in the way the individual mirrors the physical world as a whole. The more complete and integrated this picture, the more able the individual becomes in formulating a philosophy of life with which to direct his behavior. Since philosophy has no other subject matter than the nature of the real world, rational images of the universe can yield wholesome philosophies that direct

⁵Robert Adrian Bullington, "The Subject-Matter Content of General Education Science Courses," Science Education, XXXVI (December, 1952), 292.

⁶Paul DeH. Hurd, "Mid Century Trends in Science Teaching," California Journal of Secondary Education, XXVIII (May, 1953), 245.

rational behavior. Narrow and unconnected understandings of the physical world engender less mature philosophies and less rational behaviors. Today's citizen must achieve a depth and breadth of experience with the physical world to meet the current challenge of survival in a seemingly complex environment. Such depth and breadth would seem to be best available to most students through a curriculum organized about unifying principles of science.

III. Definition of Terms Used

Unified Science curriculum. The structured broad area sequential program in science where "big ideas" or generalizations form the organizing core of study and where science content is adduced as needed regardless of all subject matter boundaries. "Fused" and "integrated" and "general" are used to describe science curriculum organizations that are essentially the same. However, "fused science" has, among other meanings, described courses such as biology and physical science that are the results of bringing together pre-existing distinct subjects, "integrated" is commonly used to describe science curricula organized around life needs and human relationships, and "general" has acquired the connotation of superficiality and piecemeal.

Generalization of science. Any one of the comprehensive big ideas or principles of natural science, useful at nearly all levels of study, commonly draws upon many specific branches of science for component concepts. Orderliness of nature is a generalization of science reflected in the periodicity of elements, the spectral arrangement of radiant energy and the phylogenetic classification of organisms.

Rational universe image. One's conception or picture of the physical world as a whole, gained through the sense experiences with things and events. The image is rational because it enlarges by intellectual processes, collectively termed scientific methodology. The image is universal in that the immediate and proximate extend continuously to the remote and cosmic. Five general features of a rational universe image have been identified as measurable in this study. They are--

1. Phenomena reflect the interdependencies and interactions of matter, energy and life.
2. The forms of matter, energy and life reveal a natural orderliness.
3. Things and events are perceived in accurate perspective in relation to time and space.
4. Real problems in controlling, predicting and interpreting events in the universe transcend single disciplines.
5. Man's relationship with his universe, as an observer and as a part of the "unit" is perceived realistically.

Treatment. The conditions to which the experimental group was exposed. In the reported study, the treatment was the program in Unified Science experienced by one member of each matched pair.

Control group. Those students, one member of each pair, who experienced only subject-centered science.

Level. Any one of the six characteristics shared by matched pairs of subjects, and any one or a combination of characteristics shared by two

or more matched pairs of subjects. Thus, every matched pair ideally shares the levels of sex, age, academic performance in science, grade, and years of sequential science since the ninth grade. Also a grouping of paired subjects whose sex was female would constitute the female level of the sample, or those members of the control group whose science course work in the ninth grade included Physical Science would constitute the Physical Science Level. Level is also used in describing the area in the normal distributing curve in which a statistical test of significance is being made.

Treatment instrument. A test designed to measure the rational universe images of all subjects involved in the experiment.

Levels instruments. All devices (tests, questionnaires and school records) used to achieve a high degree of similarity of characteristics between members of potential matched pairs.

IV. Overview of Remainder of Dissertation

Scope of Problem

To place this study in historical perspective, a brief recapitulation of the efforts to organize science for general education in unified context is presented and analyzed in Chapter II. The current status of science, science education and the psychology of learning are then expounded to justify the need for development and evaluation of secondary school programs in Unified Science. The objective of a rational universe is defended as a focus for inquiry into the effectiveness of a Unified Science program.

The Unified Science Program at The Ohio State University School

Chapter III describes the philosophy, role in the College of Education, general curriculum, students, faculty and facilities of the University School. Following a recounting of how Unified Science became a part of the school's experimental curriculum, the content and methods of Unified Science I, II, III and IV are briefly related.

Methods and Materials Used Preparatory to Testing the Main Hypothesis

Chapter IV sets forth the details of the experimental design, a treatment by levels. The instruments and methods for obtaining seventy-eight matched pairs from two high school populations are presented. The equality of the pairs are evaluated statistically and qualitatively.

The Treatment Instrument-Test on the Measurement of a Rational Universe Image

The construction of the instrument used in testing the main hypothesis is described in Chapter V. Questions representative of five features of a rational universe image are illustrated and discussed. Validation and reliability determination procedures and results are reported.

Findings

Chapter VI presents data that compare the performances of the experimental and control groups at various levels in terms of performances within divisions of the criterion instrument. In the analysis, the t statistic is employed to aid in the identification of significant differences between the means of paired measures.

Summary, Conclusions and Implications

The final chapter takes the knowledge gained as a result of this study and fits it into the body of understanding that has existed regarding the teaching of science in the secondary school. The frontier in the region of the Unified Science curriculum is redefined and new and further areas for inquiry are proposed.

Appendixes

Appendix A includes content outlines, sample activities, materials and bibliography for Unified Science I, II, III and IV. Appendix B includes the course of study outlines in science for the ninth, tenth and eleventh grades in the control school. The treatments instrument, divided as to features with most acceptable responses indicated, appears in Appendix C.

CHAPTER II

THE SCOPE OF THE PROBLEM

I. History of Efforts to Unify Science

The organization of science content in the curriculum of the American secondary school has changed considerably throughout the past century and a half. The facts of curricular evolution indicate a central tendency toward unification of subject matter with universal scientific literacy the goal. In this chapter the trend is explicated and analyzed. The place for Unified Science in the high school curriculum is argued, and one objective is defined.

The Trend toward the Unification of Science in the Secondary School

Physics was taught as a school subject in the first public secondary school established in Boston in 1821. Since that date and until after 1893 the American secondary schools' curricula included a large and increasing number of short term specialized science courses that contributed much "to the superficiality and general ineffectiveness of science instruction."⁷ By recommending that a sequence of one-year courses, including Physical Geography, Biology, Chemistry and Physics,

⁷ Herbert Smith and Kenneth E. Anderson, "Science," Encyclopedia of Educational Research (1960), p. 1217.

be established, the conference arranged by the Committee of Ten tended to control the number of science offerings.

Biological science courses occurred in various forms around the turn of the century. The most common offering was one semester of Botany and one semester of Zoology for either the tenth or ninth grades. The Committee on College Entrance Requirements recommended for the tenth grade Biology, Botany or Zoology, or Botany and Zoology. Thereafter, one of the four kinds of courses was to be found in the tenth or ninth grades. The emergence of biology as the most popular of the life science courses is credited to the authors of textbooks who correlated and fused the contents of Botany and Zoology.⁸

The Physical Geography recommended for the ninth grade by the Committee of Ten science conferees failed to gain the acceptance received by Biology, Chemistry and Physics. Beginning possibly in Springfield, Massachusetts, in 1900, ninth grade general science grew in popularity displacing nearly all competing specific science subjects.

General Science was conceived by some as the non-specialized course that could provide a foundation upon which to build a specialized curriculum and also be a terminal course that could provide students with breadth and depth in all the major science subject areas. During the early years of the General Science movement the Committee on a Unified High School Science Course recommended:

The first year science of the high school should be organized upon a broad basis involving fundamental principles of the various sciences and using materials from all,

⁸Harold E. Wise, "An Integration of Physics and Chemistry," Science Education, XX (April, 1936), 70.

if needed. Certain large topics should be selected for study. These should have coherence in themselves; they should be so chosen as to allow of the scientific interpretation of the more common experiences of the pupils, and to lead to new experiences with common phenomena. Use should be made of materials from any of the sciences as may be needed for the study of the topics selected. Such a use of topics upon which various sciences are focused will introduce the pupils to the differentiated subjects.⁹

Despite these and similar recommendations General Science became a hodge-podge of separate subjects based on college texts.¹⁰ It was attacked by those who regarded it either impossible but desirable or undesirable but possible.¹¹ General Science was especially criticized by science specialists. In defense of general science Slosson eloquently stated:

General Science is not a crazy-quilt, made up of patches torn from the various sciences. On the contrary, the various sciences consist of patches torn from the seamless robe of truth, which it is the object of General Science to present in its pristine unity, its natural integrity.¹²

And to the critics of General Science he said:

. . . outside the artificial atmosphere of the classroom, the specialist cannot keep to his speciality. As soon as he comes into contact with actuality, with real things and real problems, he will find that the sciences are all mixed up in every single thing; that he can not comprehend the flower in the crannied wall, all in all, by botany alone, but has to consider it in the light of chemistry, physics, geology, entomology, meteorology and anthropology. . . . All nature is one and we should

⁹Otis W. Caldwell, "Preliminary Report of the Committee on a Unified High School Science Course," School Science and Mathematics, XIV (February, 1914), 167.

¹⁰Victor H. Noll, "What about Integration in Science?" School Science and Mathematics, XLI (March, 1941), 242.

¹¹Edwin E. Slosson, "The Philosophy of General Science," School Science and Mathematics, XXV (January, 1925), 12.

¹²Ibid., p. 10.

never forget that in contemplating her various aspects as described in the several sciences.¹³

Despite objections from scientists and educators to its discontinuous organization, General Science has persisted to this day as the dominant ninth grade offering. Yet, in practice, "General Science is no more integration than mixing water and sand forms a compound."¹⁴

Beginning in about 1920 with the report of the Commission on the Reorganization of Secondary Education emphases in science education moved away from subject matter transmission for the exclusive later use of college preparatory students. Science was being conceived as having value for individuals regardless of their career interests or abilities. Teachers were being requested to develop appreciations of inner meanings, the inter-connections of things and the service of science to life and civilization. The committee on the Reorganization of Science in Secondary Schools, although not setting forth effected guidelines for the reorganization of content and method, did observe that "Neither in common life nor in research is the artificial stratification of the sciences maintained in solving problems."¹⁵

It was not until 1931 that a specific general education program for the teaching of science was proposed. Writers of the Thirty-first Yearbook of the National Society for the Study of Education set forth a plan whereby the life enrichment objectives of science education would

¹³ Ibid., p. 13.

¹⁴ Noll, op. cit., p. 244.

¹⁵ Commission on the Reorganization of Secondary Education, Reorganization of Science in Secondary Schools, United States Bureau of Education, Bulletin No. 26 (Washington: U.S. Government Printing Office, 1920), p. 16.

be realized through a subject matter organization that focused upon certain listed teachable generalizations. Such generalizations--distances in space seem vast when compared with distances on earth, or the sun is the earth's chief source of energy--differed from pure science generalizations in that they interpreted the natural world for the purposes of providing comprehensive knowledge and coordinated and humanized understandings of natural science.¹⁶

Many writers in response to the ideas as stated in the Thirty-first Yearbook quickly recognized that in order to organize science content and method around interpretive generalizations the separate science subjects as taught in the high school must be brought together. A small sampling of this expression follows:

The present differentiation of high school science into a large number of special science, Physics, Chemistry, Biology, Domestic Science, etc., is seriously questioned. Fundamental and thorough-going experimentation to develop new and broader groupings of subject matter which will cut across the present differentiated sciences is greatly needed and should be definitely undertaken whenever possible.¹⁷

Broad generalizations cannot be made if the individual's knowledge is to be isolated into logically organized subject matter fields, namely biology, chemistry and physics. The very interrelationship of the subjects themselves would tend to make such organization illogical. The need is for generalized courses cutting across all subject matter fields if the growth of the whole individual is attained, in the basic aspects of living.¹⁸

¹⁶Robert J. Havighurst, "Survey Courses in the Natural Sciences," The American Physics Teacher, III (September, 1935), 97-101.

¹⁷Raymond W. Osborne, "Report of Group Conference on Modernizing Our Secondary School Science," School, Science and Mathematics, XXXI (May, 1931), p. 608.

¹⁸Stanley Williamson, untitled manuscript descriptive of the science program of the University High School, University of Oregon during the late 1930's.

. . . this changing conception leads logically and naturally to the integration of the sciences. The maintenance of subject matter boundaries--water-tight compartments--is consistent with the earlier viewpoint (college preparation). The emphasis on use seems to me to carry with it a disregard for boundaries of chemistry, biology, physics, etc. as such, and to encourage the fusion and intermingling of all sciences as they add to our understanding of the world about us.¹⁹

Although the proponents of general education stormed the walls of the separate science subjects no general revolution occurred. In certain of the thirty schools participating in the Eight Year Study sponsored by the Progressive Education Association, science course sequences for all students were organized around areas of life needs and human relationships and drew materials from the physical and biological sciences.²⁰ Williamson described a four-year integrated science program developed for the University School at the University of Oregon during the late 1930's. The course titles for the ninth, tenth and eleventh grades respectively were, "Man's Relationship to His Natural Environment," "Man's Control and Use of His Natural Environment" and "Man's Place in a World of Sciences." During the twelfth year a project problems course, or "functional" chemistry or physics were available electives.²¹ However successful all such programs may have been, either World War II, college pressures, unpublished evaluations, or the dissolving of the school (as

¹⁹Noll, op. cit., p. 241.

²⁰Progressive Education Association, Publications Commission on the Relationship of School and College, Adventure in American Education, Vol. V: Thirty Schools Tell Their Story (New York: Harper and Brothers, 1943), p. 231.

²¹Stanley Williamson, Personal interview, Summer, 1960, and untitled manuscript descriptive of the science program of the University High School, University of Oregon during the late 1930's.

in the case of the University High School at the University of Oregon) the programs were discontinued.

The wall that separated physics from chemistry in the upper grades of high school began to crack early in the 1930's. By 1941 a very definite trend toward fusion was observable. The resulting course, currently most commonly titled Physical Science, acquired one of two general characteristics.

1. The course imparted practical information mainly to terminal students of lesser academic ability. Application was stressed in preference to theory with topics such as "City Water Supply" or "The Automobile" serving as central themes which pulled in appropriate science and technology content. Little to no laboratory work accompanied the year's work. Chemistry and Physics were also usually taught in the same school.

2. The course integrated in varying degrees, the theoretical contents of chemistry, physics and sometimes astronomy, geology or other physical sciences. Enrollments often included college preparatory students of high ability and substituted for chemistry and/or physics in one or two-year sequences.

Several research projects were carried out to determine the relative efficacies of Senior Science (1 above), Physical Science (2 above), physics and chemistry. Peterson discovered through the use of an instrument that mainly measured factual information:

Under controlled conditions in which intelligence quotient and chronological age were statistically equated, the physical science mean scores of students who had had one year of the fusion of Physics and Chemistry were significantly

higher than that of students who had had either 1 one year of traditional Physics, 2 one year of traditional Chemistry, 3 one year of Senior Science, or 4 one year of traditional Physics plus one year of traditional Chemistry.²²

Heidel discovered that the generalized Senior Science Course proved no less effective than high school Physics in teaching general facts and principles, and application of the principles after differences in mental ability and previous achievement were statistically equated.²³

Wise²⁴ and Miles²⁵ attempted to ascertain through literature and opinion research the most significant generalizations and activities respectively for the high school Physical Science Course. A survey study conducted by Ferguson revealed the dichotomous nature of the trend in fusion of physical science in the high school.²⁶

World War II was underway when most of the above mentioned research was reported. During the war the senior high school fusion courses were largely preempted by various kinds of preinduction courses.

²²Shailer Peterson, "The Evaluation of a One-Year Course, the Fusion of Physics and Chemistry, with other Physical Science," Science Education, XXIX (December, 1945), 263.

²³Robert H. Heidel, "A Comparison of the Outcomes of Instruction of the Conventional High School Physics Course and the Generalized High School Senior Science Course," Science Education, XXVIII (March, 1944), 89.

²⁴Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education," Science Education, XXV (December, 1941), 371-379.

²⁵Vaden Miles, Principles and Experiments for Courses of Integrated Physical Science (Ann Arbor: Edwards Brothers, 1950).

²⁶William C. Ferguson, "Instructional Problems of Generalized Science in the Senior High School," Science Education, XXIV (February, 1940), 72-75.

After the war the general education course reappeared and spread rapidly. However, in the post-war era the type of course that stressed the "understanding of major principles of physical science, rather than a knowledge of the technology of science"²⁷ dominated the scene.

Several factors may have contributed to the post-war shift towards a physical science course based upon the contents of traditional physics and chemistry: (1) the research studies, which reported favorably toward a subject-centered physical science; (2) the sensitivity of the nation to the need for scientific and technologic manpower; (3) the deemphasis of the need to relieve the human tensions of the economic depression; (4) the thoughtful analysis of what a physical science course should be at the secondary level; and (5) the return of expressed concern of scientists and college faculties as to what constitutes acceptable high school science preparation.

Among the wartime writers who argued strongly in favor of an integrated physical science in preference to Physics, Chemistry or forms of a problems of living centered approach was Hogg. He observed that the contents of Physics and Chemistry provided valuable general education that need not depend upon college for rounding off, that neither the traditional Physics to Chemistry, nor Chemistry to Physics sequences were educationally sound, that Physics and Chemistry were two aspects of the same science and were not convenient divisions for high school students, and that a two-year Physical Science sequence eliminated

²⁷Margaret J. McKibben, "The Study of New Development in Secondary Science--Grades 7-12," Science Education, XLV (December, 1961), 407.

many of the inherent difficulties of separate courses including overlap and repetition.²⁸

About the problems of everyday living chemistry courses Hogg expressed the increasingly heard sentiment about such courses in general. He said their offering

attempts to link up chemistry with everyday experience and avoids the more rigorous theoretical approach; it exploits the excitement inherent in the magic word chemistry. The danger is that the method may become an educational frill and form a veneer which hides the sterner stuff that develops the intellect.²⁹

Also during World War II faculty members of Harvard University stated a viewpoint regarding the relations of the discrete science to the broad field of science that may yet have some influence in preventing an eventually true integration of secondary school science. In response to proponents of a general unified science they said:

It is clear that important lines of thought and content interconnect the sciences with one another. Yet it must be added that despite their many interconnections and similarities, the individual sciences differ widely. These differences are not simply foisted upon us by the predilections of scientists.

In going from physics to chemistry, from chemistry to biology one crosses genuine hierarchial boundaries. The basis of consideration of the natural world changes, different frames of reference are involved. One either considers different things, or one considers the same things from wholly different standpoints.³⁰

²⁸John C. Hogg, "Science in Schools," Journal of Chemical Education, XXI (March, 1944), 131.

²⁹Ibid., p. 131.

³⁰Harvard University Faculty Committee, General Education in a Free Society (Cambridge, Massachusetts: Harvard University Press, 1946), p. 153.

The Harvard committee continued to maintain that a world naturally partitioned physically, biologically and chemically must be appropriately represented in the organization of general education science content. Although they approved of a "rigorous" one- or two-year sequence in physical science for terminal and propaedeutic students they clearly stated that an objective of such course work should be to segregate for the student the different points of view and approaches to science which are the basis of the divisions of science into separate disciplines.³¹

The prestige of Physical Science was increased as a result of a study carried out by Carleton at about the same time. He mailed to a sample of college admission offices copies of a Physical Science course outline he had developed, and requested that the course be evaluated in terms of its acceptability for entrance credit. He found that most colleges would accept the course without reservation. Reservations, expressed by at least one college, included a rejection of the thesis that Physical Science can do with Physics, Chemistry, etc. what Biology has done with Botany, Zoology, etc. Other reservations reflected concern over the lack of "rigor" and "meat" in generalized courses.³²

The trend toward integrated science studies in general education has not been limited to secondary schools. Few educators or scientists claim that the natural world of elementary school and junior high school

³¹Ibid., pp. 158-159.

³²Robert H. Carleton, "The Acceptability of Physical Science as a College Entrance Unit," Science Education, XXX (April, 1946), 127-131.

children is perceived in subdivisions of Physics, Chemistry and Biology. Rather, the things and events perceived by children that capture their interests and stimulate inquiry defy a subject-centered approach. Even Seeger who has written of his success in teaching physics in lower elementary grades rhetorically asks, "Is the study of a tree, biology, chemistry, physics or geology?"³³

Above the secondary school a great variety of general education science courses had been instituted since the 1930's either to be foundational for the science specialization to follow or to serve the needs of students not aiming towards careers in science. Such courses vary, especially in the degree to which they have been divorced from the restrictive boundaries of the separate subjects. At Moorehead State University a successful program, employing team teaching, developed through the cooperation of the total science faculty. In stating the rationale for this program Schwartz said:

Too many students complete the requirements for undergraduate degrees in chemistry, physics, biology, and other sciences failing to see the integration of science in a vast universe of interrelated living and non-living things. This course, *The Nature of Things*, recommended to all our students both science and non-science majors, is planned to develop the understanding of and give practice in scientific methodology and its open-minded, systematic and critical approach to problems; to provide perspective of the student's own place in an ever changing scientific world; and to help him see that chemistry, physics, biology and geology are very closely interwoven.³⁴

³³Raymond J. Seeger, "On General Science Courses," The Catholic Educational Review, LX (February, 1962), 91.

³⁴Donald Schwartz, "Fundamental Science Course: The Nature of Things," Science Education, XLV (October, 1961), 357-358.

The number of integrating general education science courses appears to be increasing. This is occurring despite the currents of claims that general education courses lack the discipline of scholarly work that characterizes the separate sciences and despite the difficulties of staffing interdisciplinary courses.

With general science education preceding and following the predominantly still specialized science organization of the high school there seemed little cause to challenge Hurd's prediction in 1953 that "within the next ten years one may expect high schools to teach Science I, II, III, and IV, rather than general science, biology, physics and chemistry."³⁵

However, enrollment and course offering figures for the succeeding decade did not seem to have supported Hurd's prediction. The traditional science subjects of Biology, Chemistry and Physics appeared to have become even more firmly established as the accepted sequence for senior high school. Earth Science, often as a ninth grade subject, gained in popularity.

The 1950's were not without curricular ferment, especially within the disciplines. Dissatisfactions were expressed with the way in which courses were handling the knowledge explosion. Under the flood of new information on top of old information students were failing to recognize unity even within one science area. In most instances for a science teacher to cover the old body of knowledge, the new knowledge (which often rendered the old knowledge invalid) was never encountered. Texts

³⁵Hurd, op. cit., p. 247.

and examinations were so encyclopedic the teaching of science as inquiry was often of secondary importance. The cold war intensified criticism directed at high school science and added a sense of urgency to the need for reorganization.

Beginning in 1956 with the original intention of developing a two-year integration of physics and chemistry,³⁶ the Physical Science Study Committee formulated a one-year course in physics that concentrated upon big ideas and the type of inquiry that led to those ideas. Subsequently parallel distillations and reformulations of content were conducted by the Chemistry projects, the Chemical Bond Approach, the Chemical Education Materials Study, and the Biology project, the Biological Science Curriculum Study.

At the time of this writing the secondary schools are feeling the impact of the new courses. It is therefore appropriate to anticipate and study the next saltation of the evolving secondary science curriculum.

II. A Rationale for a Unified Science Program

The Interdisciplinary Nature of Science

Viewed from a vantage point apart from any one of its many disciplines, science is seen as a single structure which represents man's search for an interpretation or an understanding of his environment. The major concepts and the processes of science interconnect the life, matter and energy study areas, and by their converging nature

³⁶Statement by Elbert P. Little, personal interview.

indicate that the ultimate goal of science is the production of a single series of theories on a cosmic scale to account for all phenomena.

This interdisciplinary view of science was observed by Rene Descartes when in 1629 he wrote:

And it must be believed that all things are so interconnected that it is much easier to learn them all together than to study each in isolation. Therefore, if someone wishes to make a serious investigation of the truths of nature, he should not choose some particular science, for they are all interconnected and interdependent.³⁷

And later in 1854 while the traditional science disciplines were rapidly diverging into academic compartments Herbert Spencer wrote:

Without further argument, it will, we think, be sufficiently clear that the sciences are none of them separately evolved--are none of them independent either logically or historically; but that all of them have, in a greater or less degree, required aid and reciprocated it. Indeed, it needs but to throw aside theses, and contemplate the mixed character of surrounding phenomena, to at once see that these notions of division and succession in the kinds of knowledge are none of them actually true but are simple scientific fictions; good, if regarded merely as aids to study; bad, if regarded as representing realities in Nature. No facts whatever are presented to our senses uncombined with other facts--no facts whatever but are in some degree disguised by accompanying facts: disguised in such a manner that all must be partially understood before any one can be understood.³⁸

Documentation of the desirability of thinking in terms of Unified Science is continued in the following written by Niels Bohr, whose monumental synthesis of the modern model of the atom gives him considerable stature among the creative scientists of all time:

Notwithstanding the admittedly practical necessity for most scientists to concentrate their efforts in special

³⁷Rene Descartes, Rules for the Direction of the Mind (Indianapolis: Bobbs-Merrill Company, 1961), p. 4.

³⁸Herbert Spencer, "The Genesis of Science," Recent Discussions in Science, Philosophy and Morals (New York: D. Appleton and Company, 1883), p. 225.

fields of research, science is, according to its aim of enlarging human understanding, essentially a unity.
 . . . history of science teaches us again and again how the extension of our knowledge may lead to the recognition of relations between formerly unconnected groups of phenomena. . . .³⁹

For the professional scientist the division of the physical world into discrete areas of study has been a convenience that has provided research avenues toward the end of viewing and comprehending the universe as a genuinely corporate whole. On the frontiers of knowledge today inquiry is being conducted by biochemists, physical chemists, biophysicists, physiological psychologists, geophysicists, etc., ad infinitum. The current rational universe image is without subject matter barriers: there are no inviolate disciplines, each with distinctive names, materials, principles, processes and problems.

The Current Fragmentation of School Science

Without denying the need for linear specialization, science educators today are still asking whether even for the future specialist, there is not great virtue in first presenting science as a unity of processes and products. Certainly, the general education school program for the citizen must aim toward as comprehensive an experience with science as possible.

The unity of science is not now visible to the majority of the population whose formally organized high school study is limited to Biology. Biology is important, but secondary to the literacy desired

³⁹Otto Neurath (editor-in-chief), International Encyclopedia of Unified Science (Chicago: University of Chicago Press, 1938), p. 28.

for the whole of the scientific enterprise. Without depth experiences in physics and chemistry a rational universe image for them is incomplete. Required General Science remains a disintegrated collection of topics, and the trend toward substituting Earth Science only provides a second isolated channel.

A student who has studied Biology, Chemistry and Physics has successively explored life, matter and energy of his environment. Depending upon his and his teacher's abilities he has cleared out the barrier between these special courses and discovered relationships that are basic to the whole of science. To leave the discovery of the relationships of science to chance is dangerous where an integrated image of the universe is esteemed.

If the current curriculum pattern of differentiated science subjects meets neither the needs of terminal nor propaedeutic students in terms of providing for scientific literacy, what alternate program can?

The Current Recognition of the Need for Program Development in Unified Science

The premise of this study is that high school science can better realize its objectives of providing a scientifically literate population and an inspired, well prepared group for college specialization through a sequential program determined and directed by the natural unity of science and the mental development of adolescents. A unified program should provide all students with depth and breadth in studies involving matter, energy, life and their intrinsic relations, regardless of the number of years students are enrolled in the sequence.

During the past five years specialists in physics, chemistry and biology, in separate convocations, have sorted through the burgeoning content of their respective areas and identified the solid cores of these disciplines. Appropriate knowledge and experience has been adapted for study by the high school student in each subject.

There is a strong feeling, even by those closely associated with the national curricular studies, that now is the time to explore ways of weaving the whole of science together into meaningful sequences. Paulson, Associate Director of the Course Content Improvement Section of the National Science Foundation wrote:

. . . we have considered that the first phase of work to improve the substance of high school courses had to be carried out within the framework of the traditional disciplines. It was necessary to get the chemistry, physics, etc., straight first in order to have a basis for a curriculum. Many of us feel that the second phase must direct itself to the re-examination of the relationships of topics among disciplines over a period of several years within the K-12 span. Now that new instructional materials are being created in each of the basic disciplines, it is felt that the time has come to begin to look at different ways in which these components might be set together in curricula.⁴⁰

Wareham, the science specialist for a textbook publishing company, predicted that Unified Science sequences were inevitable for the high school. He believed that with more teachers becoming familiar with the new curricula they had been acquiring attitudes and information that better prepared them to accept the ideas of integration.⁴¹

⁴⁰Letter from Richard E. Paulson to Irwin L. Slesnick, July 19, 1961.

⁴¹Letter from Richard T. Wareham to Irwin L. Slesnick, March 5, 1962.

Needless to document or say, the profession of education has felt that the time for integration of science processes and content has been ripe for at least fifty years. However, at the time of this writing this investigator knows of only three school systems that are developing Unified Science curricula.

The Current Model of the Learner

The task of creating a good Unified Science course sequence is formidable. The body of science must be held in one hand, the learner in the other. The task is to induce an integration in the latter with selected bits from the former. The bits are the structured pervasive themes--the generalizations or big ideas of science. The induction is provided by the method of teaching--the techniques employed by a teacher to provide a student with experience in the richest possible environment. The integration is the behavioral change evident in the student: integration is learning.

In older mechanistic or behavioristic psychologies learning is conceived as a series of stimulus-response bonds developed from situations contrived by teachers. Here the learner is a mosaic composed of independent parts without unity. Into his sponge of a mind are to be poured authoritative compendia of organized knowledge. The more he cries in pain the better the experience, since the mind is conceived to toughen in a manner analogous to the way callouses form on hands.

In organismic or gestalt psychology learning is a growth process resulting from the interaction of an undivided articulate whole organism

and a similarly unified environment. The learner grows three dimensionally by seeking satisfaction for his felt needs to become informed about how he relates to the physical world, and to gain proficiency in meeting the many faceted challenges in adapting to his social and physical surroundings.

The essential nature of human learning, to people who accept the gestalt model, may be described more specifically by such statements as the following:

1. Learning is an active, continuing process on the part of an individual. Each separate piece of learning, while it may very well at the moment appear to the learner as an end in itself, is in the long run only a step which influences the personality, the individual's self-concept, and his capacity for later learning. This influence may be either positive or negative; it is the responsibility of teachers to see that each step enhances the personality and facilitates next steps. This view of learning looks forward. (In contrast is the view which assumes that an act of learning is complete in itself and can be evaluated by testing the knowledge and skills presumed to have been learned.)

2. Learning is achieved by stressing the "act of discovery." Until an individual has learned something for himself it is not really his. (The opposite viewpoint teaches the child to memorize answers, generalizations and concepts developed by others.)

3. Learning is further achieved by freeing the human to synthesize. All humans have an instinct to explore; teaching is arousing and motivating this instinct and encouraging synthesis. In other words

fitting new knowledge into a conceptual framework is an extremely important part of learning. (When this is not accepted as basic to learning children either acquire a knowledge of unrelated facts which are unlikely to be retained or else are taught as absolute and final some organization which the teacher or the textbook has worked out, an organization which will surely need to be modified later, but which the learner has not been taught to handle critically.)

4. Cognitive development must honor the individual child's level of perception of himself and of his world. Learning raises the level of perception and understanding, but age, intelligence, and experiential background also are factors. (Where this is not recognized learning is likely to be mainly verbal and irrelevant to the individual.)

5. A child's perception is based upon his past experiences; it is further developed upon the extension of experiences; meaningful relationships are discovered when the child is encouraged to examine how these experiences are brought to bear upon each other and upon the present. (Teachers who are not sensitive to the perceptions of children tend to assume that it is the child's fault if he does not learn what they intended to teach.)

6. Emergent "open hypotheses" lead to continued inquiry and growth (as apposed to the stultifying effects of "closed hypotheses," jumping at conclusions before taking more things into account). To keep testing generalizations in light of new evidence and insights is essential if learning is to be continuous and self-corrective. (Teachers who do not accept this tend to deal in absolutes and to expect to reach final answers.)

7. The function of teaching is to initiate, stimulate, facilitate, and mediate. (The contrasting concept sees the teacher as the source of information and the final authority.)

8. A classroom social environment that is non-threatening frees the child to express himself fully without fear of recrimination or ridicule, and yet encourages him toward a growing awareness of social responsibility. Intellect cannot function freely if individuals feel themselves under pressure always to give "the right answer." The creative hunch and the flash of insight which may turn out to be an inspiration or a mistake need to be encouraged and respected--not necessarily accepted but considered worthy of examination. In such an environment children will learn to respect themselves and others, and to do the best thinking of which they are capable. (A threatening environment leads a child to conformity, withdrawal, or rebellion, and prevents him from seeing himself as a competent, self-directive individual.)

9. Expectations must be realistic in terms of a child's total environment; age, family, school, peers, and community. The child's own capacities, in terms of intellect, creativity, and physical strength and energy are important factors. No matter how "homogeneously" children are grouped the same performance cannot be expected of any two pupils. (The contrast to this is the belief that it is possible to create homogeneous groups, based on I.Q. and a limited number of other factors.)

10. The cliché that values are "caught not taught" is only partially true. Such values as respect, consideration, honesty, responsibility and good humor which the good teacher exemplifies in his relations with colleagues, with the class, and with individual pupils are

enormously important. Equally significant is his conscious teaching as he helps children learn how to be individuals who can work well alone or in a group. Such teaching can be done effectively only in terms of actual situations. The notion that preaching or precept will result in the learning of values is still widely held though it is unsupported by evidence. Literature, where the pupil identifies with a character in a book, can have a genuine influence on values, though usually less than the living experiences of the school. It is in the society of his peers that the child lives by and hammers out his values; as the school is a society in which the teacher can participate and guide it has an enormous opportunity to influence values. (The strictly controlled classroom under a teacher-dictator may be very orderly, and may foster certain values. It is questionable how much influence it can have on the values children bring with them.)⁴²

The mandate of modern psychology to increase efforts to fuse the whole individual with the whole of the physical environment was summarized by Williamson when he wrote:

In view of our new psychologies the organization of the science program into distinct subjects makes it too narrow in scope, and limits the development of adequate understandings of all life experiences found in one's environment. Broad generalizations cannot be made if the individual's knowledge is to be isolated into logically organized subject matter fields, namely biology, chemistry and physics. The very interrelationship of the subjects themselves would tend to make such

⁴²The Faculty of the University School, The Teaching-Learning Process--A Tentative Statement (Unpublished Study Committee Statement. Columbus: The Ohio State University, 1962).

organization illogical. The need is for generalized courses cutting across all subject matter fields if the growth of the "whole individual" is attained, in the basic aspects of living.⁴³

The Common Objectives of High School Science

The guidelines for achieving the above end are implicit in the general objectives of science education. A comprehensive review of objectives is not within the scope of this study. However, a synthesis of recent studies indicates a consensus that the goals of science teaching are--

1. To develop a logical and interrelated picture of the physical world through a mastery of facts, concepts and generalizations of science.
2. To develop ability to think critically and use, where applicable, methods of science.
3. To direct understandings, ways of thinking and appreciations toward their functional use in meeting the needs of the individual and society.
4. To develop appreciation, love, respect and reverence for the things and events that compose the environment.

The goals of Unified Science are no different from the goals now set for the subject-centered approach to the teaching of science. The comparative realization of the first above stated objective in a traditional and a unified science program is the task of this investigation. The objective is condensed to the phrase, a rational universe image.

⁴³Williamson, op. cit., p. 8.

III. The Features of a Rational Universe Image

When a student studies science he encounters things and events, phenomena, that when assimilated are held in the mind and create for him a picture of the universe as a whole. This conception of environment has many characteristics including dimensions, cohesion, growing edges, clarity, and relationship to the images of self and society. The fullness of the image is determined by age, mental ability, interest, motivation and experience. The degree to which a science program presents through experience the real world, should determine to some measure the nature of the image held by the student.

To explicate a rational universe image the investigator has identified several features of the image which he believed are measurable through objective testing and which a Unified Science program can better realize. In the following five paragraphs a feature of the rational universe image is identified and illustrated.

1. Phenomena reflect the interdependencies and interactions of matter, energy and life. The origin of species through natural selection occurs when traits, determined by physically mutable chemical compounds, genes, are passed on by chance through sexual reproduction in plants and animals that are in turn selected for survival by a continually changing physical environment. The phenomenon is evolution, traditionally, biological, but truly an integration of matter-energy reactions in the site of living organisms that must adapt to matter-energy reactions in an external environment.

2. The forms of matter, energy and life reveal a natural orderliness. Ordinary matter as observed on the earth's surface, in meteors, in stars, or in the tissues of a living dog consists of some of the same nearly one hundred elements that are organized in the periodic table. Similarly, forms of energy can be traced to a spectrum of electromagnetic radiation, and forms of life to pre-existing forms of life that by convergence makes up the phylogenetic tree of life.

3. Things and events are perceived in accurate relative in relation to time and space. The time required for continental glaciers to form, carve valleys and melt is much longer than the life span of any animal or the time required for the earth to revolve around the sun, but is much shorter than the half life of Uranium 238 or the time required for the earth to revolve around the center of the Milky Way.

4. Real problems in controlling, predicting and interpreting events in the universe transcend single disciplines. The design of a space suit for surface exploration on the moon requires knowledge from the specialized branches of physics, chemistry and biology. Non-technological problems as in the search for an explanation of why the moon appears larger on the horizon than when high in the sky are also not in the bailiwicks of any one of the classical sciences.

5. Man's relationship with his universe, as an observer and as a part of the "web" is perceived realistically. Man is an organism physiologically and anatomically not unique among animals. He conforms to the same basic physical laws as do all organisms. His adaptive advantage is a highly developed nervous system which enables him to

control and symbolically interpret his environment better than any animal has apparently done in the past. Man's ancestors were also ancestors of today's gibbons, goats, snakes, insects, ameba, and oak trees.

IV. The Social Impact of a Rational Universe Image

The convenience of treating science as though it were one body of knowledge and method that exists apart from the human intellect is a dangerous trap. For it then becomes easy to postulate that the sole task of the educator is to incorporate into the mind of the learner enough of the essence of science to effect an alliance. The test of the effectiveness of the teaching of science then would be the mere examination of how well the science that reradiates from the learner's mind matches the model that originated it.

Science is the light that generates in the human intellect as a result of the stimulation of things and events in the natural world. Science is not the light that shines upon the brain and is then reflected back upon itself. The teacher contrives to generate science in the learner by confronting the learner with ideas and materials that tend to expand and deepen existing percepts of the universe. When the ideas and materials are freed from the restrictive and artificial subject matter boundaries, the learner is then also freed to create his own science.

The learner creates science in the same manner scientists extend their understandings of the natural world. In fact, in order to learn science the student must himself become a scientist. Although young learners may differ considerably from scientists with regard to the

extent of their knowledge and the sophistication of their methods of inquiry, the similarities in procedures are striking. To initiate the learning process each must be motivated--the problem for study must be real and meaningful. To define his problem each must maintain close sensory contact with it. To solve the problem and extend his understanding each suspends judgments, controls the environment, observes carefully and then makes inference based upon test results. There is no substitute for wide-eyed submergence into the real world. Reading and listening are unquestionably important ways of gaining contact with the unknown. Yet the self-discovery that results from direct experience becomes an indelible portion of the rational universe image.

The learner's science manifests itself as behavior under the guidance of his image of the natural world and the experience acquired in formulating that image. The rational universe image is a reference point from which stems behavior influenced by science. It is no more science than the photograph of a mountain is a mountain. However, the rational universe image has the capacity to reveal the personal science of the individual just as the photograph can reveal much about the mountain.

The image of the natural world gained informally through everyday activities and gained formally through the vehicle of a science curriculum is of no value whatever unless it be translated by the individual into purposeful social behavior.

Many of the major problems of social concern today are results of the scientific revolution. Examples of such problems include population expansion, threat of nuclear war and great disparities in the

distribution of wealth. These problems are by-products of blessings. By gaining increasing control over the natural world, man has used his science to create the affluence we enjoy. Science is credited primarily with having maximized the pursuit of happiness, extended the span of life and made life possible for a large population. The problems that have accompanied these blessings need to be solved if the blessings are to continue. As in the analogy, the causes of cancer are also cures of cancer, the social problems that originate in science must also be solved with the science that created them.

However, social problems are not solved by one brilliant and creative individual nor by a small group of inspired intellectuals. Rather, social change is effected only after the tide of individuals within a society effect the change themselves. The problem of inter-racial hatred cannot be solved by the brotherhood of a few. Nor is any social problem the exclusive responsibility of any one of the areas of human study. The population problem must be solved by all individuals whose behaviors are directed by a literacy in the areas of learning that collectively compose general education.

It is inconceivable that effective citizenship can exist without the assimilation of science in breadth and depth into the whole of the mental experience of all individuals. The learner of science must be taught in the light of the goal of achieving patterns of behavior that meet the present and future needs of society and the individual.

The problems of youth are not always the problems of the adults of a society. However, the areas of learning that impinge upon youth and adult needs are the same. There are few, if any, areas of social

concern in which a rational universe image cannot contribute guidance for solution.

One concern common to youth beginning in the middle adolescent period is the problem of choosing a career.⁴⁴ To fully explore the vocational possibilities, the field of science cannot be omitted. The career opportunities in science are extensive. By exploring science in a unified context the adolescent would note that no career is an island. Each career however far removed from careers in pure science, be it housewife, salesman, politician, plumber or farmer, is rooted with the application of knowledge, skills, values, and attitudes of science. The science experience provides something more than a choice. It provides knowledge and method for selecting from among other alternate careers.

Similarly the science of the individual directs decisions in making friends, planning leisure time activities, buying a car, taking a political stand, and planning and raising a family. The whole of science permeates the whole of life from birth to death, and the whole of social history from generation to generation.

V. Limitations of Previous Studies

A search of the literature has revealed (1) no sequence of Unified Science courses for the high school has been developed that exploits as pervasive themes major generalizations of science, (2) no instrument has been utilized or constructed to measure a rational universe image.

⁴⁴The Faculty of the University School, How Children Develop (Columbus: The Ohio State University), p. 63.

This is not to deny the valuable contributions of the many secondary school curriculum workers whose efforts during the past sixty years have resulted in such innovations as general science, biology, senior science and physical science. The guidelines set forth in the Thirty-first Yearbook of the National Society for the Study of Education, the several reported sequences of science courses structured around everyday problems of living, and the increasing number of Unified Sciences offerings available for general education at the college level certainly aid efforts to develop a high school Unified Science program. Nor can it be claimed that measurement of features of a rational universe image have never been sought by test constructors. In fact, many items in published science tests would have been appropriate for inclusion in the treatment test employed in this study.

VI. Summary

Despite an approximately fifty-year history of efforts to unify the content of science in the secondary school, the pattern of the curriculum remains subject centered. However, science educators, with increasing support from scientists, are predicting that course content will soon reflect the natural integrality of science. There exists in the literature of the day a mandate to develop pilot programs in sequential Unified Science. Such programs will disregard the artificial boundaries of the disciplines and will build upon the major generalizations of science. The internalization of a content and method presented

in such a manner should yield for the individual an image of the universe of greater scope than has been realized by traditional approaches. Although the rational universe images of students are believed to be measurable, the true value of the image to the individual does not manifest itself until it is translated into social behavior.

CHAPTER III

THE UNIFIED SCIENCE PROGRAM AT THE OHIO STATE UNIVERSITY SCHOOL

The units and sequence of presentation that had been elaborated for a unified four-year science program were worked out to meet the conditions in the University School at The Ohio State University. It is therefore desirable to relate aspects of the school, its student population and facilities as they pertained to the developing program. The Unified Science program is then described under headings of development and structure.

I. The Setting for the Pilot Study

The University School. The University School is an experimental school, a department of the College of Education, functioning in a manner parallel to the role of a university hospital as related to a college of medicine. The staff of the school includes permanent personnel and faculty shared with other campus departments. Within the Department of University Schools is the Center for School Experimentation, a departmental division primarily engaged in coordinating joint research studies carried out in the University School and in affiliated public schools. Educational research carried out with students in the school has been usually sponsored and field tested by the Center for School Experimentation.

The program in Unified Science has been developed by a team of teachers in the University School, the staff of the Center for School Experimentation and advisers and consultants from the faculties of departments of science, education and psychology of Ohio State and other universities. After one kind of Unified Science program has been developed, tests of its applicability to various schools and school populations would reasonably be made through the sponsorship of the Center for School Experimentation.

Students and faculty. The kindergarten through twelfth grade enrollment of the University School has been approximately four hundred, of whom approximately one hundred thirty-five have been in grades nine through twelve. Efforts had been made to select and admit from the many applications, students who would contribute to a racial, religious, socioeconomic, boy-girl, behavioral and mental ability balance to the school. However, because of such factors as tuition, a sampling of a random population has not been achieved. The median intelligence quotient of students has ranged from 125 to 129 (Binet) in a generally bimodal distribution. Over ninety per cent of the graduates of the school have attended college.

The atmosphere of the school has been permissive. In the democratic tradition the individual has been granted many opportunities for intelligent decision making. This condition should not be confused with the situation at the stereotyped progressive school, where the limits of choice and behavior extend beyond manageable levels. To illustrate, progress reports have been written in lieu of grades, and in courses (including science) teacher and students together have planned specific

study about a superstructure of preplanned content. One result of this educational philosophy in practice has been that the responsibility for learning shifts from teacher to student. By the time students reach high school they are often well versed in independent and self-directed study.

The student-faculty ratio in the University School has been approximately eleven to one. There was one teacher of science for grades kindergarten through six, and two for grades seven through twelve throughout the period of the reported study. Both upper school science teachers (primary developers of the Unified Science program) had had over five years of science teaching experience in large and small public schools. Each had formally studied and taught established biological and physical science subjects.

Science, kindergarten through grade eight. The elementary science program had been structured to spiralling science concepts and provided students with depth and diverse experiences. Junior high school (grades seven and eight) science was part of the daily three hour block core program. Three of the six broad problem areas studied during the two years focused upon the area of science and had included: "Understanding My Body," "Outdoor Education" and "Problems in Space Travel." The Unified Science program for grades nine through twelve articulated with this foundation.

Problems of adapting a Unified Science program to the University School. The high school program in science had to meet a wide range of student needs in one course, since school size usually prevented there

being more than one science class at any grade level. Also, work at each grade level needed to be flexible enough to challenge and interest students within broader than usual spectra of ability and motivation. Although the students and their parents expected many phases of the curriculum of the University School to be "experimental," they did demand that these school innovations in program maintain a quality that enabled articulation with college study.

Before the program in Unified Science was initiated in 1959, parents and students were assured that the content of Unified Science would contain the subject matter cores of Biology, Chemistry and Physics. However, it was conceded that the traditional College Board Examination areas could not be chosen with mastery confidence during the junior year. The hope was expressed that the realized objectives of an integrated science program would increase science understandings, better achieve educational values and more fully meet the felt needs of the students.

The facilities and equipment of the University School had, in part, molded a pattern for the Unified Science program. The school plant was planned and constructed during the early 1930's. The three science rooms were rigidly built for Chemistry, Biology and Physics classes. Although the Physics room was later adapted to also serve general education classes, little had been done to change the Chemistry and Biology laboratory-classrooms to multipurpose functions. Similarly, the Unified Science program had been developed while utilizing a legacy of traditional demonstration and laboratory equipment and textbooks, augmented by an annual budget of nine hundred dollars. These physical

restrictions had limited the scope of exploration in activities in Unified Science, and in some instances severely hampered the laboratory development of major science generalizations in a unified context. The standards of the University School library far exceeded the minimum American Library Association recommendations. There were over one thousand science books and subscriptions were maintained with ten science periodicals. These figures do not include textbooks, paper backs and a departmental library with several hundred books on advanced subjects.

II. The Program

The Study Committee and Its Work

During the academic year 1958-1959 members of the science faculty of the University School assembled weekly for purposes of assessing the current University School science program and exploring areas for research appropriate to the times, the school and the Center for School Experimentation. The committee included Alexander Frazier, Chairman of the Department of University Schools and Director of the Center for School Experimentation, Lewis Evans, elementary science consultant, Sylvan Mickelson, science teacher, Irwin L. Slesnick, science teacher, Adrian Stilson, core and science teacher, and William Williams, core and science teacher. John S. Richardson, Department of Education, and Alfred Garrett, Department of Chemistry, aided the committee in consulting roles.

After several months of study and discussion the committee chose as one of its projects the development of a program in Unified Science

for grades nine through twelve. To represent their image of the structure of science as it might be presented, a cube was constructed to illustrate the three-dimensional growth of students experiencing Unified Science. The chart (revised to reflect the most recent image) appears as Figure 1.

In this structure, one dimension represents the diversity of integers with which the science students work. Of course, all integers cannot be listed since there are, for example, some two million animals, over 100 elements, 700,000 compounds, and an infinite number of manifestations under various kinds of energy. Each integer occupies a segment of the box extending from front to back and from bottom to top.

The second dimension--shown as stories--represents the main topics of study in order of their appearance. Thus integers in a vertical segment can be studied in terms of Natural Schemes of Orderliness, The Star and so on. The topics actually are explicit "big ideas" which at a given locus were explored in depth.

Permeating the whole box--and represented by the dimension extending from side to side and from base to top--are the methods of inquiry. These methods can be applied through teaching techniques, both manipulative and theoretical.

Superimposing this structure upon the four-year high school sequence made possible the reorganization shown in Figure II.

Note in Figure 2 that Unified Science I and II were required of all ninth and tenth grade pupils respectively. Unified Science III and IV being elective, enrolled a decreasing percentage of eleventh and twelfth graders respectively. For those of the eleventh and twelfth

Figure 1

Content and Method Relationships for a
 Four-Year Unified Science Program

COURSE TITLE	ENROLLMENT	MATTER	LIFE	ENERGY	
Unified Science I	9th Grade 100%	Classification of Elements (Periodic Law) Meteorology	Classification of Organisms (Phylogenetic Trees) The Star Solar-Earth Processes	Classification of Radiant Energy (Spectrum of Electro- magnetic Radiation) Photosynthesis research	
Unified Science II	10th Grade 100%	Organism as an open dynamic system Reaction Chemistry--Respiration: Nerve physiology--Electricity Physical and Organic Evolution			Research
Unified Science III*	11th Grade 86%	Models	Human Senses	Quantification RESEARCH	
Unified Science IV*	12th Grade 78%	Equilibrium			Fields R E S E A R C H

* Proposed alternate course in arts areas for students with interests and aptitudes in such technology areas as: photography, electronics, mechanics.

Figure 2

Grade Level Layout of Four-Year Unified Science Program

grades not choosing science but desiring course work in cognate technological areas provision was made for such a course--to have been taught mainly by related arts personnel.

The topics appear horizontally at grade level, cutting across the integers useful in their development. The relative emphasis of self-directed inquiry is depicted by the size of the letters in "research."

The committee predicted the following advantages for the program:

1. Students would continuously experience the internal coherence of science through this integrated organization.
2. Each year would provide an end point for students with specified capacities and interests.
3. Vertical studies in energy, matter and life would permit a "readiness" for new concepts and preclude the lying dormant of previous learnings.
4. It should be possible to include more content since overlap and duplication would be avoided.
5. Theory and application would be closely mingled.

The Working Schedule

After drafting a prospectus for a four-year sequence in Unified Science and a general plan for its assimilation into the on-going secondary school program at the University School, the plan was submitted to the administration and faculty for approval. The science staff was then authorized to initiate the program beginning with the ninth grade in the 1959-1960 school year.

The primary responsibility for course development in Unified Science I and II was given to the investigator. Later in 1960, Mr. Victor Showalter assumed the parallel task for Unified Science III and IV. Specialists in science and education from the Ohio State University and other institutions were contacted by correspondence or personal interview to determine their predispositions toward the project and willingness to aid in the identification and review of unifying themes, specific content and methods.

In the fall of 1959 Unified Science I was instituted for all ninth graders. The fifty-five minute class replaced one of three hours of the Core class that had had primary responsibilities for science teaching at this grade level. The following year the second course of the sequence, Unified Science II, replaced elective biology but was required for all sophomores. In 1961-1962, elective Unified Science III replaced chemistry, and in 1962-1963 elective Unified Science IV supplanted physics. Since there was no apparent need nor demand for a science-technology course for the eleventh and twelfth grades, the course had not been initiated as of the Fall Quarter of 1962.

Prior to the teaching of each year's course a detailed outline of content and method was prepared. While the course was being taught this outline was modified when aspects of it appeared adaptable or unadaptable for classroom use or when the study did not articulate well with previous or subsequent work, or when the work became inappropriate in terms of the ever changing broad picture of the program, as indicated in Figures 1 and 2.

Unified Science I. The overriding purpose of Unified Science I has been to organize content and methods in such a way that students would discover the basic assumption that the universe is orderly and understandable: that the things and events that constitute man's environment are fundamentally interrelated; that matter, energy and life forms can be differentiated, grouped, and resolved into systems of natural classification which are the "filing cabinets" of science; and that the very interrelatedness and intrarelatedness of these components of the universe spell out the generalizations of nature.

The structure of Unified Science I led students to discover inductively and deductively that matter in the form of chemical elements, energy in the form of electromagnetic radiation and life in the form of species of plants and animals can be classified naturally on the bases of properties and ordered into periodic tables, spectra of electromagnetic radiation and phylogenetic trees of life.

Having grasped the idea of orderliness of the universe in terms of component entities, students were guided toward the discovery of generalizations in natural phenomena. A depth study of the sun, its structure, motion, position in the universe, past history and future, composition, nuclear reactions, etc. are topical studies that related matter to energy and led to such concepts as conservation of matter and energy, matter-energy equivalence, entropy, universal gravitation.

The specific relationships of the sun to earth processes was then thoroughly explored. A unit study borrowing heavily from meteorology and geology illustrated how energy from the sun interacts with the water, land and air of the earth producing weather and geological changes. A

second unit borrowing heavily from botany and chemistry illustrated how plants synthesize energy-containing compounds in the process of photosynthesis. The picture of the earth as a physical and biological stopgap in the cascade of energy was thus ideally created.

Unified Science II. The second year of the sequence had been organized around the depth study of three generalizations for which, again, previous study contributed concepts and facts and to which subsequent studies of the sequence added enlarging experiences. These themes were (1) The Organism As an Open Dynamic System, (2) Scientific Inquiry and Electricity, and (3) Facts and Mechanisms of Physical and Organic Change.

The first unit began with an intensive month-long study of the anatomy and physiology of the common earthworm. The organism was viewed as a special organization of matter through which energy degrades. The various properties of life were examined in terms of the specific anatomical and physiological adaptations. The life process of respiration was studied in considerable detail, with diffusion, reaction chemistry, catalysis and calorimetry being as much a part of the study as in the biological description of the process.

Articulating with the organism unit was a study that began with the reading and analysis of an expanded version of Frogs and Batteries.⁴⁵ Here students experienced the discoveries of early physicists, biologists and chemists as they sought the sources of animal electricity. On the

⁴⁵Leo E. Klopfer, The History of Science Cases for High Schools: Frogs and Batteries (Middleton, Connecticut: Department of School Services and Publications, Wesleyan University), 1960.

modern scene they continued to see that nerve physiology is a correlation of depth physics and chemistry in the site of an organism. Work in electrochemistry, static and current electricity, nerve physiology and electro-technology were actually secondary to the objective of, reading about and discussing and then directly engaging in, scientific inquiry. A large block of class time was given over to the identification and solution of individual science problems. The kinds of problems worked with and the general procedures are presented in the publication, Ideas for Science Projects.⁴⁶ For example, one left-handed student chose to investigate why boomerangs were reportedly practical only for right-hand throwing. Another student tested the hypothesis that the life span of fruit flies could be increased were they subjected to increased gravitational forces for extended periods of time.

The third unit exploited the concomitance of geologic and organic evolution. Through considerable field, laboratory and library study the student was led to recognize that the earth is changing, has changed, and will change, and that in adapting to a changing environment organisms change and become new species. The mechanisms of change expanded concepts of weathering and erosion, diastrophism, reproduction and genetics. The unit concluded with consideration of science-social problem areas such as conservation and eugenics.

⁴⁶National Science Teachers Association, Ideas for Science Projects, Washington, D. C., 1962.

Unified Science III. The elective course in the sequence for eleventh graders also focused upon three major themes. These were (1) Quantification, (2) The Human Senses, and (3) Models.

The quantification unit was centered on kinematics and dynamics as treated by the Physics course developed by the Physical Science Study Committee. In addition to the considerations of fundamental, derived and abstract quantifications, which are largely Physics, a quantified mole concept, and the role of measurement in the study of life processes were integral parts of the unit. The knowledge, and understanding, resulting from the study were foundational to subsequent study. Yet, an explicit objective was to lead the student to the discovery that the more sophisticated image of science is a quantified one, and that as a science becomes mature its data can better be communicated with number symbols.

In the second unit the student studied the reception of light, chemical, sound and other stimuli which enable man to perceive and then interpret and control his environment. Each sense was explored broadly. For example, content related to the light sense included light sources, optics, photochemistry, biological effects, gross anatomy, etc. The growth of man's understanding of the universe was related to his history of ability to extend his senses beyond the biological limits. In this unit as in other units students were encouraged to carry out sustained and individual research projects dealing with such problem areas as thresholds, extra-sensory perception, and pH measurements.

The utility in science of creating models was illustrated in the third unit of Unified Science III. Examples included the particulate and wave models of light, the Bohr atom and the electron configuration of atoms, gravitational and magnetic fields, and the behaviorist and gestalt models of the organism. Special emphases were given to the tentativeness of any scientific model; as knowledge increases through research, models are revised or discarded.

Unified Science IV. The content of Unified Science IV continued to be organized about unifying themes. However, the details of this course are not relevant to the reported study and are presented only in the Appendix A.

III. Unique Features of the Program

Schedule. With the exception of Unified Science I and II during the school year 1961-1962, science classes met fifty-five minutes each day, five days each week throughout the approximately 165-day school year. During 1961-1962 the ninth and tenth grade had science four hours each week. Two of the four meeting hours were consecutive to test the values of such an extended time block.

The schedule for 1962-1963 appears as Figure 3. Note that Unified Science I met four days each week while Unified Science II, III and IV met five days each week.

Special activities. The science curriculum at the University School had features that tended to be unique from the usual public school curriculum and that had been developed independently of the

9	10	11	12
8:40 (A) Sec. St. (Core) Stilson - 204 <u>OR</u> (B) Unif. Science I - 315 - Schwirian W. Music in Humanities - Rm. 100; Orch.	8:40 Sec. St. (Core) - 303 - Buchanan	8:40 Eng. Seminar - 212 - Bateman - M.W.F. Eng. Workshop - 302 - Willis - M.W.F. U. S. Hist. - 311 - Ballinger - M.W.Th.F. Core - 302 Willis - T. Th.	8:40 Core - 311 Slesnick - T.
(B) Sec. St. (Core) Ballinger - 205 <u>OR</u> (A) Unif. Science I - 315 - Schwirian W. Vocal Music - 100 & Elem. Plym; Orch.	9:35 English - 303 Bateman	9:35 Core - 302 Willis	9:35 Core - 311 Slesnick
10:30 English (A) Craig - 1 (B) Stewart - 205 Class Meeting W.	10:30 Unif. Science II - 313 & 315 - Slesnick	10:30 French II - 213 - Hatfield Spanish II - 212 - Woodruff U. S. History - 302 - Buchanan	Unif. Science IV - 311 - Showalter
Lunch 11:35-12:15 For. Lang. 12:20-12:50 302- Hatfield 303- Woodruff	11:30 Spanish I - 212 - Allen French 10 - 204 - Woodruff	11:30 Unified Science III - 311 - Showalter World History - 302 - Willis	11:30 Adv. H.S. Math - 213 - Tharp Gen. H.S. Math - 303 - Stilson
1:00 1st sem. 2nd sem. (A) Math Typing 204 Rm. 7 Hoburg Jennings (B) Typing Math - 204 - Rm. 7 Alberty Jennings	12:30 Lunch 1:00 Int. H.S. Math - 303 - Stilson	1:00 Adv. H. S. Math - 302 - Craig Nature of Proof - 212 - Tharp World Cultures - 210 - Buchanan	Lunch French III & Spanish III - 305 - Woodruff & Urrutibeheity English Workshop - 400 - Bateman (cl.)
2:00 Physical Education Orch. F.	Instrumental Music - Recreation Room - Hightshoe Vocal Music Ensembles - Rm. 100 - Tolbert Dance - Gym - Mooney Home Arts - 305 - Brotherton	Art - 117 - 188 - Orr & Hoffman	Publications F.
(A) Art Math - 204 - Hoburg	Physical Education Art		Publications F.
(B) Math 204 - Art Alberty			

Figure 3
University High School Schedule 1962-1963

Unified Science influence. The ninth grade had taken each year throughout the developmental period a four-day science field trip to Chicago; the majority of the tenth grade on alternate years had attended an optional two- to three-day Geology field trip throughout southwestern Ohio; all classes had made considerable use of the museums and research facilities on The Ohio State University campus; students were frequently involved in research projects (Unified Science II in 1960-1961 functioned in the experimental group on the project "Use of Case Histories in the Development of Student Understanding of Science and Scientists" sponsored by the Graduate School of Education, Harvard University), or service functions in educational ventures.

III. Summary

A sequential program in Unified Science for grades nine through twelve has been under development since 1958 in the laboratory school of The Ohio State University. The primary developers of the program have been the members of the science area staff of the school. Considerable guidance in the selection of content and methods that have been structured around major generalizations of science has come from science educators and scientists, mainly from Ohio State University. The specific features of the program as they manifest themselves in the classroom have departed from the idealized model where compromise with facilities, nature of the student population and time pressures have reshaped them. However, the basic premises on which the ideas of Unified Science are based have not changed since classroom development and testing began.

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Each year, starting with the 1959-1960 school year, one of the conventional science courses had been replaced with a segment of the Unified Science curriculum. Thus, Unified Science I was introduced in the ninth grade. Unified Science II replaced Biology. Unified Science III replaced Chemistry and for the school year 1962-1963, Unified Science IV replaced Physics. Unified Science I and II have been required courses for all freshmen and sophomores, while Unified Science III and IV have been elective courses.

The reported study is an attempt to determine the presence and magnitude of an enlarged rational universe image among matched pairs of science students who have experienced one, two and three years of sequential conventional and Unified Science course work.

CHAPTER IV

METHODS AND MATERIALS USED PREPARATORY TO TESTING THE MAIN HYPOTHESIS

To have merely developed and effected a sequential program in Unified Science certainly does not satisfy the stated need. Evaluation is necessary. Nor do intuitive judgments based upon qualitative observations fulfill the requirement to evaluate the program. The rationale of Unified Science claims that such a content reorganization realizes objectives of science education better than the best of the traditional designs. Where these objectives are measurable, Unified Science must be subjected to quantitative evaluation.

The "volumes" of rational universe images lend themselves to measurement by an instrument. Described below are the techniques by which two populations of ninth, tenth and eleventh graders, one having experienced an adjudged excellent program in subject-centered science and one having experienced a program in Unified Science, were matched in an experiment that tested for mean value differences of a rational universe image criterion variable. The development of the treatment instrument is described in Chapter V.

I. The Main Hypothesis and Subordinate Questions

The main hypothesis, stated in null form, was: There are no significant differences between the rational universe images of students who had studied Unified Science and the rational universe images of students who had studied science in a subject-centered content.

A complete exploration of the efficacy of Unified Science in realizing the objective of a rational universe image suggested the following subordinate questions.

1. Was the Unified Science program more effective at one grade level than at other grade levels?
2. Was the Unified Science program more effective at one specific mental ability level than at other specific mental ability levels?
3. Was the Unified Science program more effective at one specific science achievement level than at other science achievement levels?
4. Was the Unified Science program as effective for boys as it was for girls?
5. Was the Unified Science program equally effective when compared with an Earth Science, Biology, Chemistry sequence and a General Science, Biology, Chemistry sequence?
6. Was Unified Science differentially effective for combinations of two or more level variables?
7. Was Unified Science equally effective in teaching for each of the five features of a rational universe image?

8. Was Unified Science differentially effective at levels or combinations of levels for any one or combinations of the five features of a rational universe image?

II. The Experimental Design

The appropriate experimental design indicated was a treatment by levels with one observation per matched pair. Students of the ninth, tenth, and eleventh grades, whose high school science had included only Unified Science, were to be matched with students whose high school science had included only a sequence of subject-centered science courses. Students were to be individually matched on the bases of measurable and relevant characteristics. The integrity of the paired measure was to be maintained so that subordinate questions of the main hypothesis could be asked at the various levels, at combinations of levels and at all levels combined.

Levels

The levels included those characteristics that were used as criteria in obtaining individually matched pairs and those characteristics which tended to equate the student bodies of the two schools from which the control and experimental groups were to be selected. Levels included the variables: mental ability, age, past academic performance in science, and the non-ordered categories: sex, grade, and years of sequential science from the ninth grade. Less tangible qualities of instruction, socioeconomic backgrounds and school facilities were imposed upon the criteria used in selecting the school from which the control group would be selected.

Levels Instruments

1. The Otis Quick Scoring Mental Ability Tests: New Edition Gamma Test: Form Em (1959)⁴⁷ ascertained mental ability, age, grade, and sex.
2. School records provided measures of previous academic achievement in science, information on sequential science since the ninth grade and checks on age, grade and sex.
3. Authorities and the records of the Ohio State Department of Education provided information and opinions regarding the preparation and qualities of instruction and the equalities of the communities of the schools involved.

Treatment

One member of each matched pair experienced the experimental treatment, a program in Unified Science. The other member of the matched pair experienced a program in subject-centered science. Each pair was symbolized by a numeral; the member who received the treatment was designated by the symbol, a, and the member who experienced subject-centered science was designated by the symbol, b. Thus 32b refers to that member of matched pair 32 who experienced subject-centered science. Matched individuals who experienced Unified Science were referred to as the treatment group or the experimental group, symbolized, group A. Matched individuals who experienced subject-centered science were referred to as the control group, symbolized, group B.

⁴⁷Published by World Book Company, Yonkers-on-Hudson, New York.

Group A had had only Unified Science I and were late ninth grade pupils, or only Unified Science I and II and were late tenth grade pupils, or only Unified Science I, II, and III and were late eleventh grade pupils. (A fourth treatment group characterized by having had Unified Science I and II as ninth and tenth grade pupils and were late eleventh grade pupils at the time of testing, were not matched.) Group B paralleled group A, except the science course work sequence was Earth Science or Physical Science (General Science) in the ninth grade, Biology in the tenth grade and Chemistry in the eleventh grade.

Treatment Instrument

The treatment instrument is a test that purports to measure a rational universe image. In the form in which it was employed in the reported study, it was a 65 five-item multiple-choice test. It was administered to all potential members of the experimental and control groups within one day of the administration of the Otis Mental Ability Test.

III. General Procedures in Obtaining Matched Pairs

The first step in obtaining matched pairs was to construct a profile of the experimental group (A). A survey of University School records revealed that during the three-year period 1959-1962 one hundred eighteen students had experienced at least one year of Unified Science. Imposed upon this group described in Table I, was the selective criterion of having experienced a sequence of Unified Science available and/or

required of them throughout the period 1959-1962. Note that all eleven twelfth graders were unqualified since none had Unified Science I and II. Among 1961-1962 eleventh graders, three with Unified Science I, eight with Unified Science I and II and twenty-three with Unified Science I, II and III met the criterion. Among 1961-1962 tenth graders, two with Unified Science I and thirty with Unified Science I and II met the criterion. All ninth graders qualified.

Two more restrictions were imposed upon the resulting ninety-four students: (1) They were not to have taken any other kind of science course since the ninth grade and (2) they were to have been available in May, 1962 for levels and treatments testing. This selection eliminated the five eleventh and tenth graders who experienced only Science I, and two of the eleventh graders who experienced Unified Science I and II. The size of the potential experimental group was reduced to eighty-seven.

Table II describes the population for which a match was sought in terms of grade level, high school science background, sex and approximate median IQ.

Selection of a control school. The decision was made to secure matches for the Unified Science group from one large high school that included grades nine through twelve. In this way the controlled group would have experienced a fairly uniform science program, be likely to have more commonality among intangible factors than if selected from more than one community and be rated more consistently in terms of academic achievement. The complications and expenses of administering treatments and levels tests simultaneously to more than two schools was to be avoided.

TABLE I
NUMBERS OF STUDENTS AT 1961-1962 GRADE LEVELS HAVING
EXPERIENCED EACH POSSIBLE COMBINATION
OF UNIFIED SCIENCE COURSES

Class	Unified Science							Total
	I	II	III	I and II	I and III	II and III	I, II and III	
Senior	0	0	11	0	0	0	0	11
Junior	3	1	1	8	1	4	23	41
Sophomore	2	6	0	30	0	0	0	38
Freshman	28	0	0	0	0	0	0	28
Total	33	7	12	38	1	4	23	118

Note: This table should be read as follows: Among forty-one 1961-1962 juniors who experienced any Unified Science three have had only Unified Science I and four have had Unified Science II and III.

TABLE II
SOME CHARACTERISTICS OF PRELIMINARY EXPERIMENTAL GROUP
FOR WHICH CORRELATED MEASURES WERE SOUGHT

Class	I Unified Science	II Unified Science	III Unified Science	Male	Female	Approximate Mean IQ
Junior	X ———	X ———	23	13	10	120
Junior	X ———	6		1	5	95
Sophomore	X ———	30		13	17	115
Freshman	28			19	9	125-130
Totals	87	59	23	46	41	120

The plan was to administer on the same two consecutive days late in the spring of 1962, the Otis Mental Ability Test and the treatments test to the entire ninth through eleventh grade science enrollments of the University School and the control school. In addition to the agreement of school administrators to this use of student and teacher time the following selection criteria were established to increase the probability of close matching.

1. The science enrollment in grades nine through eleven should exceed five hundred.
2. The median IQ of the student population should be about 120, and the spread of measured abilities should be wide.
3. The teachers of the involved classes should express willingness to cooperate in the study.
4. The socioeconomic stratum of the community should be predominantly upper middle class with noticeable representation from other strata. There should also be some racial and religious heterogeneity.
5. The adjudged quality of instruction in the tradition sequence of science subjects should be high.
6. The school must request no more in material repayment than mental ability and treatment test scores.

With these criteria in mind the schools of Central Ohio were examined in separate oral discussions with heads of the science education section and the Center for School Experimentation at The Ohio State University. An ordered list of three schools resulted from these conferences. Two schools were from Franklin County, Ohio and one was

from Montgomery County, Ohio. The first school to be contacted was Worthington High School, Worthington, Ohio located in the northern part of Franklin County. Early in April the Associate Dean of the College of Education of The Ohio State University was requested to contact the principal of Worthington High School, briefly explaining the nature and importance of the study, advising him that this investigator would soon request an interview.

During mid-April details of the study were presented to the principal of Worthington High School during a personal interview. He in turn submitted the proposal to the staff of science teachers for approval. At a subsequent meeting with the principal he communicated the willingness of the administration and the science faculty to participate in the study. He requested that the treatments and levels tests be administered on Wednesday, May 16 and Thursday, May 17, respectively. These specific dates fitted best to the science staff's plan to begin reviewing for final examinations the following week. The order in which the tests were to be given was influenced by the fact that an assembly was scheduled for May 17 and class periods would be reduced in length, favoring the administration of the shorter Otis Mental Ability Test.

The principal objected to attempting to match the six eleventh graders in the experimental group who had had only Unified Science I and II. He felt that the inconvenience of interrupting non-science classes for so small a sample size was not a worthy use of student and teacher time. He further doubted whether half the group could be matched considering the lowness of their previously measured mental ability.

Without these six students the number of students in the experimental group for whom matches would be sought would become eighty-one.

A final request of the principal of Worthington High School was that he be allowed to screen the treatments examination before the end of the first week in May.

With the conditions for cooperation mutually acceptable, Worthington High School officially became the control school in this experimental design.

Table III contrasts Worthington High School and University School in terms of significant comparable features, and Table IV contrasts the preparation, experience and teaching loads of science teachers whose students were involved in the study.

Aside from certain expected feature differences between a public school and a campus laboratory school (enrollment, teacher-pupil ratio and teacher contact hours with students) the schools in terms of the aforementioned criteria were well matched.

Individual Matching Procedures

Treatments and levels tests were administered to students in science classes at Worthington High School May 16 to 17 respectively. Tests were taken by the students in twenty sections of Chemistry, Biology, Earth Science and Physical Science according to the schedule appearing in Table V. The same tests were administered in the same order, May 17 and 18 at the University School, according to the schedule appearing in Table VI. Reasons for the one day lag were-- (1) the investigator was requested to be present at Worthington High School during the day of the

TABLE III
SIGNIFICANT AND COMPARABLE FEATURES OF UNIVERSITY HIGH SCHOOL
AND WORTHINGTON HIGH SCHOOL*

Feature	University High School			Worthington High School		
	Male	Female	Total	Male	Female	Total
Enrollment						
Ninth grade	20	10	30	188	162	350
Tenth grade	18	20	38	127	126	253
Eleventh grade	19	18	37	117	106	223
Twelfth grade	14	18	32	97	83	180
Total	71	66	139	529	477	1006
Median IQ Range	115-120			115-120		
Percentage of graduates who go to college	>90%			>90%		
Home background	Upper middle class			Upper middle class		
Teacher-pupil ratio	10.8			21.6		
Number of school days per year	166			178½		
Length of class period	55 minutes			55 minutes		
Age of school plant	31 years			Older building--9 years Newer building--5 years		
Number of science teachers	2			6		
Number of science classes	5			26		
Average enrollment of science classes	22			25		

* Data gathered from 1961 principal reports filed at the Ohio State Department of Education and from descriptive literature distributed and available from the administrative offices of both schools.

TABLE IV

PREPARATION, EXPERIENCE AND TEACHING LOAD OF SCIENCE TEACHERS
OF STUDENTS INVOLVED IN STUDY*

Teacher	Degrees Earned	College Semester Hours in Science	Years of Teaching Experience		Science Teaching Load	
			Present School	Other Schools	Students	Classes
<u>University High School</u> Mr. Slesnick	BS, AB, MS	Biology - 81 Physical Science - 36	6	6	68	2
Mr. Showalter	BS, BSc, MS	Chemistry - 52 Physics - 29	2	10	40	3
<u>Worthington High School</u> Mr. Clauson	BS	Science - 45 Biology - 37	1	1	153	5
Mr. Dindal	BS, MA	Biology - 50 General Science - 48	3	0	146	5
Mr. McBurney	BS, ME	Science - 80	8	3	134	5
Mr. Stevenson	BS, MA	Science - 80	2	1	140	5
Mr. Williams	BS, ME	Biology - 42	3	4	108	4
Mr. Wingett	BS, MA	Chemistry - 34 Physics - 14	3	2	115	5

*Data gathered from 1961 principal reports filed at the Ohio State Department of Education.

TABLE V

SCHEDULE OF SCIENCE CLASS SECTIONS AT WORTHINGTON HIGH SCHOOL TO WHICH
TREATMENTS AND LEVELS TESTS WERE ADMINISTERED
MAY 16 AND 17, 1962

Teacher	Period I 8:55-9:50	Period II 9:55-10:50	Period III 10:55-11:50		Period IV 11:55-12:50		Period V 12:55-1:50	Period VI 1:55-2:50	Period VII 2:55-3:50
			Section I 10:55- 11:30	Section II 11:30- 11:50	Section III 11:50- 12:20	Section IV 12:20- 12:50			
Mr. Clauson	Physical Science								
Mr. Dindal	Biology		Biology				Biology		Biology
Mr. McBurney	Chemistry	Chemistry	Chemistry						
Mr. Stevenson			Earth Science				Earth Science	Earth Science	Earth Science
Mr. Williams		Biology	Biology					Biology	Biology
Mr. Wingett					Physical Science		Chemistry	Chemistry	Chemistry

TABLE VI

SCHEDULE OF SCIENCE CLASS SECTIONS AT UNIVERSITY HIGH SCHOOL
TO WHICH TREATMENTS AND LEVELS TESTS WERE ADMINISTERED
MAY 17 AND 18, 1962

Teacher	Period II 9:35-10:25	Period III 10:30-11:30	Period IV 11:30-12:20	Period V 1:00-2:00
Mr. Slesnick	Unified Science I	Unified Science II		
Mr. Showalter			Unified Science III	Unified Science III

treatments test administration and therefore could not be present at the University School to administer tests to his Unified Science I and II classes; (2) Unified Science I and II during 1961-1962 were not scheduled to meet on Wednesdays, and a rescheduling of classes would be an inconvenience.

Although levels and treatment tests for both groups were hand scored before any matching procedures were initiated, the tests on the measurement of a rational universe image remained inviolately separate from other data until matching procedures were concluded.⁴⁸

The mechanics of matching were planned and carried out by the investigator. The Otis Mental Ability tests with age, raw score and computed Gamma IQ, sex and grade level appearing on the upper margin were laid out for each individual in each science class of the

⁴⁸ It was, of course, necessary as a final step in matching to make certain that both control and experimental members of the matched pair had taken the treatment test.

experimental group. Test papers for the control group were then sorted and arranged in piles behind the control group so that each experimental student was tentatively paired with a number of persons of the same sex and grade level and in corresponding controlled science classes, e.g., Unified Science II paired with biology students. Where the Gamma IQ, raw mental ability score and age of an individual from the control group departed widely from the standards set by the experimental subject, the paper was removed from the operation. Where the number of possible control subjects for pairing exceeded five the purity of the matchings was increased by tossing out the papers of controls that departed most widely, attaching highest selective priority to Gamma IQ.

The papers of the control group candidate were then taken to the records room of Worthington High School where the additional information of academic achievement in science classes, and course work history was obtained. Yearly letter grades served as the index of academic achievement.

In the second distillation disparities in academic achievement eliminated a high percentage of the candidates, as did, of course, the failure of some candidates to have followed the conventional high school science sequence. The final pairings were made, for cells where more than one control candidate remained, by eliminating the individual(s) whose combinations of measured characteristics departed most widely from the experimental mate.

Before the matches were considered consummate, a check was conducted first, to be certain that both control and variable subjects had taken the treatments test and second, to check all level

information including rescoring of the Otis Test and a re-examination of the school records.

Three students of the experimental group were not matched: a Unified Science I boy was absent from school during the days of testing, and a Unified Science II boy and a Unified Science III girl achieved mental ability scores too low for pairing. The final total numbers of matched pairs was 78. Of this number 27 pairs were ninth graders, 29 pairs were tenth graders, and 22 pairs were eleventh graders.

Table VII presents the data that describe the members of each matched pair in terms of the continuous variables; age, mental ability (raw score and derived Gamma IQ) and academic achievement, and the non-ordered categories; sex, grade level and science course background. For later reference the final column includes the scores achieved on the treatment test.

Qualities of the Match--The Continuous Variables

Mental ability. The Otis Mental Ability tests are well known and need not be described in detail. The Gamma Test in New Edition Forms Em and Fm is designed to measure the thinking power or the degree of maturity of the mind of high school and college students. The IQ that can be computed from the raw score of the Gamma Test is not a true IQ since it is a value derived from the Binet Scale and not really a quotient arrived at by dividing mental age by chronological age. IQ's found by this

TABLE VII
DATA FOR EXPERIMENTAL (A) AND CONTROL (B) GROUPS

Pair	Individual	Sex	Class	Science Courses in Background*	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
1	a	F	11	I, II, III	17-3	66	125	3.0	34
	b	F	11	EBC	16-9	66	125	3.6	19
2	a	M	11	I, II, III	17-1	60	119	3.0	26
	b	M	11	EBC	16-11	60	119	3.3	18
3	a	M	11	I, II, III	17-0	65	124	3.3	37
	b	M	11	PBC	16-9	67	126	3.6	27
4	a	M	11	I, II, III	15-6	67	129	4.0	45
	b	M	11	EBC	17-1	70	129	4.0	36
5	a	M	11	I, II, III	17-1	69	128	3.6	43
	b	M	11	EBC	16-11	69	128	3.6	36
6	a	M	11	I, II, III	16-8	69	128	2.3	29
	b	M	11	EBC	16-9	68	127	2.6	31
7	a	M	11	I, II, III	17-4	72	131	4.0	42
	b	M	11	PBC	17-3	72	131	4.0	43
8	a	M	11	I, II, III	17-11	37	95	1.3	23
	b	M	11	EBC	17-3	35	94	1.6	26
9	a	M	11	I, II, III	17-1	54	113	2.6	43
	b	M	11	EBC	16-6	54	114	2.6	15
10	a	M	11	I, II, III	17-6	54	112	3.0	34
	b	M	11	EBC	16-7	54	113	3.0	21
11	a	M	11	I, II, III	16-0	55	116	2.0	24
	b	M	11	PBC	16-5	56	116	2.3	23
12	a	M	11	I, II, III	16-11	58	117	4.0	40
	b	M	11	EBC	16-11	56	115	4.0	32
13	a	F	11	I, II, III	16-5	50	110	2.3	21
	b	F	11	PBC	16-10	53	112	2.0	26

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background*	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
14	a b	F F	11 11	I, II, III PBC	16-9 17-3	64 66	123 125	2.3 2.3	18 23
15	a b	M M	11 11	I, II, III EBC	17-3 17-1	75 77	134 136	4.0 4.0	48 34
16	a b	M M	11 11	I, II, III EBC	16-6 16-7	72 74	132 133	3.6 3.3	41 30
17	a b	F F	11 11	I, II, III EBC	17-2 16-10	68 66	127 125	3.0 3.6	32 27
18	a b	F F	11 11	I, II, III PBC	16-4 17-1	69 70	129 129	2.3 3.3	26 25
19	a b	F F	11 11	I, II, III GBC	16-8 16-7	68 68	127 127	3.3 3.3	39 27
20	a b	F F	11 11	I, II, III EBC	16-5 16-9	71 71	131 130	2.6 3.3	45 36
21	a b	F F	11 11	I, II, III EBC	16-8 17-2	74 73	133 132	3.3 4.0	41 26
22	a b	F F	11 11	I, II, III GBC	17-2 17-2	42 44	101 103	2.6 2.6	20 27
23	a b	F F	10 10	I, II PB	16-7 16-2	45 44	104 104	1.5 2.0	20 13
24	a b	F F	10 10	I, II EB	15-8 15-9	46 47	107 108	2.5 2.0	31 13
25	a b	F F	10 10	I, II EB	15-11 15-9	46 49	107 110	3.0 4.0	32 24
26	a b	F F	10 10	I, II GB	16-11 16-1	48 49	107 109	3.0 3.0	29 22

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
27	a b	F F	10 10	I, II PB	15-5 15-7	50 50	112 112	3.0 2.5	24 19
28	a b	F F	10 10	I, II EB	16-4 16-2	51 51	111 111	3.0 2.5	28 20
29	a b	F F	10 10	I, II EB	15-5 15-4	52 51	114 113	3.0 3.0	31 21
30	a b	F F	10 10	I, II PB	15-2 15-11	52 58	115 119	2.0 2.0	26 28
31	a b	F F	10 10	I, II EB	16-3 16-3	54 54	114 114	3.0 3.5	36 19
32	a b	F F	10 10	I, II PB	15-9 15-7	56 56	117 118	2.5 2.5	24 21
33	a b	F F	10 10	I, II PB	16-2 15-9	59 58	119 119	3.0 3.0	30 18
34	a b	F F	10 10	I, II PB	15-11 15-10	61 62	122 123	3.0 3.0	27 27
35	a b	F F	10 10	I, II EB	15-6 15-10	74 74	136 135	4.0 4.0	46 30
36	a b	M M	10 10	I, II PB	17-2 17-3	33 34	92 93	1.5 1.5	14 19
37	a b	M M	10 10	I, II PB	16-0 15-10	35 39	96 100	2.5 1.5	23 14
38	a b	M M	10 10	I, II PB	16-9 16-3	34 35	93 95	2.0 1.5	26 18
39	a b	M M	10 10	I, II PB	15-8 15-5	43 42	104 104	1.5 1.5	24 22

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
40	a b	M M	10 10	I, II EB	16-2 16-1	45 45	105 105	3.0 2.5	25 18
41	a b	M M	10 10	I, II EB	15-8 16-2	47 45	108 105	2.0 2.0	24 15
42	a b	M M	10 10	I, II EB	15-8 15-6	54 54	115 116	1.5 2.0	23 25
43	a b	M M	10 10	I, II EB	15-3 15-4	58 59	120 121	2.0 2.0	31 19
44	a b	M M	10 10	I, II EB	15-11 16-0	66 64	127 125	4.0 4.0	42 36
45	a b	M M	10 10	I, II EB	15-6 15-7	67 67	129 129	4.0 4.0	41 29
46	a b	M M	10 10	I, II PB	15-5 15-7	67 66	129 128	4.0 4.0	40 40
47	a b	M M	10 10	I, II PB	15-8 16-2	68 69	129 129	4.0 4.0	38 3.5
48	a b	F F	10 10	I, II PB	16-2 17-1	35 38	95 97	2.0 3.0	18 24
49	a b	F F	10 10	I, II PB	15-9 15-7	37 38	98 100	2.0 1.5	12 20
50	a b	F F	10 10	I, II PB	16-3 16-3	42 41	102 101	2.5 2.5	23 23
51	a b	F F	10 10	I, II PB	15-10 15-8	44 45	105 106	1.5 1.5	17 17
52	a b	M M	9 9	I E	15-1 15-1	40 40	103 103	2.0 2.0	19 21

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
53	a b	M M	9 9	I E	15-7 15-9	37 39	99 100	2.0 2.0	15 17
54	a b	M M	9 9	I P	15-5 15-3	37 37	99 99	2.0 2.0	8 19
55	a b	M M	9 9	I E	13-8 14-6	44 46	112 111	2.0 2.0	26 14
56	a b	M M	9 9	I E	14-7 14-8	49 51	113 115	3.0 3.0	24 18
57	a b	M M	9 9	I E	15-1 14-10	45 45	108 109	3.0 3.0	24 27
58	a b	M M	9 9	I E	15-0 15-2	50 52	113 115	2.0 2.0	27 26
59	a b	M M	9 9	I E	15-4 14-8	50 50	112 114	3.0 3.0	34 23
60	a b	M M	9 9	I E	14-11 14-11	51 52	114 115	3.0 2.0	20 24
61	a b	M M	9 9	I E	15-0 14-9	53 53	116 117	3.0 3.0	26 26
62	a b	M M	9 9	I E	15-3 15-2	58 57	120 120	3.0 4.0	31 17
63	a b	M M	9 9	I E	14-10 14-9	60 60	124 124	3.0 3.0	30 18
64	a b	M M	9 9	I E	15-4 15-3	61 62	123 127	3.0 3.0	36 31
65	a b	M M	9 9	I E	14-6 14-5	61 61	126 126	3.0 3.0	32 27

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
66	a b	M M	9 9	I E	14-10 14-10	62 62	126 126	3.0 3.0	31 27
67	a b	M M	9 9	I E	15-2 15-1	65 65	128 128	3.0 3.0	32 28
68	a b	M M	9 9	I E	14-9 15-2	65 67	129 130	4.0 4.0	52 24
69	a b	M M	9 9	I E	15-1 14-11	77 76	140 139	4.0 3.0	51 43
70	a b	F F	9 9	I E	15-4 15-1	73 71	135 134	4.0 4.0	31 22
71	a b	F F	9 9	I E	14-1 14-11	68 68	134 131	4.0 4.0	42 34
72	a b	F F	9 9	I E	14-6 14-9	57 59	122 123	3.0 3.0	22 14
73	a b	F F	9 9	I E	14-10 14-8	51 53	115 117	3.0 3.0	27 21
74	a b	F F	9 9	I P	15-4 15-6	51 49	113 111	2.0 2.0	20 26
75	a b	F F	9 9	I E	14-9 15-4	49 49	113 111	2.0 2.0	13 25
76	a b	F F	9 9	I E	14-9 15-3	42 44	106 106	2.0 2.0	20 16

TABLE VII (contd.)

Pair	Individual	Sex	Class	Science Courses in Background	Age (Years & Months)	Otis Score	Gamma IQ	Average Yearly Grade in Science	Treatments Test Score
77	a	F	9	I	14-10	31	95	1.0	11
	b	F	9	P	14-5	31	96	1.0	15
78	a	F	9	I	14-4	39	104	2.0	15
	b	F	9	P	14-8	40	104	3.0	20

Note:

This table should be read as follows: The experimental individual, a, of pair 1 is a girl of the eleventh grade who has had Unified Science I, II, and III, was seventeen years, three months of age to the nearest whole month as of the seventeenth day of May, 1962, scored sixty-six correct responses on the Otis Mental Ability Test which for her age is equivalent to a Gamma IQ of 125, her average of three course grades in science is 3.0 where A is 4, B is 3, C is 2, etc., and she correctly answered 34 questions on the treatments test.

* Symbols indicate courses as follows: I, Unified Science I; II, Unified Science II; III, Unified Science III; E, Earth Science; B, Biology; C, Chemistry; G, General Science; P, Physical Science.

method tend to be less variable and cluster more about a value of 100.⁴⁹ There is precedence for using this test ". . . to obtain two or more groups of equal mental ability or brightness which may be given different methods of instruction for the purpose of determining which method is superior."⁵⁰ In this design, however, differential instruction preceded matching.

Four hundred eighty-three Gamma Tests taken by unselected students from the control school, and 80 tests taken by students from the experimental school were hand scored. The means and medians of the control and experimental groups before matching were 117.0, 117 and 115.3, 115 respectively.⁵¹ The distribution of Gamma IQ scores for each population is depicted graphically in Figure 4. Each curve is negatively skewed and shows slight bimodal tendencies. Successful mental ability matching is favored about the means of the distribution with the probability of close matching decreasing at the extremes, particularly true at the lower ability tails of the curves. The choices for a match under the body of the curve (IQ range, from about 105 to 135) were about six to one, whereas at IQ ranges below 100 the choice for a match were about two to one. The failure to match only two of eleven individuals of the control group in this area was fortunate.

⁴⁹Manual of Directions for Gamma Test Forms Am and Bm and New Edition: Forms Em and Fm (New York: Harcourt, Brace and World, Inc., 1954), p. 5.

⁵⁰Ibid., p. 6.

⁵¹These values should not be used to compare the two schools since the data were not derived from a random sampling of either school's populations.

FIGURE 4
SPREAD OF MEASURED ABILITY OF EXPERIMENTAL
GROUP AND OF CONTROL GROUP FROM WHICH
MATCHES WERE OBTAINED.

The final quality of the match in terms of mental ability is reflected in Tables VIII and IX. Coefficients of correlation for the Otis test raw score, derived Gamma IQ and other continuous variables have been computed by the Pearson product-moment method using the formula:

$$r = \frac{\sum ab}{N \sqrt{\frac{\sum a^2}{N}} \sqrt{\frac{\sum b^2}{N}}}$$

In each case the intensity of relationship is very high. Coefficients of correlation of .998 and .995 are nearly perfect and would be even more so were the standard error of measurement, 3.0 points, taken into consideration. It should further be noted that the means of scores favor the control group.

Ages. A similar coefficient of correlation was computed for the ages of matched pairs and presented in Table X. With ages expressed in months it was found that the mean age for both groups was 190 months or 15 years 10 months. However, the coefficient value of .892 reflects wide disparities between certain pairs. Although mean difference between ages in months of the pairs is about 3.6 months, pair number 4 differs in age by 19 months and pairs 48, 55, and 69 differ by about 10 months. In each case of wide difference, greater weight on mental ability and/or academic achievement was placed when the final decisions on pairings were made.

TABLE VIII
CORRELATION BETWEEN OTIS MENTAL ABILITY TEST RAW SCORES
OF SEVENTY-EIGHT MATCHED PAIRS

	Experimental A	Control B	a^2	b^2	ab
Sum	4274	4312	11146	10738	10846
Mean	54.8	55.3			
S.D.	11.9	11.7			
r	.998				

TABLE IX
CORRELATION BETWEEN "GAMMA IQ'S" OF
SEVENTY-EIGHT MATCHED PAIRS

	Experimental A	Control B	a^2	b^2	ab
Sum	9058	9086	11070	10384	10629
Mean	116.1	116.5			
S.D.	11.9	11.5			
r	.995				

Academic achievement. The continuous variable of academic achievement in science since the ninth grade is probably the most difficult to quantify. This is especially true since it had been the policy of the University School not to give grades to students or to represent numerically in the cumulative records of the students any measure of academic achievement other than occasional standardized tests. Neither group had followed any usable pattern of periodic or related testing. However, the records of student performance maintained by the teachers of Unified Science over the three-year period were such that grades (A, B, C, D, and E) could be determined and compared with the paired individuals of the control group. These grades were primarily a measure of mastery of content, motivation, effort and attitude subject to the limitations of value judgments in general.

The values compared in selecting the matches were the means of the final grades assigned each student at the end of a year of science. To the grade "A" was assigned the point value of 4; to B, 3; C, 2; etc. Thus the achievement measure of an eleventh grade pupil who received a grade of A for his performance during his ninth year and grades of B for his work as a sophomore and junior, would be $\frac{4+3+3}{3}$ or 3.3.

Table XI shows that the coefficient of correlation between paired measures was .877, which is approximately what one expects when mental ability shows perfect correlation. Again a slight difference between the means, 2.77 and 2.82, favors the control group.

TABLE X
CORRELATION BETWEEN AGES IN MONTHS
OF SEVENTY-EIGHT MATCHED PAIRS

	Experimental A	Control B	a^2	b^2	ab
Sum	14816	14842	9244	7980	7660
Mean	190.0	190.3			
S.D.	10.9	10.1			
r	.892				

TABLE XI
CORRELATION BETWEEN GRADE SCORES OF ACADEMIC ACHIEVEMENT
IN SCIENCE OF SEVENTY-EIGHT MATCHED PAIRS

	Experimental A	Control B	a^2	b^2	ab
Sum	215.9	219.6	4745	5240	4377
Mean	2.77	2.82			
S.D.	7.8	8.2			
r	.877				

Qualities of the Match--The Non-order Categories

Pairs were matched perfectly with regard to sex and grade level. Students of the control group whose status either because of partial acceleration or failure were classified intermediate between two class levels were eliminated from the selection procedures.

Three members of the control group did not experience their ninth grade science at the Worthington School. They are 19b, 22b, and 26b. The course in general science at the schools which they did attend, however, was considered, after inquiries, to be of the same quality, as courses offered at the Worthington School.

Limitations and Advantages of Matchings

Certainly it cannot be said that the individuals of the matched pairs were mirror images of one another. They differed, very probably, in innumerable physical and mental features. There were, without doubt, wide variations in racial, religious, social and emotional characteristics. Perhaps if there were a way to measure directly creativity quotients, this would have been a significant index to add to the battery of continuous variables in a study of this type. Critics of the experimental design urged the inclusion of a subject matter test measuring the student's general background in the sciences. This, too, would have contributed greatly to the validity of the match. Other tests on scientific attitudes or ability to reason in the natural science also would have been appropriate. However, the line had to be drawn; two days of testing were all that either school would permit.

The purpose of matching subjects as precisely as possible in an experimental design is not to discover alter egos. Rather, the intent is to reduce the inherent errors present in a design where mean differences are sought in independent samples. Cornell wrote of the advantages of paired measures as follows:

The reason for matching is to reduce the error variance, that is, to increase the precision of the experiment. If the bases upon which subjects are matched is such that pairs will be highly correlated in the measures used in the outcome of the experiment, the experimental error is greatly reduced. This increases the chance of finding a significant difference between the two populations if the true difference is not zero.⁵²

IV. Summary

The reported study sought to test the main hypothesis that no significant difference existed between the rational universe images of students who experienced subject-centered science and students who experienced Unified Science. The experimental design selected was a comparison of test performances by matched pairs of ninth, tenth and eleventh grade pupils. One member of each pair attended The Ohio State University High School, collectively making up the experimental group, the other member attended Worthington (Ohio) High School collectively making up the control group. The control school was selected on the basis of the quality of instruction in science, the socioeconomic status of its community and the willingness of its administrators and faculty to cooperate in the study. Also, the greater than five-to-one ratio in student enrollment increased the probability of matching a University School student with a Worthington High School counterpart. Each pair

⁵²Francis G. Cornell, The Essentials of Educational Statistics (New York: John Wiley and Sons, Inc., 1956), p. 227.

was matched as closely as possible on the bases of mental ability, academic achievement in science, sex, grade level, age and parallel experience in sequential science since the ninth grade. Data for matching were gathered from Otis Mental Ability Tests administered concurrently at both schools, questionnaires and permanent school records. Seventy-eight acceptable pairings were achieved. The reason for highly selective matching was to increase the chances for discovering significant differences, if such existed, between the performance of control and experimental groups. A test on the measurement of a rational universe image was the instrument developed to determine, if possible, whether such differences exist.

CHAPTER V

THE TREATMENT INSTRUMENT--TEST ON THE MEASUREMENT OF A RATIONAL UNIVERSE IMAGE

Theoretically, the best way for a student to communicate his picture of the whole of the physical world would be through the use of an essay type test, or even better possibly, an open-ended interview. However, neither technique lends itself well to the quantitative demands of validity and reliability in an experimental design of this sort. Furthermore, the time required to interpret the responses of 156 subjects in the sample would have been prohibitive.

The test design chosen for the measurement of a rational universe image was five-item multiple-choice. The multiple-choice form was selected because (1) alternate responses can be created that require much keenness of discrimination to distinguish between them, (2) alternate responses can be created that measure gradations of unified images, (3) multiple response questions need not be corrected for chance, (4) the reliability of tests of this form is usually high, (5) the mechanics of taking multiple-choice tests is familiar to most students, (6) hand scoring is easily accomplished. Offsetting the advantages are the difficulties of construction, the usually large volume of the test and the limits imposed upon the examiner in expressing the realization of pervasive objectives.

In final form the test consisted of sixty-five five-alternate multiple-choice items contained in a 14-page mimeographed booklet.

I. Construction of Test

Before any items of the test were written the objective of a rational universe image was restated in the form of five specific features that lend themselves to objective testing and which can manifest as a result of the curricular experiences of both control and experimental groups. In other words test items were intended to be written to measure concrete aspects of a rational universe image where the contributing knowledge is commonly present or absent in the traditional subject-centered approach and in Unified Science.

Test items were, therefore, constructed through the suggestion of things and events that appeared (or did not appear) in the content of textbooks and syllabi followed by the experimental and potential control groups. Since Worthington High School's participation as a control group was anticipated the texts and curricular guides used and assembled by the teachers of the school were included among reference materials employed during test construction. The test draft, revised before administration, was thoroughly compared with the content of the ninth, tenth and eleventh grade science courses taught at the Worthington High School. Considerable effort was made to avoid the selection of any facts, experiences, phenomena or, of course, previous test items that were unique to the Unified Science course of study.

Test construction began in February, 1962. Since then the revision, rejection and addition of items has been a continuous process.

The fifth draft of the instrument was administered to the control and experimental groups involved in this study. This draft could not be considered most satisfactory since throughout the gauntlet of pretesting procedure no student who had ever experienced course content in unified context could be given the opportunity to check out the test. Therefore a sixth draft of a test designed to measure a rational universe image was a natural product of the reported study.

The content and nature of the test of a rational universe image can perhaps be best indicated by illustrating and discussing one test item of each feature of a rational universe image. Starred choices are the most acceptable responses.

Feature 1

PHENOMENA REFLECT THE INTERDEPENDENCIES AND INTERACTIONS OF MATTER, ENERGY AND LIFE.

Item 10

Which statement is true regarding the nature of energy?

- *a. Energy makes matter move.
- b. Energy can be detected in the absence of matter.
- c. The ultimate source of energy is the electron.
- d. Energy can be generated in the absence of matter.
- e. Most forms of energy can be sensed by the nervous system of man.

In the above item the student must recognize a basic relationship that exists between matter and energy, that energy is not divorced in origin, interaction, or detection from matter. However, he was required to know that an electron is not, uniquely, the ultimate source of energy and that the forms of energy extend far beyond the ranges of the sense receptors of man.

Feature 2

THE FORMS OF MATTER, ENERGY AND LIFE REVEAL A NATURAL ORDERLINESS.

Item 4

The chemical elements of which plants and animals are composed

- a. cannot exist in gaseous form.
- b. differ from those elements of which man is composed.
- *c. are known to exist in the stars.
- d. take on different properties outside the organism.
- e. are described by none of these.

Item 4 measures the concept of universality of matter, that the same elements with the same properties that compose the proximate material things, including life forms, are the very same substances that make up the cosmic bodies and that the organism is a site where ordinary matter and energy interact.

Feature 3

THINGS AND EVENTS ARE PERCEIVED IN ACCURATE PERSPECTIVE IN RELATION TO TIME AND SPACE.

Item 55

Which sequence is out of order?

- a. proton, atom, molecule, crystal
- b. nucleus, cell, tissue, organ
- *c. earth, moon, sun, milky way
- d. core, mantle, crust, earth
- e. lead, wood, paint, pencil

Students whose pictures of the universe were more complete would recognize that whereas distractors a, b, d, and e of Item 55 represent a succession of structures from the center to the whole, the earth is not the center of the Milky Way and failure to indicate this may reflect a geocentric image.

Feature 4

REAL PROBLEMS IN CONTROLLING, PREDICTING AND INTERPRETING EVENTS IN THE UNIVERSE TRANSCEND SINGLE DISCIPLINES.

Item 47

A thorough study of the element magnesium would also be a study of

- a. chemistry (matter)
- b. physics (energy)
- c. biology (life)
- *d. all three of the above
- e. chemistry and physics

Since magnesium is a chemical element the first expected circle of concern would be chemistry, yet after analysis the student may recognize that the properties of the element are indefinable without the knowledge of physics. However, a depth study of magnesium cannot avoid also its essential involvement in the biological sciences.

Feature 5

MAN'S RELATIONSHIP WITH HIS UNIVERSE, AS AN OBSERVER AND AS A PART OF THE "WEB" IS PERCEIVED REALISTICALLY.

Item 43

Science serves the graphic artist and the music composer best by

- a. providing them with improved materials and equipment with which to carry out their creative work.
- b. creating an intellectual climate where creative products are better appreciated by the public.
- *c. revealing more understanding of the universe which they can creatively interpret.
- d. discovering the genetic formula responsible for the inheritance of creative talent.
- e. increasing their life span which in turn increases their productivity.

In the above item the measurement was two-fold. First the student was to see science as a search for understanding rather than only a

search for immediate application. Second, he must discriminate between ways in which science and other human activities (fine arts) interact.

II. Validation

Individual test items and the test in its entirety was subjected to criticism and evaluation throughout four stages before its acceptance as the treatments instrument. Throughout this developmental period the test was examined and/or taken by a science education specialist, a secondary education specialist, an education research specialist, a biologist, a physicist, a Worthington High School science teacher, a Unified Science teacher, three public school science teachers of broad preparation, an engineer, three public school students from the ninth, tenth, and eleventh grades, eleven graduate students specializing in science education, and ninety-seven Westerville High School students enrolled in either general science, biology or chemistry. Since the date of the administration of the instrument to the subjects of the experiment, the test items were rated by a group of six selected doctoral graduate students in science education.

The first of the revision studies primarily involved the investigator and his colleague in the teaching of Unified Science. Emphasis in reviewing items was placed upon the appropriateness of the item in measuring an aspect of a rational universe image. A second draft was submitted to specialists who were requested to give special attention to the validity of test items in terms of their factual accuracy. Where the idea was acceptable but the illustrative phenomena inappropriate, they were invited to suggest substitute vehicles. The

third draft was submitted primarily to teachers and graduate students who were requested to predict the success of the items individually and the test as a whole in achieving the objective features of the rational universe image. At this stage the procedure was to have the validator take the test for one hour, score his paper, and then discuss the test soon after he reexamined it. In each of the above mentioned drafts inappropriate questions, measuring mere recall, served to gauge the degree of scrutiny offered by the examiner.

The fourth draft of the test was field tested. On April 30, 1962, the two chemistry, one general science and one biology sections of Mr. Ronald Dietrick of Westerville High School took the test for forty-minute periods during their regularly scheduled classes. An item analysis was carried out upon the entire sample. Items which appeared to be of little challenge were entirely rewritten or discarded. For other items where the distractors showed a high incidence of avoidance, new distractors were substituted. However, extremely difficult items were not discarded or revised if it was felt that the item may later prove valid as a measure for students of Unified Science.

The fourth draft was also administered to three students of each of the three grade levels after which items were discussed individually.

The final (fifth) draft of the instrument was examined individually by six doctoral level graduate students in science education. In this form the items were grouped according to features of a rational universe image and the acceptable responses were starred. Below each test item the numbers 1, 2, 3, 4 and 5 and a space for comments were included. Each person was requested to score his opinion of the quality

of the item as a measure of the feature. A rating of "1" was highest, "5" lowest. Any item receiving a mean score of three or higher was to be considered invalid and discarded for consideration in the main analysis. The results of final validation (actually occurring after the administration of the fifth draft to the matched pairs) appears in Table XII. As can be observed the score of no item exceeded the critical value.

III. Reliability

The reliability of the fourth draft of the test without the adjustment for items discarded was calculated by the odd-even method using the Spearman-Brown prophecy formula: $r_{xx} = \frac{2r_{hh}}{1 + r_{hh}}$ where r_{xx} is the test's total reliability when r_{hh} is the correlation between parallel halves of the test. The coefficient of reliability thus obtained was 0.80 using statistics presented in Table XIII.

Further studies of the reliability of the instrument (fifth draft) appear in Chapter 5.

IV. Administration and Scoring

The fifth draft of the criterion instrument was given to all students present in the twenty Worthington High School science sections on Wednesday, May 16 (see Table V for class schedule). Instructions for administration were straightforward with specific directions printed on the cover of the test booklet. Each teacher was invited to ask questions about the mechanics of administration two days prior when the tests were delivered. During this first day of testing this investigator visited

TABLE XII

MEAN RATINGS (1 THROUGH 5 SCALE) OF INDIVIDUAL FIFTH DRAFT TEST ITEMS
AS MEASURERS OF A RATIONAL UNIVERSE IMAGE BY SIX DOCTORAL
GRADUATE STUDENTS IN SCIENCE EDUCATION

Item	Mean Rating	Item	Mean Rating	Item	Mean Rating
1	1.6	23	2.0	45	1.4
2	1.7	24	1.3	46	1.5
3	1.2	25	1.7	47	1.4
4	1.5	26	2.4	48	2.2
5	2.5	27	1.5	49	*
6	2.6	28	1.7	50	2.0
7	1.6	29	2.0	51	1.8
8	1.4	30	1.8	52	1.5
9	1.2	31	1.8	53	1.7
10	1.6	32	1.5	54	2.8
11	1.2	33	1.7	55	1.7
12	1.8	34	1.5	56	1.7
13	1.5	35	1.7	57	1.2
14	1.0	36	2.0	58	1.0
15	1.7	37	1.5	59	1.3
16	1.7	38	1.3	60	1.8
17	2.0	39	1.8	61	1.6
18	1.8	40	1.2	62	1.8
19	1.2	41	1.5	63	2.4
20	1.2	42	1.2	64	2.0
21	1.8	43	1.0	65	1.8
22	1.7	44	1.6		

* An incorrect response was mistakenly indicated as a correct response on the questionnaire.

the school and observed procedures in one of each teacher's classes. Upon completion of tests they were immediately boxed and returned to the investigator.

TABLE XIII

RELIABILITY COEFFICIENT DETERMINATION (ODD-EVEN METHOD)
OF FOURTH DRAFT OF CRITERION INSTRUMENT
USING NINETY-SIX WESTERVILLE
HIGH SCHOOL SUBJECTS

	Odd Items X	Even Items Y	x^2	y^2	xy
Sum	1263	1269	1697	1831	1177
Mean	13.2	13.2			
S.D.	4.2	4.4			
r_{hh}	0.67				
r_{xx}	0.80				

The same procedures were followed on May 17 at the University School. However, the examination, as well as the Otis test on the following day, were given Science I and II classes in the lunchroom rather than in the crowded classroom. Science III sections were examined in their regular classrooms.

Throughout the three days of examination, weather conditions were trying. Room temperatures averaged about 90° Fahrenheit and the humidity was uncomfortably high. Although specific details of the nature of the research project were not explained to students until after the testing period, the general importance of performing as best they were able was

stressed. Teachers at both schools noted that students generally did not display quite the same concern for these tests as they did for tests that figured in their grades (Worthington) or written reports (University). A small amount of copying was observed and detected in several of the classes. There was also some evidence presented in Table XXIX that certain classes in the control group may have exceeded the 40 minute time limit.

The 502 completed tests from the control classes and the 80 completed tests of experimental classes were hand scored. The tests of matched pairs were rechecked by the investigator after pairings were completed. The number of correct responses for each member of each pair appears in the right column of Table VII.

V. Data Processing

Since the significance of differences between two means of paired measures was sought, the collected data on the criterion variable instrument lent itself to relatively simple and direct analysis procedures. Data for testing the main hypothesis and all subordinate hypotheses concerning the differences in performance of various groupings (ability, grade level, etc.) was conveniently contained in Table VII. Whenever a levels test was carried out, the specific pairs were extracted and the significance of mean difference determined. Data concerning pair performance on individual test items and individual performance on test items were maintained on cards which also could be sorted in accordance with questions asked regarding written test performance.

In the long run it might have been more convenient to process data on machine cards. However, the investigator is grateful for the experience of having discovered the powers of an electronic card computer over the manual calculators.

VI. Summary

The instrument used for the measurement of a rational universe image was a paper and pencil test consisting of 65 five-alternate multiple-choice items. Individual items were created from the common subject matter of Unified Science and the traditional science curriculum throughout the ninth, tenth and eleventh grade span. Each item was written specifically to measure one of five explicated features of a rational universe image.

Prior to its use as the measure of the comparative effectiveness of the two treatments, the instrument was subjected to a gauntlet of tests of validity and one test of reliability. The investigator assumed primary responsibility for developing the test although his colleague in Unified Science and numerous validators suggested new items and revision of existing items. In all, the instrument underwent four revisions before it was used in the research. Each draft was studied as follows:

First draft: Each item was examined and discussed by the two teachers of Unified Science in an effort to determine its appropriateness as a measure of a rational universe image.

Second draft: Each item was studied by subject matter specialists with reference to factual accuracy.

- Third draft: The entire test was administered to a seminar of graduate students in science education and to other professional persons after which individual items and the test as a whole were critically discussed.
- Fourth draft: The test was administered to 97 ninth, tenth and eleventh grade students under simulated experimental conditions. Item analysis and time studies were carried out. Three students were interviewed after having taken the test.
- Fifth draft: The test was administered to experimental and control groups. Each item was rated on a 1-5 quality scale by six doctoral level graduate students in science education. Each involved experimental class evaluated the items of the instrument in class discussion.

The fourth and fifth drafts of the instrument have been statistically tested for reliability.

CHAPTER VI

THE FINDINGS

The data derived from the criterion instrument were used in two series of analyses. In the first series, hypotheses that no significant differences existed between the means of paired measures were tested. Paired measures were grouped at combined mental ability, academic achievement, sex and background of course work levels. In the second series of analyses comparisons were made of the differences in performance of the matched pairs with respect to the collective items for each feature of a rational universe image. For all paired comparisons the t -distribution statistic was calculated and compared with critical values of t at the five per cent level of significance.

I. Symbols, Equations and Terminology

The symbols used in the analyses of data with their translations are listed below.

- t The t test statistic
- $\bar{D}$ The mean difference between paired measures
- N The number of pairs in the test sample
- SD^2 The variance of differences
- SD The standard error
- v The number of degrees of freedom
- α The level of significance of the test

The following combinations of symbols have special meanings and are to be read as indicated.

$H_0: \mu_{A-B} = 0$ The statistical hypothesis reading, the mean difference of scores between the experimental group, A, and the control group, B, is zero.

$t (\alpha; v)$ The critical value of t at the α level of significance with v degrees of freedom.

Equations employed in calculating the variance of differences, SD^2 ; the standard error, $\bar{SD}$; and the t test statistic are--

$$SD^2 = \frac{\sum D^2}{N} - \bar{D}^2$$

$$\bar{SD} = \sqrt{\frac{SD^2}{N - 1}}$$

$$t = \frac{\frac{\bar{D}}{\sqrt{\frac{\sum D^2}{N} - \bar{D}^2}}}{\sqrt{N - 1}}$$

It will be recalled that the following terms used in describing the experimental design have special connotations.

Level refers to any one or a combination of the six characteristics used in obtaining matched pairs of subjects. For example, the group of matched pairs, all female, will be referred to as the female level.

Treatment instrument refers to the test designed to measure a rational universe image.

II. Analyses Based upon the Whole Instrument at Various Levels

In the following series of tests the main null hypothesis under test was--

There are no significant differences between the rational universe images of students who had studied Unified Science and the rational universe images of students who had studied science in a subject-centered context.

Since the pairs of subjects naturally lent themselves to subgrouping, the same hypothesis was asked of groups of pairs sharing one or more levels variables. For example, the question of no difference in treatments could have been asked of ninth graders only, girls only, "C" average students only, or high ability boys with low academic achievement.

Significance of Differences between Means of Paired Measures at All Levels Combined

Table XIV presents the analysis of difference between the mean scores on the total test for the total group of 156 paired subjects. The mean score of correct responses for the experimental group and control group were 29.17 and 24.11 respectively. The mean difference 5.06 was found to be significant at the 5 per cent level with 77 degrees of freedom. Thus it is clear that the overall effect on the formation of a rational universe image is favored by the Unified Science curriculum experienced by the experimental group.

TABLE XIV

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT ALL LEVELS COMBINED

	Experimental A	Control B	D	D ²
Sum	2275	1880	395	6649
Mean	29.16	24.10	5.06	
<hr/>				
N	= 78	H ₀ : u _{A-B} = 0		
SD ²	= 59.6	α = .05		
SD	= .880	v = 77		
t	= 5.75	t(α:v) = 2.00		
<hr/>				
Reject H ₀				

Significance of Differences between Means
of Paired Measures at Each Grade Level

The second series of questions asked of the data concerned the significance of differences between the mean scores on the total test for the paired measures at each grade level. Tables XV, XVI, XVII test the hypotheses of significant difference for the ninth, tenth and eleventh grade groups respectively. In each case a significant difference at the 5 per cent level was detected.

As would be expected, the differences between means of successive grade groups displayed a fairly regular rise: 3.56 to 5.38 to 6.50. The continuation of this trend into the fourth year (Unified Science IV and Physics) is a matter for further testing.

The mean scores for the experimental group and the control group at the three grade levels did not display the same regularity as did the

mean differences. The means of the experimental group at the three grade levels, 26.63, 27.76, and 34.14, at first examination exhibited a great saltation from the tenth to the eleventh year. In the control group there is even an apparent regression at the tenth grade level, 23.07, 22.38 and 27.64. The phenomenon becomes more confounding when it was noted that the difference between means of paired measures at the tenth grade level was actually significant at the .001 level whereas the same confidence could not be argued for either the ninth or eleventh grades. The most possible explanation resided in one or a combination of level criteria other than grade level. For example, it was noted that the mean Gamma IQ for the tenth grade group was about 111

TABLE XV

TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT THE NINTH GRADE LEVEL

	Experimental A	Control B	D	D^2
Sum	719	623	96	2208
Mean	26.63	23.07	3.56	
<hr/>				
N	= 27		$H_0: \mu_{A-B} = 0$	
SD^2	= 69.11		$\alpha = .05$	
$\bar{SD}$	= 1.63		$v = 26$	
t	= 2.18		$t(\alpha : v) = 2.05$	
<hr/>				
Reject H_0				

TABLE XVI

TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT THE TENTH GRADE LEVEL

	Experimental A	Control B	D	D ²
Sum	805	649	156	1998
Mean	27.76	22.38	5.38	
N	= 29		H ₀ : μ_{A-B} = 0	
SD ²	= 39.95		α = .05	
SD	= 1.19		v = 28	
t	= 4.52		t(α :v) = 2.04	
Reject H ₀				

TABLE XVII

TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT THE ELEVENTH GRADE LEVEL

	Experimental A	Control B	D	D ²
Sum	751	608	143	2443
Mean	34.14	27.64	6.50	
N	= 22		H ₀ : μ_{A-B} = 0	
SD ²	= 68.79		α = .05	
SD	= 1.81		v = 21	
t	= 3.59		t(α :v) = 2.08	
Reject H ₀				

whereas the mean value for all levels was about 116, the academic achievement rating was about 2.6 for the tenth grade and about 2.8 for all levels, and the percentage of girls at the tenth grade level was 59 compared with 45 for all levels.

A differential favorability of the treatment was then sought at levels other than class rank alone.

Significance of Differences between Means of Paired Measures at Triadic Ability Levels

Matched pairs were then sorted into three groups of equal size on the basis of Gamma IQ only. Each triad of twenty-six pairs included subjects from all levels (there were no perfectly negative correlations detected between ability and any other variable, therefore ability grouping did not result in any other homogeneous grouping). The upper third or third triad subsumed pairs with Gamma IQ's at or above 125; the second triad, 112-124; and the first triad, 92-111. There were two main reasons for dividing the sample of matched pairs into three groups of equal size in preference to any other division. (1) It was desirable to maintain as large a sample of pairs as possible at each ability level. Sample sizes smaller than 26 reduced the acuity of the test. (2) The first triad corresponded, within the error of the instrument, to the median ability of the American population.

Analyses resulting from these arrangements of data are presented in Tables XVIII, XIX and XX. Tests of significance revealed the program effective in realizing the objectives of creating a rational universe image at the third and second triadic ability levels. However, the hypothesis of no difference in mean scores was accepted at the first

TABLE XVIII

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT UPPER THIRD IN MENTAL ABILITY
LEVEL (GAMMA IQ'S 125-140)

	Experimental A	Control B	D	D ²
Sum	998	795	203	2773
Mean	38.38	30.58	7.80	
$N = 26$ $SD^2 = 45.81$ $\bar{SD} = 1.35$ $t = 5.78$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 25$ $t(\alpha:v) = 2.06$				
Reject H_0				

TABLE XIX

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT MIDDLE THIRD IN MENTAL
ABILITY LEVEL (GAMMA IQ'S, 112-124)

	Experimental A	Control B	D	D ²
Sum	737	576	161	2591
Mean	28.35	22.15	6.19	
$N = 26$ $SD^2 = 57.87$ $\bar{SD} = 1.52$ $t = 4.07$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 25$ $t(\alpha:v) = 2.06$				
Reject H_0				

TABLE XX

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT LOWER THIRD IN MENTAL ABILITY
LEVEL (GAMMA IQ'S, 92-111)

	Experimental A	Control B	D	D ²
Sum	540	509	31	1495
Mean	20.77	19.58	1.19	
<hr/>				
N	= 26		H ₀ : μ_{A-B}	= 0
SD ²	= 56.08		α	= .05
SD	= 1.50		v	= 25
t	= 0.79		t(α ;v)	= 2.06
<hr/>				
Accept H ₀				
<hr/>				

triadic ability level, thus indicating that the program has not been equally effective at all ability levels. Although the mean scores of the three ability groups increased regularly with increasing Gamma IQ's, the mean differences between pairs, 1.19, 6.19 and 7.80, did not display the same regularity. It also appeared that the program was about equally effective for the two top groups, slightly favoring the higher ability triad.

Significance of Differences between Means of
Paired Measures at Triadic Academic
Achievement Levels

The high positive correlation between mental ability and academic achievement that normally exists in a population suggested that another

division of the pairs into school performance levels might also reveal that low achievers profited least from a Unified Science program in regard to the criterion variable.

Paired measures were then sorted into three groups on the basis of academic achievement in science scores. Where an "A" yearly grade rated 4.0; B, 3; C, 2 and D, 1, three levels of near equal size were established. Mean academic achievement scores in the third triad ranged from 3.1 to 4.0, 2.1 to 2.9 in the second triad and 1.0 to 2.0 in the first triad.

The analyses of mean differences at the three levels, presented in Tables XXI, XXII, and XXIII revealed three significant facts.

- (1) Students of high science academic achievement in the experimental group showed the greatest gains over their counterparts in the control group.
- (2) Students of the experimental group in the middle range of academic achievement scored significantly higher than their matches.
- (3) There was no significant difference in the mean scores of the students in the lower level of academic achievement.

Significance of Differences between Means of Paired Measures Where Course Work Background of Control Groups Varied

The science curriculum in the control school was differentiated only at the ninth grade level. Students with generally high academic ability who evidenced a desire to continue their science studies beyond the ninth grade were counseled into Earth Science, while students with generally less ability and less science interest were directed to enroll in Physical Science. An examination of the mental ability, academic achievement scores, and grade level of the subjects in the control group

TABLE XXI

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT HIGHER THIRD ACADEMIC
ACHIEVEMENT LEVEL IN SCIENCE
(RATING, 3.1 TO 4.0)

	Experimental A	Control B	D	D ²
Sum	950	708	242	3282
Mean	39.58	29.50	10.08	
N	= 24		H ₀ : μ_{A-B} = 0	
SD ²	= 35.14		α = .05	
$\bar{SD}$	= 1.24		v = 23	
t	= 8.13		t(α :v) = 2.07	
Reject H ₀				

TABLE XXII

TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT MIDDLE ACADEMIC ACHIEVEMENT
LEVEL IN SCIENCE (RATING, 2.1 - 3.0)

	Experimental A	Control B	D	D ²
Sum	903	757	146	2472
Mean	27.36	22.94	4.42	
N	= 33		H ₀ : μ_{A-B} = 0	
SD ²	= 35.14		α = .05	
$\bar{SD}$	= 1.31		v = 32	
t	= 3.37		t(α :v) = 2.04	
Reject H ₀				

TABLE XXIII

TEST OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT LOW ACADEMIC ACHIEVEMENT LEVEL
IN SCIENCE (RATING, 1.0 - 2.0)

	Experimental A	Control B	D	D ²
Sum	422	415	7	1015
Mean	20.10	19.73	0.33	
N	= 21		H ₀ : μ_{A-B}	= 0
SD ²	= 48.22		α	= .05
$\bar{SD}$	= 1.55		v	= 20
t	= 0.21		t(α :v)	= 2.09
Accept H ₀				

revealed that the dual track system in the ninth grade was not homogeneous for ability or achievement, nor was Physical Science necessarily a terminal course. Of the 29 of 78 control subjects having had a physical or general science, 18 were among the upper two-thirds in academic achievement and 16 were among the upper two-thirds in measured mental ability. Eight of the 22 eleventh grade students had had physical science when in the ninth grade.

The apparent heterogeneity in the Earth Science and Physical Science groups suggested that a test of the significance of difference between mean scores on the whole treatment instrument would be appropriate for each of the background levels. Such a test could, perhaps, compare the relative effectiveness of Earth Science and Physical Science in creating a rational universe image.

Table XXIV presents data that argue strongly in favor of Unified Science over Earth Science in terms of the criterion variable. However, Table XXV presents evidence that indicates that for the students whose ninth grade science experience included Physical Science no significant difference can be detected between their scores and the scores of their matches in the experimental group.

TABLE XXIV

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT LEVEL WHERE CONTROL GROUP
EXPERIENCED EARTH SCIENCE IN NINTH GRADE

	Experimental A	Control B	D	D ²
Sum	1579	1199	380	5662
Mean	32.22	24.47	7.75	
N	= 49		H ₀ : u _{A-B}	= 0
SD ²	= 55.49		α	= .05
SD	= 1.08		v	= 48
t	= 7.18		t(α:v)	= 2.01
Reject H ₀				

Before exploring the obvious possibilities of interaction between more than one level a final single trait levels comparison was made.

Significance of Differences between Means of
Paired Measures at Sex Levels

Among the 78 pairs of subjects, 35 were female and 43 were male. It is well known that in our culture boys are generally more motivated in formal science study than girls. Standardized science tests consistently

TABLE XXV

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST AT LEVEL WHERE CONTROL GROUP
EXPERIENCED PHYSICAL OR GENERAL SCIENCE IN
THE NINTH GRADE

	Experimental A	Control B	D	D ²
Sum	696	681	15	1107
Mean	24.00	23.48	0.51	
N	= 29		H ₀ : μ_{A-B}	= 0
SD ²	= 37.91		α	= .05
$\bar{SD}$	= 1.16		v	= 28
t	= 0.44		t(α ;v)	= 2.04
Accept H ₀				

reflect this selection where boys outscore girls. The treatment instrument revealed the same tendency. However, the primary question asked of the raw data was whether significant differences existed between the mean scores of paired girls and the mean scores of paired boys.

Tables XXVI and XXVII show that the mean differences of 4.09 and 5.86 for pairs of girls and boys respectively are sufficient to claim that Unified Science has been more effective in realizing the objective of a rational universe image for boys and for girls than has been the subject-centered program in the control school. The differences between the mean differences for boys and girls ($5.86 - 4.09 = 1.77$) lies outside the standard error and indicates that Unified Science may favor the male student over the female student. Whether the magnitude of favor is the

TABLE XXVI

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST FOR GIRLS

	Experimental A	Control B	D	D ²
Sum	931	788	143	2759
Mean	26.60	22.51	4.09	
N	= 35		H ₀ : μ_{A-B} = 0	
SD ²	= 62.10		α = .05	
SD	= 1.35		v = 34	
t	= 3.03		t(α :v) = 2.03	
Reject H ₀				

TABLE XXVII

TEST OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF PAIRED
MEASURES ON TOTAL TEST FOR BOYS

	Experimental A	Control B	D	D ²
Sum	1344	1092	252	4010
Mean	31.26	25.40	5.86	
N	= 43		H ₀ : μ_{A-B}	= 0
SD ²	= 58.92		α	= .05
SD	= 1.18		v	= 42
t	= 4.97		t(α ;v)	= 2.02
Reject H ₀				

same as that within the traditional curricula cannot be computed with available data.

Determination of Combinations of Levels
Unfavorable to Unified Science

Throughout the tests of mean differences cited above there appeared to be a tendency for certain groups of paired subjects not to show a significant difference with regard to treatment instrument scores. The main hypothesis was accepted in null form when applied to pairs in (1) the lower ability tetrad, (2) the lower academic achievement in science group, and (3) the group in which the control subjects experienced Physical Science. An examination of Tables XX, XXIII and XXV revealed that for each of these levels the mean difference in paired measures on the instrument was less than 1.2, far below mean difference at all other levels. One explanation for this phenomenon may have been that the course in Unified Science was no more effective for below average science students (as defined by the sample population) than the traditional Physical Science course. A second alternative explanation was that possibly within these below average levels there were combinations of levels that were favored by subject-centered content. A third possible explanation lay in the inability of the test to measure satisfactorily the images of those students who have less capacity or less desire to think abstractly than the majority of subjects.

Table XXVIII presents tests for the significance of mean differences between pairs at mental ability, academic achievement, Earth Science and Physical Science levels each in combination with grade levels. Several compound levels such as eleventh grade low ability and

TABLE XXVIII

TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF PAIRED MEASURES
ON TOTAL TEST AT GRADE LEVELS SEPARATELY COMBINED WITH MENTAL
ABILITY LEVELS, ACADEMIC ACHIEVEMENT IN SCIENCE LEVELS
AND LEVELS WHERE THE CONTROL GROUP EXPERIENCED
PHYSICAL SCIENCE (OR GENERAL SCIENCE) OR
EARTH SCIENCE IN THE NINTH GRADE

Combined Levels	N	$\bar{A}$	$\bar{B}$	$\bar{D}$	P .05
Ninth Grade--Lower Ability	9	16.78	19.33	-2.55	Not Significant*
Ninth Grade--Medium Ability	11	27.00	22.18	4.82	Significant
Ninth Grade--Higher Ability	7	38.71	29.29	9.42	Significant
Tenth Grade--Lower Ability	15	23.07	18.80	4.27	Significant
Tenth Grade--Medium Ability	9	28.00	21.89	6.11	Significant
Tenth Grade--Higher Ability	5	41.40	34.00	7.40	Not Significant
Eleventh Grade--Lower Ability	2	21.50	26.50	-5.00	Not Significant
Eleventh Grade--Medium Ability	6	31.33	22.50	8.83	Not Significant
Eleventh Grade--Higher Ability	14	37.14	30.00	7.14	Significant
Ninth Grade--Lower Achievement	9	17.67	19.89	-2.22	Not Significant
Ninth Grade--Medium Achievement	13	27.15	23.38	3.77	Significant
Ninth Grade--Higher Achievement	5	41.40	28.00	13.40	Significant
Tenth Grade--Lower Achievement	11	21.82	19.09	2.73	Not Significant
Tenth Grade--Medium Achievement	11	26.36	20.55	5.81	Significant
Tenth Grade--Higher Achievement	7	39.29	30.43	8.86	Significant
Eleventh Grade--Lower Achievement	1	23.00	26.00	-3.00	Not Significant
Eleventh Grade-Medium Achievement	9	28.89	25.22	3.67	Not Significant
Eleventh Grade-Higher Achievement	12	39.00	29.58	9.42	Significant
Ninth Grade Physical Science	4	13.50	20.00	-6.50	Significant
Ninth Grade Earth Science	23	28.92	23.61	5.31	Significant
Tenth Grade Physical Science	17	24.41	22.35	2.06	Not Significant
Tenth Grade Earth Science	12	32.50	22.42	10.08	Significant
Eleventh Grade Physical Science	8	28.38	27.63	0.75	Not Significant
Eleventh Grade Earth Science	14	37.43	27.64	9.79	Significant

Note:

This table should be read as follows: Of the nine pairs of ninth graders in the lower ability group the mean score for the experimental group was 16.78 and the mean score for the control group was 19.33. The mean difference of 2.55 favoring the control group was not significant at the five per cent level.

eleventh grade low achievement contained unusably small samples and were included only to provide continuity in the presentation.

Tenth grade pupils of the experimental group scored significantly higher than the tenth grade pupils of the control group at the lower ability level. However, while the mean differences for tenth grade pupils at low achievement and physical science levels were positive, superiority could not be claimed statistically.

The mean scores of ninth grade pupils of the experimental group were exceeded by their pairs at low ability and low achievement levels. At the Physical Science level the difference in mean scores actually statistically favored the ninth grade control group. It should be noted, however, that the sample size in the latter test was four.

Thus it appeared from the data that at the ninth grade level where ability and performance levels were below average for the sample the instrument indicated a tendency to favor the traditional subject-centered curriculum, especially the course Physical Science as opposed to Earth Science. The performance of the ninth grade at first and second ability and achievement levels and at the Earth Science level significantly favored Unified Science. At tenth and eleventh grade levels, where sample size was sufficiently large, the scores generally reflect favorably to Unified Science except at Physical Science levels.

The values of combining other levels for purposes of discovering combined effects cannot be denied. The total sample, however, was so small that by the time two or more selective factors were imposed, the sample size of paired measures became reduced to an unusable number.

III. Analyses Based upon Performance within
Parts of the Total Instrument

The criterion instrument consisted of 65 items each measuring one of five features of a rational universe image. For the experimental and the control group there was therefore a possibility of responding correctly to a total of 5070 items. As will be noted in Table XXIX the difficulty of the examination can be reflected in the ratio of items answered most correctly to total items. For the experimental group this value was 0.45 and for the control group the value was 0.37. However, it was noted that whereas .09 of all items were not attempted by the experimental group, .05 of all items were not attempted by the control

TABLE XXIX

DISTRIBUTION OF TOTAL ITEMS ON CRITERION INSTRUMENT
 SCORED AS CORRECT, INCORRECT AND NOT ATTEMPTED

	Experimental A	Control B
Total number of items	5070	5070
Number of items answered correctly	2267	1883
Ratio of correct items to total	0.45	0.37
Number of items not attempted	476	242
Ratio of items not attempted to total	0.09	0.05
Number of items answered incorrectly	2327	2945
Ratio of incorrect items to total	0.46	0.58
Ratio of correct items to total attempted	0.49	0.39

group. Whether the administrators did not subscribe to the 40-minute time limit or whether the students of the control and experimental school were conditioned to respond differently to puzzling items, was not ascertained. The difference in total items, 234, was large enough to calculate a ratio of correct items to total items attempted. The resulting values of 0.49 and 0.39 for the experimental and control groups respectively varied enough to warrant the additional use of the relationship in subsequent analyses of performances within parts of the total instrument.

Test items measuring the five features of a rational universe image were randomly distributed throughout the instrument and in no way were they identified to the examinee. The features by reference number and the number of test items measuring each were--

Feature	Number of items
1. Phenomena reflect the interdependencies and interactions of matter, energy and life.	24
2. The forms of matter, energy and life subscribe to a natural orderliness.	12
3. Things and events are perceived in accurate perspective in relation to time and space.	15
4. Real problems in controlling, predicting and interpreting events in the universe transcend single disciplines.	6
5. Man's relationship with his universe, as an observer and as a part of the "web" is perceived realistically.	8

Responses to individual items were separately tabulated for the following analyses.

Significance of Differences between Means of
Paired Measures for Features at All Levels

Tests for the significance of differences between means of paired measures were imposed upon the data after determining the number of correct responses to a given test item for the entire experimental and control groups. The values for each test item were then grouped according to features. In addition, accompanying tests for each feature were carried out using the percentage of correct responses to the total number of attempted responses to each test item. Thus each analysis of a feature was two-parted; first, the means of the raw scores were compared, second, the means of scores scaled to the percentage of correct responses to the total number of correct and incorrect responses were compared. The double tests for each feature appear in twin Tables XXX through XXXIV.

Tests of Feature I. In Table XXX(A), it will be noted that while a mean of 34.04 of 78 examinees of the experimental group responded correctly to the 24 items included in this feature, the 30.62 of 78 examinees in the control group who also responded correctly was not sufficiently different to make the mean difference of 3.42 significant at the 5 per cent level. However, the mean difference of 5.71 determined by the ratio of total correct responses to total items attempted, analyzed in Table XXX(B) was significant at the 5 per cent level.

Tests of Feature II. Table XXXI(A) and (B) indicates that the responses of examinees in the experimental group were significantly more favorable to the realization of the objective stated as Feature II than the responses of examinees in the control group.

TABLE XXX
TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF
PAIRED MEASURES FOR FEATURE I

	Experimental A	Control B	D	D ²
A. Means derived from total correct responses				
Sum	817	735	82	1956
Mean	34.04	30.62	3.42	
<div> <div> N = 24 SD² = 69.80 SD = 1.74 t = 1.97 </div> <div> H₀: μ_{A-B} = 0 α = .05 v = 23 t(α:v) = 2.07 </div> </div>				
Accept H ₀				
B. Means derived from ratio of total correct responses to total items attempted				
Sum	1105	968	137	4035
Mean	46.04	40.33	5.71	
<div> <div> N = 24 SD² = 135.53 SD = 2.43 t = 2.35 </div> <div> H₀: μ_{A-B} = 0 α = .05 v = 23 t(α:v) = 2.07 </div> </div>				
Reject H ₀				

TABLE XXXI
TESTS OF SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF
PAIRED MEASURES FOR FEATURE II

	Experimental A	Control B	D	D ²
A. Means derived from total correct responses				
Sum	445	342	103	2319
Mean	37.08	28.50	8.58	
<div> <div>N = 12</div> <div>SD² = 119.63</div> <div>S$\bar{D}$ = 3.29</div> <div>t = 2.61</div> </div> <div> <div>H₀: μ_{A-B} = 0</div> <div>α = .05</div> <div>v = 11</div> <div>t(α:v) = 2.20</div> </div>				
Reject H ₀				
B. Means derived from ratio of total correct responses to total items attempted.				
Sum	633	459	174	5130
Mean	52.75	38.25	14.50	
<div> <div>N = 12</div> <div>SD² = 217.25</div> <div>S$\bar{D}$ = 4.44</div> <div>t = 3.27</div> </div> <div> <div>H₀: μ_{A-B} = 0</div> <div>α = .05</div> <div>v = 11</div> <div>t(α:v) = 2.20</div> </div>				
Reject H ₀				

Tests of Feature III. Table XXXII(A) and (B) indicates that the responses of examinees in the experimental group were significantly more favorable to the realization of the objective stated as Feature III than the responses of examinees in the control group.

Tests of Feature IV. Table XXXIII(A) and (B) indicated that the responses of examinees in the experimental group were not significantly more favorable to the realization of the objective stated as Feature IV than the responses of examinees in the control group.

Tests of Feature V. Table XXXIV(A) and (B) indicated that the responses of examinees in the experimental group were significantly more favorable to the realization of the objective stated as Feature V than the responses of examinees in the control group.

Summary of feature tests. The mean number of students of the experimental group, considering both the total number of correct responses and the ratio of correct responses to the total items attempted was significantly larger in paired measures for Features II, III and V than the means of the control group. No significant difference can be argued for the mean difference of 6.84 students and 11.82 per cent in the test for Feature IV. The latter test involved the small sample size of six. Feature I significantly favored the experimental group on the B test. No significant difference could be claimed for the difference between total correct responses in Feature I.

TABLE XXXII
TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF
PAIRED MEASURES FOR FEATURE III

	Experimental A	Control B	D	D ²
A. Means derived from total correct responses				
Sum	530	440	90	1304
Mean	35.33	29.33	6.00	
<div> <div> $N = 15$ $SD^2 = 50.93$ $\bar{SD} = 1.91$ $t = 3.14$ </div> <div> $H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 14$ $t(\alpha:v) = 2.14$ </div> </div>				
Reject H ₀				
B. Means derived from ratio of total correct responses to total items attempted				
Sum	766	593	173	3337
Mean	51.07	39.53	11.53	
<div> <div> $N = 15$ $SD^2 = 89.53$ $\bar{SD} = 2.53$ $t = 4.56$ </div> <div> $H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 14$ $t(\alpha:v) = 2.14$ </div> </div>				
Reject H ₀				

TABLE XXXIII

TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF
 PAIRED MEASURES FOR FEATURE IV

	Experimental A	Control B	D	D ²
A. Means derived from total correct responses				
Sum	237	196	41	611
Mean	39.50	32.66	6.84	
$N = 6$ $SD^2 = 55.04$ $\bar{SD} = 3.32$ $t = 2.06$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 5$ $t(\alpha:v) = 2.57$				
Accept H_0				
B. Means derived from ratio of total correct responses to total items attempted				
Sum	329	258	71	1815
Mean	54.83	43.00	11.82	
$N = 6$ $SD^2 = 162.79$ $\bar{SD} = 5.71$ $t = 2.07$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 5$ $t(\alpha:v) = 2.57$				
Accept H_0				

TABLE XXXIV

TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF
 PAIRED MEASURES FOR FEATURE V

	Experimental A	Control B	D	D ²
A. Means derived from total correct responses				
Sum	238	170	68	884
Mean	29.75	21.25	8.50	
$N = 8$ $SD^2 = 38.25$ $\bar{SD} = 2.34$ $t = 3.63$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 7$ $t(\alpha:v) = 2.36$				
Reject H_0				
B. Means derived from ratio of total correct responses to total items attempted				
Sum	346	229	117	2429
Mean	43.25	28.62	14.63	
$N = 8$ $SD^2 = 89.59$ $\bar{SD} = 3.58$ $t = 4.09$				
$H_0: \mu_{A-B} = 0$ $\alpha = .05$ $v = 7$ $t(\alpha:v) = 2.36$				
Reject H_0				

Item Analysis

The form of the instrument employed in this study was the fifth draft. The sixth draft will have been built upon the findings resulting from an item analysis involving the tests of the experimental subjects and the ratings of the validators reported in Table XIX. In addition to statistically purifying individual test items as regards the discriminating power of the multiple choice items, students in Unified Science classes will have been asked to respond to items orally in evaluating sessions. Of further value in making the fifth revision will have been the editorial comments of fifth draft validators. Since the instrument as used was judged valid for the purposes of this study, the data and product of the analysis were omitted from this report.

The reliability of the fifth draft of the test was calculated by the odd-even method using the Spearman-Brown prophecy formula described in Chapter IV. The statistics presented in Table XXXV yielded a coefficient of reliability for the tests of the 78 subjects of the experimental group of 0.86. The value for the fourth draft using students prepared in the traditional sciences was 0.80.

IV. Other Findings

The performance on the criterion instrument by the 497 ninth grade science, Biology and Chemistry students of the control school are compared with treatment instrument scores achieved by the control and experimental groups in Table XXXVI. The scores achieved by the selected control groups at grade levels did not depart widely from the mean and median scores of the general science population of the school. At the

TABLE XXXV

RELIABILITY COEFFICIENT DETERMINATION (ODD-EVEN METHOD) FOR
FIFTH DRAFT OF CRITERION INSTRUMENT USING THE SEVENTY-
EIGHT EXPERIMENTAL GROUP SUBJECTS

	Odd Items	Even Items	x^2	y^2	xy
Sum	1103	1159	1633	2421	1504
Mean	14.1	14.8			
S.D.	4.57	5.57			
r_{hh}	.76				
r_{xx}	.86				

ninth and eleventh grade levels the selected control groups showed a slight to about a two-point advantage over the population from which they were selected. The tenth grade selected control group lagged approximately two points below the population from which it was selected. The data are generally as expected since on criteria such as mental ability and academic achievement the mean values for the ninth and eleventh grade treatments groups rated higher, and in the tenth grade lower, than the mean values for the control school population.

V. Summary

In the main analyses of data the significance of differences between the means of paired measures were determined at the five per cent level of significance using the two tailed t test. Table XXXVII summarizes the fourteen major comparisons of scores between the experimental and control groups. It should be noted that the rational universe images of

TABLE XXXVI
PERFORMANCE ON CRITERION INSTRUMENT OF CONTROL SCHOOL
POPULATION COMPARED WITH SCORES OF CONTROL
AND EXPERIMENTAL GROUPS

Group	Number	Mean	Median
Earth Science and Physical Science	160	22.9	22
Control	27	23.1	23
Experimental (Unified Science I)	27	26.6	26
Biology	214	24.3	24
Control	29	22.4	21
Experimental (Unified Science II)	29	27.8	26
Chemistry	123	25.5	26
Control	22	27.64	27
Experimental (Unified Science III)	22	34.1	35

the experimental group measured significantly higher than those of the control group in eleven of the tests. No differences were detected at the lower ability level, the lower academic achievement level, and at the level established by the control group's experience with Physical Science in the ninth grade.

Analyses of the above three non-significant levels in combination with grade levels (summarized in Table XXVIII) tended to indicate that the generalized Physical Science as taught to the slower learning student may be as effective as Unified Science. However, the acuity of these

combined levels tests was reduced by the smallness in size of the samples.

A second series of analyses compared the performances of the control and experimental groups with reference to each of five featural divisions of the treatment instrument. Students of Unified Science were favored in four of the featural divisions. No significant difference in performance on items measuring a fifth feature could be claimed by either the experimental or control groups.

TABLE XXXVII
SUMMARY OF FINDINGS IN THE MAIN SERIES OF ANALYSES

Levels	N	$\bar{A}$	$\bar{B}$	$\bar{D}$	P .05
All Combined	78	29.16	24.10	5.06	Significant
Ninth Grade	27	26.63	23.07	3.56	Significant
Tenth Grade	29	27.76	22.38	5.38	Significant
Eleventh Grade	22	34.14	27.64	6.50	Significant
Higher Ability	26	38.38	30.58	7.80	Significant
Medium Ability	26	28.35	22.15	6.19	Significant
Lower Ability	26	20.77	19.58	1.19	Not Significant
Higher Achievement	24	39.58	29.50	10.08	Significant
Medium Achievement	33	27.36	22.94	4.42	Significant
Lower Achievement	21	20.10	19.73	0.33	Not Significant
Earth Science	49	32.22	24.47	7.75	Significant
Physical Science	29	24.00	23.49	0.51	Not Significant
Girls	35	26.60	22.51	4.09	Significant
Boys	43	31.26	25.40	5.86	Significant

Note:

This table should be read as follows: Of the twenty-nine pairs of students in the tenth grade level the mean score for the experimental group was 27.76 and the mean score for the control group was 22.38. The mean difference of 5.38 favoring the experimental group was significant at the five per cent level.

CHAPTER VII

SUMMARY, CONCLUSIONS AND IMPLICATIONS

In this chapter the background, procedures and findings of the study are summarized: conclusions based upon the analyzed data are stated, and the implications of the study for educational practice and further research are discussed.

I. Summary

The teaching of secondary school science has rested upon a content organization of physics, chemistry and life science for as long as science has been a part of the high school curriculum. This traditional departmentalization of science at general education levels has been criticized by science educators and scientists throughout the twentieth century for not providing maximally for the scientific literacy of all citizens and for not presenting a true picture of the methods and structures of science to students at any level of sophistication. Several curricular mutations with integrative qualities that have survived the tests of general acceptance include: the surveys of science at junior high school levels (General Science), the fusions of botany and zoology (Biology) and the most recent development of courses in combined physical sciences. During the 1930's two major trends toward a science integration that promised to conjoin all the science in unitary studies were discussed, recommended and tried out in a

vigorous climate that ended abruptly with World War II. One trend focused upon interpretive generalizations as explicated in the Thirty-first Yearbook of the National Society for the Study of Education. The foci for science study as promulgated by the Progressive Education Association were problems of everyday living.

The political pressures, economic demands for scientific and technical manpower, the explosion of scientific discovery and the apparent lag of high school science behind modern science as known to science scholars stimulated a series of distillations of science content projects beginning in the middle 1950's. The products of the studies were courses in biology, chemistry and physics where the presentation of content and method was organized around central themes.

The established organization of science into discrete disciplines is being challenged. Matter, energy and life are becoming recognized as not mutually exclusive studies for either specialists or generalists. To know the natural world one must see the interconnections of things and events within phenomena. The real problems in life, the solutions to which formal school experience in science can contribute are not unidisciplinary. To see in depth and breadth a universe composed of matter, energy and life a student in the modern school must take course work in physics, chemistry and biology. Even then, the internal integration of a whole picture of the world is left very much to chance.

The nature of the learning process as it is currently understood is predicated on the model of a whole organism reacting with the whole of its environment. Science taught as separate subjects at general education levels seems out of phase with such accepted understandings.

A frontier in science curriculum research is the development of integrated articulated science programs for grades K-12. Within these programs, continuous threads of concepts are perceived to spiral vertically during the span of school experience while they are also crosswoven at grade levels into organizations of course content and method that integrate naturally merging concepts.

The appropriate change at the secondary school level will be a dissolution of subject matter boundaries as integrated sequences of science courses are structured of the big ideas of science as they prepare, motivate and interest adolescents who will become effective citizens in our society.

One pilot program that has been under development since 1958 was initiated at the University School at The Ohio State University. During the academic year 1959-1960 the first course of the sequence, Unified Science I, was instituted for the entire ninth grade class in the laboratory school. Throughout the succeeding three years Unified Science was introduced at the next higher grade level replacing the classical science subject. Unified Science I and II were required of all students while Unified Science III and IV were elective courses.

As part of the rationale for a Unified Science at the high school level, it was postulated that the picture of the real world held by students who had formally studied science in unified context would be more embracing of things and events in the environment than the pictures held by students who had experienced the highest quality of traditional subject-centered approaches to the learning of science. The mental

picture that reflects the universe as a whole has been phrased, a rational universe image.

The study herein reported was a measurement-comparison of the volumes of rational universe images held by 78 matched pairs of students with high school preparation in a Unified Science program (experimental group) and preparation in a subject-centered program (control group). The experimental design was a treatment by levels with one observation per matched pair. Students of the ninth, tenth and eleventh grades were matched so as to control the continuous variables: mental ability, age and academic performance in science; and the non-ordered categories: sex, grade level, and years of sequential science from the ninth grade. One member of each pair experienced only Unified Science in The Ohio State University School, the other member experienced subject-centered science in the Worthington (Ohio) High School.

The levels instruments were an Otis Mental Ability test and the cumulative student records of both schools. The treatment instrument was a 65-item multiple-choice test that purported to measure a rational universe image characterized by five features. The treatments test was developed through four revisions among which it was subjected to validating scrutiny by educators, scientists, teachers, high school and college students, and laymen. The fourth draft was statistically tested for reliability in a school of comparable quality with the control and experimental schools.

Levels and treatments tests were administered to all science students in the ninth, tenth and eleventh grade science classes of the control and experimental school on successive days during the week of

May 13, 1962. Matches were effected with 78 students of the experimental group from a selected population of approximately 500 students in 20 classes in the control school. After the highest possible quality matches were assured, performances of matched pairs were compared.

The main hypothesis stated in null form for statistical testing purposes was--

There are no significant differences between the rational universe images of students who had studied Unified Science and the rational universe images of students who had studied science in a subject-centered context.

The main analyses of data obtained determined the significance of differences between means of paired measures using the t distribution as the statistical model. All conclusions were argued at the 5 per cent level of significance for two-tailed tests. Statistical tests were imposed upon test results of paired measures grouped at all combined, mental ability, academic achievement in science, sex and background in course work in science levels. Other tests sought significant differences between paired measures at combinations of grade levels with ability, academic achievement in science and background in course work levels. A second series of tests determined the effective realization of five measured featural parts of a rational universe image.

Significant differences between the means of paired subjects that favored the experimental treatment were argued for the following:

1. All levels combined
2. Ninth grade level
3. Tenth grade level

4. Eleventh grade level
5. Upper third mental ability level (Gamma IQ, 125-140)
6. Middle third mental ability level (Gamma IQ, 112-124)
7. Upper academic achievement in science level (Rating 3.1-4.0)
8. Middle academic achievement in science level (Rating 2.1-3.0)
9. Level where control group experienced Earth Science in ninth grade
10. Female level
11. Male level
12. Combination of ninth grade level and upper third mental ability level (Gamma IQ, 125-140)
13. Combination of ninth grade level and middle third mental ability level (Gamma IQ, 112-124)
14. Combination of tenth grade level and lower third mental ability level (Gamma IQ, 92-111)
15. Combination of tenth grade level and middle third mental ability level (Gamma IQ, 112-124)
16. Combination of eleventh grade level and upper third mental ability level (Gamma IQ, 125-140)
17. Combination of ninth grade level and upper academic achievement in science level (Rating 3.1-4.0)
18. Combination of ninth grade level and middle academic achievement in science level (Rating 2.1-3.0)
19. Combination of tenth grade level and upper academic achievement in science level (Rating 3.1-4.0)
20. Combination of tenth grade level and middle academic achievement in science level (Rating 2.1-3.0)
21. Combination of eleventh grade level and upper academic achievement in science level (Rating 3.1-4.0)
22. Combination of ninth grade level and level where control group experienced Earth Science in ninth grade

23. Combination of tenth grade level and level where control group experienced Earth Science in ninth grade
24. Combination of eleventh grade level and level where control group experienced Earth Science in ninth grade

Significant differences between the means of paired measures that favored the control treatment was argued for:

1. Combination of the ninth grade level with the level where the control group experienced Physical Science.

No significant differences between the means of paired measures were argued for the following:

1. Lower third mental ability level (Gamma IQ, 92-111)
2. Lower academic achievement in science level (Rating 1.0-2.0)
3. Level where control group experienced Physical Science or General Science in the ninth grade
4. Combination of the ninth grade level and lower third mental ability level (Gamma IQ, 92-111)
5. Combination of the tenth grade level and upper third mental ability level (Gamma IQ, 125-140)
6. Combination of eleventh grade level and middle third mental ability level (Gamma IQ, 112-124)
7. Combination of eleventh grade level and lower third mental ability level (Gamma IQ, 92-111)
8. Combination of ninth grade level and lower academic achievement in science level (Rating, 1.0-2.0)
9. Combination of tenth grade level and lower academic achievement in science level (Rating, 1.0-2.0)
10. Combination of the eleventh grade level and medium academic achievement in science level (Rating, 2.1-3.0)
11. Combination of eleventh grade level and lower academic achievement in science level (Rating, 1.0-2.0)

12. Combination of tenth grade level and level where control group experienced Physical Science or General Science in the ninth grade
13. Combination of eleventh grade level and level where control group experienced Physical Science or General Science in the ninth grade

The analyses of features within the criterion instrument revealed the following understandings to favor significantly Unified Science with respect to the total number of correct responses to items of the feature, and the ratio of students responding correctly to the number of students attempting each item within the featural division.

- Feature 2. The forms of matter, energy, and life subscribe to a natural orderliness.
- Feature 3. Things and events are perceived in accurate perspective in relation to time and space.
- Feature 5. Man's relationship with his universe, as an observer and as a part of the "web" is perceived realistically.

Response to the following feature was divided. No significant difference could be claimed where failures to respond to items were scored as incorrect responses. However, the scores significantly favored Unified Science when failure to respond to an item was not regarded as an incorrect response.

- Feature 1. Phenomena reflect the interdependencies and interactions of matter, energy and life.

The following feature of six items failed to exhibit a significant difference for either of the above described analyses.

- Feature 4. Real problems in controlling, predicting and interpreting events in the universe transcend single disciplines.

II. Conclusions

The study has shown that course content and method organized upon a superstructure of the big ideas of science, unrestricted by subject matter boundaries, accomplished the goal of enabling students to form a more inclusive rational image of the universe than did students whose school science experiences were subject centered. While this statement is actuarially true, the gain in understanding cannot be claimed for all levels of the sample population, nor for all features of a rational image.

The effectiveness of Unified Science in realizing the objective of a rational universe image clearly favored students, regardless of grade level and sex, whose measured mental abilities and academic achievements levels were located within the average and above average divisions of the sample. Matched pairs within the lower third of scholarly promise and productivity and who in the control school were usually guided to Physical Science in the ninth grade, tended to show less differences between scores on the criterion instrument. Within the groups of pairs whose measured Gamma IQ's ranged from 92 to 111, or whose academic achievement in science averaged within the range 1.0 to 2.0 the differences in scores favored Unified Science upper classmen more than lower classmen. At ninth grade levels the control individuals outscored their counterparts, significantly so, at the Physical Science level. These results imply that the sequence in Unified Science was directed primarily to higher ability students, or that the criterion instrument became increasingly less effective in measuring a rational universe image as grade, ability and achievement levels are descended,

or that Physical Science as taught in the control school was as effective as Unified Science in teaching for a rational universe image.

In but one of the features of a rational universe image did the total experimental group fail to show a significant advantage over the control group. Here, although the numerical difference in mean number and percentage of subjects responding correctly leaned strongly toward Unified Science the sample size of six imposed a high critical volume for t . Nevertheless, it cannot be argued that Unified Science is effective in teaching that real problems of science transcend the single disciplines.

III. Implications and Recommendations

The findings of this study have implications for practice and further research in secondary science education.

When the facts, concepts and methods of science are taught as a unity of relationships, the relationships are learned better than when the same facts, concepts and methods are presented in the context of isolated disciplines. Students who have studied Unified Science have demonstrated a superior understanding of the unity and orderliness in nature. They understand well the role of man as a part of the matter-energy-life complex, his role as an observer, a predictor and controller of the natural world. They can use in their thinking an extended feeling for space and time dimensions. Within any specific phenomenon they are prepared to see a large number of pertinent components yielding insights that stimulate cogent appreciations. Since greater insight into the nature of things tends to stimulate the quest for more

understanding, their predisposition to inquiry may reasonably be expected to be enhanced.

However, the specific course sequence in Unified Science involved in this study revealed certain significant limitations. The effectiveness of Unified Science increased with grade level and with general academic ability. The subjects involved in the study were well above the national norms in mental ability. The so-called lower group (Gamma IQ, 92-111) fell close within the range of what is considered the national average IQ (90-110). The course in Unified Science admittedly had been directed primarily toward the academically talented high school student.

To discover whether Unified Science significantly enlarges the rational universe images of the average and below average student the following studies are recommended.

1. Develop programs in Unified Science in public schools where the distribution of mental abilities and academic incentive is more nearly normal for the population.

2. Recast the criterion instrument employed in the reported study so as to reduce the levels of abstraction of items to levels favoring slower students. This revised instrument might then be employed in a re-examination of the pairs in the reported study and as an evaluation tool for course developments as described in (1) above.

3. Determine within the control school whether a sequence of science beginning in the ninth grade with Earth Science or a sequence of science beginning in the ninth grade with Physical Science contributes more to a rational universe image. Such a study would be applicable in

almost any large school where differentiation begins in the ninth grade. Where placement is determined by ability and achievement, test results would need to be adjusted to correlating indices.

4. Determine whether students at all levels in a ninth grade general science, biology, chemistry and physics sequence show significant differences between matched students in a four-year sequence of specialized science studies with regard to a rational universe image.

Studies (3) and (4) above would tend to answer the questions arising in the reported study regarding the apparent equal effectiveness of a unified science and a sequence of special science based upon a ninth grade general science. If no difference be detected in study (3) above, the effects detected in the study would then more certainly have been caused by ability and/or achievement levels. If advantage for the generalized course be shown in (3) and (4) above it would then be appropriate to test the hypothesis that Unified Science is as effective as a specialized sequence of science courses founded upon a ninth grade general science.

The usually poorer performance of girls than boys in science was reaffirmed in this study. While the advantage of Unified Science over subject-centered science was significant for boys and for girls, it was not established whether Unified Science raised the levels of achievement of girls above a known disparity level. Were there elements implicit in Unified Science to reduce performance differences between the sexes, the cause of Unified Science in general education would certainly be enhanced.

Critics may claim that although Unified Science did realize the objective of a rational universe image more effectively than did subject-centered science, the gain may have been made at the expense of acquisition of basic facts of science, important relationships or depth within an area, or ability to solve problems. The students involved in the reported study should be compared on measures of future performances in science and cognate areas wherever situations, contrived, as in another testing program, or natural, as in student decisions to undertake further school work in science, are inviting to the investigator.

The instrument used to measure the criterion variable of this investigation needs to be refined still further for most efficient use at the level for which it was intended. A recasting for lower ability and lower incentive high school level use has already been discussed. Many universities and teacher education institutions claim to provide general education courses and comprehensive general science programs that impart a literacy that enables students to view the universe as a whole. The instrument after appropriate modification should be adaptable to these levels for use as an evaluation tool.

IV. Recommendations for Research in Unified Science Education beyond the Scope of the Reported Study

Listed below are problem areas that should be explored before Unified Science can or cannot be recommended for general acceptance as a curriculum superstructure for the secondary school.

1. To what extent are students, teachers, scientists, laymen and university admission boards disposed to accept Unified Science as a substitute for the currently accepted high school science subjects?

2. What constitutes the optimum pre-service and in-service education for teachers of Unified Science? Are there any unique characteristics a teacher of Unified Science must possess in order to be effective?

3. At what level can consensus be achieved among scientists and educators regarding the identification and placement of the generalizations of science?

4. Does Unified Science achieve the objective of teaching for critical thinking as well as does the science subject-centered approach?

5. What are the best ways for reorganizing a traditional science program into a Unified Science program?

6. What laboratory and field experiences are uniquely adaptable to Unified Science? What facilities and equipment would be most useful?

7. Should content of Unified Science be presented primarily to students by way of textbook series that accompany a sequence of courses, a series of unit texts with topical treatments, a reference library, or combinations of the three?

APPENDIX A

Unified Science I

Unified Science II

Unified Science III

Unified Science IV

Unit I of Unified Science I

References Used in Unified Science

Unified Science I

Orderliness of Nature

- I. Matter, energy and life identified as contents and concerns of science
 - A. Properties of matter
 - 1. General
 - 2. Specific
 - B. Properties of energy
 - 1. General
 - 2. Specific
 - C. Properties of life
 - 1. General
 - 2. Specific
 - D. Names and symbols
 - E. Classification
 - 1. Distinguishing characteristics and grouping
 - 2. Model scheme
- II. Order in matter
 - A. Forms of ordinary matter
 - 1. Solid, liquid, gas
 - 2. Organic-inorganic
 - 3. Mixtures and pure substances
 - 4. Pure substances--compounds and elements
 - 5. Elements as species of matter
 - B. Significant characteristics of elements (Bohr model)
 - C. Periodicity
 - D. Natural beauty of periodic table
- III. Order in energy
 - A. Radiant energy
 - 1. Waves, $\lambda = v/f$
 - 2. Electromagnetic radiation distinguished
 - B. Bands of electromagnetic radiation
 - 1. Radio
 - 2. Infra-red
 - 3. Visible
 - 4. Ultra-violet
 - C. Generation and detection
 - D. Development of spectrum
- IV. Order among animals
 - A. Established classification scheme
 - 1. Phyla . . . species
 - 2. Survey of phyla
 - 3. Ordering phyla toward increasing complexity

- B. Reflection of evolution in ordered scheme
 - 1. Comparative anatomy
 - 2. Embryology
 - 3. Paleontology
- V. Equivalence of matter and energy

The Sun

- I. Dimensions of the sun
 - A. Volume, mass and density
 - B. Temperatures
 - C. Position in universe
 - D. Motions
 - E. Compared with other stars
- II. Surface characteristics
 - A. Surface layers
 - B. Sun spots
 - 1. Prominences
 - 2. Magnetic storms
 - a. Auroras
 - b. Cyclic occurrence
 - 3. Rotation of sun
- III. Composition of sun
 - A. Spectroscopy
 - 1. Instruments
 - 2. Types of spectra
 - 3. Qualitative analysis
 - B. Interpretation of solar spectra
 - C. Doppler effect
- IV. Star as a thermonuclear reactor
 - A. Fusion reactions
 - B. Fission reactions
 - C. Prout hypothesis
 - D. Packing fraction curve
- V. Life histories of planets, stars and universe
- VI. Star as fountainhead of energy

Effects of Sun on Earth Processes Part I. Meteorology

- I. Atmosphere
 - A. Composition
 - B. Vertical structure
 - C. Humidity
 - D. Pressure
 - E. Heat
- II. Radiant energy, atmosphere and earth interaction
 - A. Reflection, transmission, absorption
 - B. Greenhouse effect

- III. Dynamics of earth's atmosphere
 - A. Wind and general circulation
 - B. Air masses
 - C. Weather fronts and storm structure
 - D. Precipitation
 - E. Weather mapping
- IV. Synoptic meteorology
- V. Climatology
- VI. Weather and geological change

Part II. Photosynthesis

- I. Plant anatomy and function
 - A. Gross
 - B. Cellular
- II. Kinds of plants
 - A. Photosynthetic
 - B. Nonphotosynthetic
 - 1. Free living
 - 2. Symbiont
- III. Photosynthetic process
 - A. Role of radiant energy
 - 1. Intake of low energy matter
 - 2. Photolysis--electrolysis
 - 3. Catalysis
 - 4. Chlorophyll
 - B. Carbon fixation
 - 1. Biochemical synthesis--production of sugar
 - 2. Secondary synthetic reactions
- IV. Analysis of factors controlling photosynthesis
 - 1. Light
 - 2. CO₂
 - 3. Water
 - 4. Chlorophyll
 - 5. Temperature
- V. Food pyramids
- VI. Struggle for place in sun

Part III. Summary

Water cycle and carbon cycle: entropy

Unified Science II

Part I. The Organism as an Open Dynamic System

- I. Species study--the earthworm
 - A. External--internal anatomy
 - B. Phylogenetic position
 - C. Ecological niche
 - D. Structural and physiological adaptation for carrying out life processes
 - 1. Motion
 - 2. Ingestion--digestion--egestion
 - 3. Circulation
 - 4. Secretion
 - 5. Respiration
 - 6. Excretion
 - 7. Sensitivity
 - 8. Reproduction
 - E. Interspecific and Intraspecific relations
- II. Reaction chemistry in living and nonliving systems
 - A. Respiratory structures of organisms
 - B. Diffusion of gases
 - C. Nature of chemical reactions
 - 1. Chemical bond
 - 2. Reaction equations
 - 3. Mole concept
 - 4. Rates of reactions
 - 5. Heats of reactions
 - D. Oxidation reactions
 - 1. Nonliving systems
 - 2. Living systems
- III. Role of life in the matter-energy environment

Part II. Inquiry and Electricity

- I. Case history--Frogs and Batteries
 - A. Static electricity
 - B. Animal electricity
 - C. Electrochemistry
 - D. Formal study of scientific inquiry and inquirers
- II. Magnetism and electricity
 - A. Interrelations
 - B. Utility of interrelations
- III. Electrical circuitry (DC)
- IV. Nerve physiology
 - A. Nerve impulse
 - B. Electrocardiography, E.S.P. etc.
- V. Comparison of science and technology (electronics)

Part III. Facts and Mechanisms of Physical
and Organic Change

- I. Evidence of geological change
 - A. Structure of earth
 - 1. Concentric layers
 - 2. Rocks and minerals
 - 3. Static face of earth--mapping
 - B. Past, present and future change
 - C. Age of earth
- II. Mechanism of geological change
 - A. Weathering and erosion
 - 1. Running water
 - 2. Glacial ice
 - 3. Wind
 - B. Volcanism
 - C. Diastrophism
 - 1. Isostasy theory
 - 2. Other theories
 - D. Mountains
 - E. Plains
- III. Evidence of organic change
 - A. Historical record in rock
 - 1. Stratigraphy and time
 - 2. Fossils
 - 3. Interpretation of fossils
 - a. Geographic
 - b. Climatic
 - c. Rock dating
 - d. Reconstruction of organisms
 - e. Evolution
 - B. Additional evolutionary evidence
 - 1. Comparative anatomy and physiology
 - 2. Embryology
 - 3. Geological distribution of organisms
 - 4. Plant and animal breeding
 - C. Coincidence of organic change with physical change
- IV. Mechanism of organic change
 - A. Darwinian theory
 - 1. Strengths
 - 2. Weaknesses
 - B. Genetics
 - 1. Reproduction
 - 2. Mendelian inheritance
 - 3. Non-Mendelian inheritance
 - 4. Mutations
 - C. Modern evolution theory
 - D. Social impact of knowledge of evolution
 - 1. Religion and science
 - 2. Eugenics
- V. The permanence of change

Unified Science III

Part I. Quantification

- I. The art of asking meaningful questions
 - A. Recognition of provocative aspects of observable phenomena
 - B. Typical approaches to finding answers
- II. What can be quantified?
- III. Fundamental quantifications
 - A. Length (space)
 - 1. Standards
 - 2. Orders of magnitude in the universe
 - 3. Exponential notation
 - 4. Techniques of measuring
 - 5. Limitations on significant numbers
 - B. Time
 - 1. Standards
 - 2. Orders of magnitude corresponding to physical and biological events
 - 3. Techniques for measuring long and short intervals and calibration
 - C. Mass
 - 1. Standards
 - 2. Orders of magnitude corresponding to physical objects
 - 3. Techniques for estimating mass by comparison with standards
- IV. Derived quantification
 - A. Techniques of measurement of linear motion
 - B. Accelerated linear motion
 - 1. Graphic representation
 - 2. Mathematical relationships among distance, time, speed, and acceleration
 - 3. Dimensional analysis
 - 4. Magnitudes of speed observed in the universe
 - C. Scaling
 - D. Mole
 - 1. Significance of chemical formulas
 - 2. Mole concept
 - 3. Avogadro's Number
 - 4. Application of mole concept
- V. Abstract quantifications
 - A. Force
 - 1. Force as cause of accelerated motion and sources from which force arises (Newton's First Law)
 - 2. Relationships between force and motion
 - 3. Quantity force (units)
 - 4. Newton's First and Second Laws
 - 5. Gravity
 - 6. Vector representation
 - 7. Projectile motion and weightlessness

- B. Momentum
 - 1. Impulse
 - 2. Conservation
 - 3. Newton's Third Law
- C. Energy
 - 1. Work
 - 2. Kinetic energy
 - 3. Conservation
- D. Power
- E. Forces causing rotation
 - 1. Torque
 - 2. Center of mass
- VI. Human quantification
 - A. Role of quantification in studying life
 - B. Physiological characteristics
 - 1. Body measurements and ratios
 - 2. Energy dissipation
 - 3. What is "normal"?
 - C. Psychological
 - 1. Learning curve
 - 2. Individual difference vs. complexity of behavior
 - 3. Relative value of subjective data (projective drawings)
 - D. Homeostasis
 - 1. Fundamental needs
 - 2. Acquired needs

Part II. The Senses

- I. Relationship between physical world and perceived world
 - A. Stimuli and senses
 - B. Effect on various evolutionary levels of life
 - C. Similarity of information sent to brain from various sensors
- II. Light sense
 - A. Sources of light
 - B. Ray optics
 - 1. Reflection
 - 2. Refraction and Snell's Law
 - C. Biological effects of light (photodermatism, photo-orientation, photoaxis, etc.)
 - D. Detection
 - 1. Physical mechanisms
 - 2. Biological mechanisms (gross anatomy of organs)
 - E. Mechanisms of signal transmission from light sensor to brain
- III. Taste sense
 - A. Stimuli
 - 1. Variety and chemical classification
 - 2. Thresholds
 - 3. Localization of sensors
 - B. Theory of solutions
 - 1. Role of solvent
 - 2. Dissociation
 - 3. Ionization
 - 4. Conductivity

- C. Detection
- D. Relationship to olfactory sense
- IV. Sound sense
 - A. Stimuli
 - 1. Range and threshold
 - B. Physical nature of sound
 - 1. Source
 - 2. Physical model
 - C. Detection
 - 1. Anatomy of the ear
 - 2. Physical detectors
 - 3. Resonance
- V. Other senses (tactile, temperature, time, balance)
 - A. Stimuli from external world
 - B. Thresholds
 - C. Range
- VI. Extra-sensory stimuli
 - A. Ionizing radiation
 - B. Magnetic field

Part III. Models

- I. Role of models in scientific enterprise
- II. Light
 - A. Particle model
 - B. Nature of wave phenomena
 - 1. Pulses
 - 2. Periodic waves
 - C. Diffraction
 - D. Interference
 - E. Ultimate model
- III. Matter
 - A. Continuous vs. discontinuous
 - B. Bohr atom
 - C. Electron configuration and quantum numbers
 - D. Interatomic bonds
 - E. Structural chemistry
 - F. Electronegativity
 - G. Model of nucleus
- IV. Organism
 - A. Behaviorist model
 - B. Gestalt

Unified Science IV

- I. Equilibrium
 - A. Forces in equilibrium
 - 1. Vectors
 - 2. Equilibrant
 - 3. Resolution of vectors
 - 4. Composition of vectors
 - 5. Frictional forces
 - B. Pressures in equilibrium
 - 1. Hydrostatics
 - 2. Fluid dynamics
 - 3. Vapor pressure
 - a. Partial pressures
 - b. Effects of temperature, solute, physical state, etc.
 - C. Equilibria among solid, liquid and gaseous phases
 - D. Ionic equilibria
 - 1. Associated vs dissociated
 - 2. Ionic reactions that go to completion
 - 3. Relative activity of elements
 - 4. Acid-base reaction
 - E. Molecular equilibria
 - F. Nuclear equilibria
 - G. Equilibria within organisms
 - H. Populations in equilibria
 - I. Equilibria in the solar system
 - J. Equilibria in the Universe
- II. Fields
 - A. Gravitational
 - B. Electric
 - C. Magnetic
 - D. Electromagnetic
 - E. Nuclear
- III. Frontiers of science

Unit I of Unified Science I

Orderliness in Nature

Students generally enter the ninth grade with a diversity of experience in science. Good elementary and junior high school programs provided a background of knowledge, skills and understanding of the scientific process which has spiralled about certain general ideas emphasizing man's interaction with his environment. Students often have an awareness that the matter, energy and life of the world compose a dynamic system. Yet, to the adolescent mind this system is phenomenologically disjointed. The events and things in the world appear as discrete and unrelated islands. Concepts of the integrality of matter, energy and life are poorly formed.

The content of Unit I aims to develop, through an inductive approach, the idea that matter, energy and life in species form, exhibit properties so related that natural schemes of classification can be observed. The resulting Periodic Law of the Elements, Spectrum of Electromagnetic Radiation and Phylogenetic Trees of Animals and Plants are models that provide a secure concept of an orderly universe and also a foundation for subsequent studies of matter, energy and life.

A. Properties of Matter, Energy and Life:

Content	Activities
Matter, energy and life are identified as the entities of the universe and of concern to science.	Problem phenomena are presented. Interplay of matter, energy and life is explicated.
Matter is defined in terms of general properties. Specific properties enable differentiation of kinds of matter.	Mass and volume are measured using balances, calipers and fluid displacement apparatus. Densities of objects are determined. (cgs units)
Energy is defined as that which will move matter. Radiant energy forms differ in action upon matter.	Kinetic and potential energy released and possessed by objects is determined. (English units)
Life is defined as a special combination of matter and energy organized in structural units and characterized by specific processes. Organisms can be distinguished on the basis of adaptations of structures that carry out life processes.	Species of living organisms are examined to observe structural differences where common life processes are carried out. Cells are microscopically observed.

Content	Activities
<p>Things have names or symbols as time saving conveniences. Scientific names are specific, descriptive, universal. Only man symbolizes.</p>	<p>Situation exercises are contrived to point out the need for symbolizing in science.</p>
<p>Grouping on the basis of properties is a uniquely human activity. Learning and application is simplified through classification.</p>	<p>An assortment of paper figures with differentiating characteristics is shown to be more easily learned when classified than when studied as a disorderly array.</p>

B. Search for Order in Matter

Content	Activities
<p>Lowest common denominator of ordinary matter is sought through the successive rejection of solid, gas, liquid; organic, inorganic; mixture, compound, to the identification of elements.</p>	<p>Demonstration that one kind of matter can exist in states, and grouping on such a basis is artificial and confusing. "Unknown" mixtures, compounds and elements (including the same elements) are identified as mixtures, pure substances, and compounds and elements on basis of physical and chemical properties.</p>
<p>Presentation of atomic structure accounts for physical and chemical properties of different elements. Atomic number, mass, size, electron configuration, isotope, molecule, subatomic particles are presented in context.</p>	<p>Atomic models are visualized in four dimensions. Films on atomic structure are shown. Trilinear Chart of the Nuclides is reconstructed to crystallize and summarize relations of atomic structure to element species.</p>
<p>Groups (triads and octaves) and periodicity is presented in a manner most conducive to self-discovery.</p>	<p>Chemical and physical properties of families of elements are examined in the laboratory. (halogens, inert gases, alkaline metals)</p>
<p>Periodic schemes of the elements are examined in various forms. Utility and short comings of charts are discussed.</p>	<p>Students predict properties of blocked-out elements in manner of Mendeleev.</p>

Content	Activities
Natural beauty and universality of periodic law are presented.	Students read and analyze for significance science fiction story of astrocryptographers' failure to translate the language of an advanced but extinct Martian civilization until a copy of a periodic table was uncovered.

C. Search for Order in Energy Activities

Content	Activities
Energy in its primary form exists as radiation of constant velocity varying in frequency and wave length.	Wave properties are observed through the use of wave form machine and ripple tank. Transverse, longitudinal, electromagnetic and mechanical waves are distinguished.
Relationship among the three properties occur according to the equation $V=f\lambda$ (A particle theory of light is not presented at this time.)	Laboratory observed polarization and interference of several forms of radiant energy demonstrate apparent differences in wave length. Evidence of constant velocity gathered. $V=f\lambda$ problems with radio, infra-red, visible light, ultra-violet and x-rays.
Electromagnetic radiation is examined at various bands in terms of general and specific properties--generation and detection.	Through a series of demonstrations students view transmitters and receivers operating at various wave lengths along the Spectrum of Electromagnetic Radiation.
Forms of radiant energy are grouped along a continuum which emerges as the Spectrum of Electromagnetic Radiation.	Through library research students trace energies possessed by matter back to radiant sources.

D. Search for Order among Organisms

Content	Activities
Deductive presentation of established taxonomic groups of organisms--kingdoms through varieties are made. A survey of the animal kingdom is conducted.	Laboratory examination (morphological and physiological) of type specimens of organisms yield characteristics useful in the grouping of organisms.

Content

Phyla of animals are grouped in sequences reflecting increasing complexity of form and function. Transition and branching relationships are noted.

Paleontology, embryology, anatomy and physiology provide evidence indicating that constructed phylogenetic trees reveal history of life on earth.

Activities

Students construct phylogenetic trees.

Phylogenetic tree is compared with fossil series in successive formations of sedimentary rock.

E. Summary

Scientific study is facilitated through knowledge of and use of classification schemes.

Individual research projects work begins.

References Used in Unified Science

The textual and reference literature for the program in Unified Science is presented below in bibliographic form. There are, of course, no parallel content presentations in book form. Each student has available standard physics, chemistry, biology and general science textbooks (1). For certain units printed monographs or "unit texts" are issued (2). There are general and special references, located in the school and/or departmental libraries, that are frequently used by students and teachers (3).

This list is not complete, nor are the references necessarily considered the best suited to integrated science study, since many of the texts were obtained before the Unified Science program was instituted.

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APPENDIX B

Descriptions of Courses of Study in Science at the Worthington (Ohio) High School

EARTH SCIENCE (Mr. Stevenson)

The academic year is divided into three course sections: the first third for astronomy, the second third for meteorology, and the remaining third for geology.

In the first third, the students learn the relationship of man to his exterior universe. This is accomplished through the studying of the following areas: the physical characteristics of the Earth (tides, latitude, longitude, time, gravitational attraction), the moon, the sun, Mercury, Venus, Mars, Jupiter and the other members of the solar system. From there the students venture out to the individual stars. After studying a while in this area they continue out to the great nebulae in space. Further out they find the distant star clusters of our own galaxies. Finally, they conclude with a study session on the exterior galaxies, their development, and general theories of the evolution of the universe.

In the second third, the students become familiar with the phenomena of weather and how man is influenced by it. First the student studies the composition of the sea of air. Then we continue with a more detailed study of what we mean by temperature, thermal gradients, pressure and the resultant gradients, deflection of winds due to Coriolis Effect, the formation and structure of the ten types of clouds. The students participate in taking of weather data during this section. The students continue with a study of air mass analysis and instabilities produced in the air. Finally we finish with general local and short term weather prediction and how it may be accomplished.

In the last third of the year the students go back to the surface of the earth and see their dependence upon the surface materials. First the students study the sea. Then they learn of the great mountain ranges and underwater basins. A study of shoreline evolution and harbors follows. From here we go back to the solid surface of the earth and start our analysis of minerals. After the students become familiar with the more common minerals, we shift over to the rocks. From here we go on to the dynamic structure of mountains, diastrophism, and then surface weathering and erosion. The next topic is the history of our earth's surface. We finally finish with a short section on conservation.

Various aids are used throughout the year's work. Among them are student group use of the observatory, a trip to a planetarium, individual student use of weather instruments, student work in the area of map interpretation and surveying, and possibly a field trip.

PHYSICAL SCIENCE (Mr. Clauson)

Physical Science deals with the fields of physics, chemistry and astronomy. It does not go into any of the principles of biology. It is basically a lecture course with demonstrations of scientific principles wherever possible. An average of three laboratory sessions each six-week period are incorporated to give the student a better understanding of the principles involved. These are individual laboratories and although we are cramped for space and need more equipment, the students seem to benefit from them.

GENERAL OBJECTIVES OF PHYSICAL SCIENCE

1. To provide for the student who has not shown a definite interest in science an exposure to the scientific fields of physics, chemistry, and astronomy.
2. To create, wherever possible, a definite interest and ability in the physical sciences.
3. To provide for the student an opportunity to prove scientific principles in the laboratory.
4. To provide a semi-advanced situation for the above average student.
5. To provide a general overview of physical science for the average student.
6. To provide a workable knowledge of scientific principles in the everyday environment for the lower ability students.

Any ninth grade pupil or any student who has not completed his science requirement can enroll in Physical Science. Students who show a definite interest in science, and are taking a science major, including physics, can take Earth Science offered by Mr. Stevenson.

MAKE UP OF THE COURSE

The course is divided into units according to the following plan.

Unit I. Air--5 chapters.

Unit II. Water--4 chapters.

Unit III. Fuels--4 chapters.

Unit IV. Forces--4 chapters.

Unit V. Chemicals--4 chapters.

Unit VI. Metals--4 chapters.

Unit VII. Sound--2 chapters.

Unit VIII. Light--3 chapters.

Unit IX. Electricity and Electronics--7 chapters.

Unit X. Atomic Energy--1 chapter.

Unit XI. Earth Science--3 chapters.

Unit XII. Astronomy.

GENERAL BIOLOGY (Mr. Dindal)

The basic biology course is an introduction to life science. The meanings and uses of the biological vocabulary and the systems of plant and animal classification are stressed. Whenever possible the biochemical, anatomical and physiological similarities of all organisms are studied thus showing the interrelationship of all life. Basic principles of genetics, embryology and evolution are introduced. Man is studied in detail.

The student will gain much experience with the use of the microscope. He should expect to dissect at least seven different types of preserved animals and observe the life habits of many living species of both plants and animals. Field trips will be taken to different habitat areas and an outdoor ecology plot study will be made at the end of the year. Relationships to other courses are made whenever possible. For example, genetics is taught from a mathematical approach. Plant and animal physiology, of course, relates to chemistry and physics. Latin and Greek derivations of most of the biological terms are presented.

Moon, Otto, and Towle's Modern Biology is used as a student text. Biology, by Relis Brown, a college text, is used as a classroom reference text.

Prerequisites include grades of "B" or better in past mathematics and science courses and an ability to read well with comprehension.

GENERAL BIOLOGY (Mr. Williams)

These sections use the text by Vance and Miller entitled, Biology for You. The laboratory manual by Vance, Barker and Miller, entitled Biology Activities, is used to supplement the text.

The course materials are arranged on the Unit Method described briefly as follows:

<u>Unit</u>	<u>Topic</u>	<u>Periods</u>
Unit One	Entomology--The study of insects, their nature and control	15
Unit Two	Botany--Plants as food makers	15
Unit Three	Cells and tissues under a microscope. The nature of protoplasm	10
Unit Four	Botany--The growth and structures of plants	15
Unit Five	The Plant Kingdom. How plants are arranged in groups	15
Unit Six	The invertebrate animals as food takers	<u>20</u>
Total		90 class periods semester one
Unit Seven	Phylum Chordata--The vertebrate animals	15
Unit Eight	Digestion, Respiration, Excretion in Plants and Animals	15
Unit Nine	The biology of man and how we function	15
Unit Ten	Reproduction and heredity	15
Unit Eleven	Evolution--The changes in living things. The theories of change	10
Unit Twelve	Field Work--Conservation and Ecology. The Web of life. Living things in relation to their environment	<u>20</u>
Total		90 class periods semester two

CHEMISTRY (Messrs. McBurney and Wingett)

Chemistry is the study of the composition of matter. The main purpose of the course is to increase the students' knowledge of facts and understanding of principles related to this area. Students participate in individual laboratory experiments, witness demonstrations, engage in discussions, see movies and tour some chemically related industry.

The chemistry course is designed to emphasize and build upon general scientific principles and concepts that the student has acquired in previous science courses. Also, the students will find use for mathematical concepts that they have learned in earlier courses.

A study of chemistry is necessary for students who are planning to enter such fields as science (both biological and physical), engineering, medicine, dentistry, nursing, home economics and many other areas.

Some of the topics that are currently studied are--

1. Atomic orbital theory and modern ideas on nuclear structure.
2. Balancing chemical equations and oxidation—reduction reactions.
3. A study of the common elements such as hydrogen, oxygen, nitrogen, sulfur, etc.
4. Solutions, acids, bases, salts and colloidal particles.
5. The periodic table, radioactivity instrumentation and nuclear equations.
6. Simple carbon compounds and more complex ones such as those in foods, medicines, textiles, plastics, etc.
7. The chemistry of light and heavy metals.
8. An individual chemistry project.
9. A short introduction to semi-micro qualitative analysis.

Prerequisites to the chemistry course:

1. Algebra I is preferred; however, a good general mathematics student can succeed.
2. General science and biology are helpful in giving the chemistry student the necessary science background.
3. Satisfactory marks in English and/or foreign language would help to indicate that the student has the ability to succeed.

PHYSICS (Mr. Stevenson)

The course suggests a background of at least three years of mathematics. The students usually are taking their fourth year concurrently with the physics course.

The course is built around the fundamental concepts of energy, its many forms of transformation, and why and how it is important to man. Although use is made of the segmented sections of physics, i.e., mechanics, heat, light, sound, etc., emphasis is not given to them for the sole clarification of these sections, but rather to aid the student in seeing the smooth blending of these natural phenomena. The students usually start out the year with some work in the area of mechanics for background purposes. From here they go to the atom and atomic physics. The natural outgrowth of this area is the section dealing with light. Again, the student is helped to see the relationships between light and modern physics. Heat as a natural extension of light is covered next. Electricity, which is further down on the spectrum of energy, is studied next. Here the student obtains a well developed background on how important our knowledge of electricity, magnetism and electronics is to our modern civilization. At the end of the area of electricity, we look at the material in sound. The students have an opportunity to conduct a number of experiments in which they can actually see functional relationships and produce them graphically.

Throughout the year, the student is presented with basic ideas for the integration of the sometimes separated areas of physics. It is through such a pattern of thought that the student has an opportunity to see the universe as it really is, without man-made empirical divisions.

ADVANCED BIOLOGY (Mr. Dindal)

This course was organized for senior science majors who are planning a future in some biological field. Advanced biology is a laboratory course that deals with more advanced material than that covered in general biology. The purposes of the course are as follows:

1. To present more advanced subject matter including
 - a. An understanding of cell physiology and biochemistry and similarities of all living things.
 - b. A study of comparative anatomy and life history study of different animals.
 - c. A more advanced study of classification, genetics, and evolution.
 - d. A study of plant physiology.
2. To provide much more field and laboratory work
 - a. Six weeks devoted to outdoor or field techniques
 - 1) aquatic ecology survey of Olentangy River
 - 2) animal population studies
 - 3) production of identification key
 - b. Relationships of termite and flagellate parasites
 - c. Comparative vertebrate anatomy
 - d. Plant and animal microtechnique
 - e. Fruit fly genetics experiments
 - f. Basic metabolic biochemical experiments
 - g. Chromatography
 - h. Life history study of water flea
 - i. Ecology study late winter pond vertebrates
3. To provide college bound students a chance for advanced placement opportunities or examination college credits

Many principles from previous science and mathematics courses will be utilized to teach advanced biology.

The text for the course is Life, by Simpson and Tiffany, and a number of college texts are available as classroom references.

Prerequisites:

The student should have passed general biology with a grade of "B" or better.

The student should have received a grade of "C" or better in chemistry.

APPENDIX C

The Treatment Instrument

Test on the Measurement of a Rational Universe Image

Included are the 65 five multiple-choice items divided according to five features of a rational universe image. Correct responses are indicated by an asterisk (*).

I. PHENOMENA REFLECT THE INTERDEPENDENCIES AND INTERACTIONS OF MATTER, ENERGY AND LIFE.

50. Among reasons medical researchers would choose to study ameba, which do you believe to be the most significant?
- a. Ameba are inexpensive and easily cultured in great numbers.
 - b. The similarity in structure and function between the ameba and the human white corpuscle is so close, answers to human blood disease problems can be found through experimentation with ameba.
 - *c. The same basic mysteries of life we seek to explain about our complex selves can be asked of the relatively simple ameba.
 - d. Experimentation with live ameba are not objected to by "ameba lovers."
 - e. Ameba easily fit upon the stage of microscopes whereas guinea pigs, mice, dogs and humans do not.
49. What is not common to the following
water
cake
dog
moon
- *a. All were created to serve mankind.
 - b. All contain atoms of the element oxygen.
 - c. All possess energy.
 - d. All are made up of molecules.
 - e. All contain isotopes of elements found in the tissues of man.
34. Water flow in the Scioto River is affected least by
- *a. the Earth's magnetic field
 - b. the Coriolis effect
 - c. the Earth's mass
 - d. human engineering
 - e. centrifugal force

33. The living organism differs from a bonfire mostly in that
- a. respiration and burning are different chemical reactions.
 - b. the bonfire releases heat.
 - *c. the rates of oxidation are very different.
 - d. there is actually no difference.
 - e. the living organism does not require fuel.
30. Which statement is part of Darwin's theory of evolution?
- *a. Individuals well adapted to their environment are more likely to live and reproduce.
 - b. The number of individuals in a species steadily increases.
 - c. Any organism quickly adapts itself to its environment.
 - d. Changes in organisms caused by environmental conditions are hereditary.
 - e. The production of a new organ results from a new need.
29. The attracting forces between electrons and nuclei in atoms, planets and stars in solar systems, and protons and neutrons in atomic nuclei are respectively
- a. magnetic, gravitational, electrical
 - b. electrical, centrifugal, magnetic
 - c. magnetic, centrifugal, nuclear
 - d. all centripetal
 - *e. electrical, gravitational, nuclear
27. When a meteor strikes the surface of the earth part of the kinetic energy it possesses
- a. warms the earth around the point of impact.
 - b. is transformed into radiant energy that returns to outer space.
 - c. remains for a while within the meteorite even though the meteorite is stationary.
 - *d. all of the above.
 - e. none of the above.
26. A difference in characteristics of nerve impulses that travel from eye to brain and from spinal cord to biceps muscle is
- a. voltage
 - b. frequency
 - c. amperage
 - d. intensity
 - *e. not known to exist

25. What is the principal cause of weather?

- *a. Differences in the amount of heat energy absorbed by different parts of the earth.
- b. The rotation of the earth, which sets the atmosphere spinning in cyclones and anticyclones.
- c. The mountains, which interfere with smooth movements of the atmosphere.
- d. The division of the earth's surface into land and water areas.
- e. The moon which produces atmospheric and hydrospheric tides.

24. In what way are the following alike?

A mountain lake
A gallon of gasoline
A star
Milk

- a. All are liquids.
- b. All are hydrogen compounds.
- *c. All represent energy sources.
- d. All are made up of equal percentages of the same elements.
- e. All the above are true.

18. Lightning on the planet Venus detected by the radiotelescope at The Ohio State University between the spring and autumn of 1956 indicates that:

- a. the atmosphere of Venus is chemically like that of Jupiter and Earth where lightning also occurs.
- b. seasonal rains on Venus may provide the conditions for life as it is known on Earth.
- c. water vapor, once thought to be absent, really does exist on the planet Venus.
- *d. differences in atmospheric temperature are producing up drafts.
- e. the Venusian winter would be the best time for exploration by space biologists, chemists and physicists.

16. If green plants are growing in a lighted air-tight room, what change occurs in the composition of the air in the room?

- *a. Oxygen increases and carbon dioxide decreases.
- b. Oxygen decreases and carbon dioxide increases.
- c. Both oxygen and carbon dioxide decrease.
- d. Both oxygen and carbon dioxide increase.
- e. The composition remains unchanged.

15. When an animal hibernates, or a plant goes into a dormant state, which one of the following conditions exists?
- a. There is no life present in most of the animal or plant cells.
 - b. The animal or plant is absorbing additional energy for use during periods of active life.
 - c. The temperature of the animal or plant is usually higher than it is during periods of active life.
 - *d. The animal or plant is using energy at a slower rate than during periods of active life.
 - e. The animal or plant becomes more responsive to outside influences than it normally is.
19. The constant loss of mass by the sun is principally due to
- a. the ejection of stripped atoms which we know as cosmic rays.
 - *b. the conversion of matter to energy which is then radiated into space.
 - c. the conversion of energy to photons which radiate into space.
 - d. the boiling away of star matter in a manner similar to the rapid evaporation of water on a hot stove.
 - e. none of the above. The statement is actually false, the sun is getting larger.
14. Is it correct to say that the heat energy obtained when a piece of wood burns comes from the sun?
- a. No, burning will take place without the help of the sun.
 - b. Yes, the oxygen in the air was formed by the action of the sun.
 - c. No, the energy was manufactured by photosynthesis.
 - *d. Yes, the process of rearranging atoms to form molecules of wood in trees requires energy from the sun.
 - e. No, solar energy and chemical energy are entirely different and unrelated.
13. It is impossible to get more or as much work out of a machine than was put into it.
- *a. True, since the laws of thermodynamics state that energy cannot be created and that energy must degrade to lower levels.
 - b. False, since animals are machines that violate this statement of physical science.
 - c. False, since atomic submarines run on far less fuel than do diesel submarines.
 - d. True, since perpetual motion is observable at the molecular level where particles are in constant motion.
 - e. False, since the levers of recording barometers, hygrometers and thermometers can be observed in constant motion.

11. Which of the following principles is best illustrated by a balanced aquarium?
- a. Matter can be changed into energy and vice versa.
 - *b. Plants and animals are dependent upon each other and upon their environment.
 - c. Food, oxygen, and certain optimal conditions of temperature, moisture, and light are essential to the life of most living things.
 - d. Protective adaptations aid survival.
 - e. All plants and animals are engaged in a constant struggle for energy.
10. Which statement is true regarding the nature of energy?
- *a. Energy makes matter move.
 - b. Energy can be detected in the absence of matter.
 - c. The ultimate source of energy is the electron.
 - d. Energy can be generated in the absence of matter.
 - e. Most forms of energy can be sensed by the nervous system of man.
9. A pint of water
- a. weighs the same throughout the universe.
 - b. weighs more on the moon than it does on the earth.
 - *c. can weigh more in an accelerating automobile than in a stationary automobile.
 - d. weighs the same regardless of temperature.
 - e. has no weight--only mass.
8. Why does the air above a hot surface appear to quiver with a wavelike motion?
- a. The quiver results from ether waves which carry heat by the process called convection.
 - b. The human eye is not adapted for vision through hot air and is confused as most of us become when faced with a new situation.
 - c. The wavelike motion consists of infrared light waves.
 - *d. Light is refracted as it passes through regions of changing air density.
 - e. The heat is radiated from the fire in waves.
7. A clear pane of glass can be invisible in air because
- *a. the atoms that make up the glass do not remove by absorption any of the color bands of electromagnetic radiation.
 - b. glass is a crystalline substance.
 - c. light is bent or refracted as it passes through glass.

- d. the full spectrum of electromagnetic radiation, from radio to gamma rays, does not interact with glass.
 - e. all of the above reasons are pertinent.
2. Niels Bohr once stated that the history of science teaches us again and again how the extension of our knowledge may lead to the recognition of relations between formerly unconnected groups of phenomena. Which of the following best illustrates this fusion of knowledge?
- a. Hooke noted that the structure of cork under a microscope resembles the cells in which monks lived.
 - *b. Oersted discovered that when a current of electricity passed through a conductor, a magnetic field formed around the conductor.
 - c. African lions can be crossed with Asiatic tigers, supporting the belief that a common ancestor roamed both continents which were at one time connected.
 - d. The frost that forms on the freezing unit of a refrigerator is structurally the same as the frost that forms on windows during cold weather.
 - e. The structure of the atom has been found to be identical with the structure of a star system, and molecules and crystals are miniature galaxies and galactic groups.
63. The reduction in size of a contracting muscle is most closely related to which of the following physical or chemical changes?
- *a. sol-gel
 - b. oxidation-reduction
 - c. anaerobic oxidation
 - d. neutralization
 - e. electromiosis
62. Which human sense is not sensitive to acid and base stimuli?
- a. smell
 - b. touch
 - c. sight
 - d. pain
 - *e. taste

II. THE FORMS OF MATTER, ENERGY AND LIFE REVEAL A NEUTRAL ORDERLINESS.

23. Which presents the simplest yet most complete image of the universe?
- a. A spherical photograph of the heavens taken by a space astronomical observatory.
 - *b. The periodic chart of the elements, spectrum of electromagnetic radiation and phylogenetic tree of plants and animals.
 - c. An atom of iron.
 - d. A living dog.
 - e. The Atomic Theory.
17. Corresponding to the some 100 elements which make up the world of matter are the _____ which make up the world of life.
- a. Phyla
 - *b. Species
 - c. Families
 - d. Specimens
 - e. Individuals
12. Light from a candle differs from light from the sun in that
- a. sunlight can be focused with a lens, whereas candlelight cannot.
 - b. sunlight is light and energy while candlelight is only light.
 - c. sunlight travels faster in air than does candlelight.
 - d. sunlight contains invisible forms of energy and candlelight is all visible.
 - *e. in none of these ways.
4. The chemical elements of which plants and animals are composed
- a. cannot exist in gaseous form.
 - b. differ from those elements of which man is composed.
 - *c. are known to exist in the stars.
 - d. take on different properties outside the organism.
 - e. are described by none of these
54. Which one of the below reactions is least appropriate to the group?
- a. $\text{Ca} + \text{Br}_2 \rightarrow \text{CaBr}_2$
 - b. $2\text{Li} + \text{Cl}_2 \rightarrow 2\text{LiCl}$
 - *c. $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$
 - d. $2\text{K} + \text{I}_2 \rightarrow 2\text{KI}$
 - e. $\text{Ba} + \text{F}_2 \rightarrow \text{BaF}_2$

53. Different kinds of energy, matter and life can be distinguished on the basis of
- *a. Characteristics
 - b. Names
 - c. Locality of occurrences
 - d. Mass-energy ratio
 - e. Spectroanalysis
52. The radiant forms of energy are distinguished from each other on the basis of
- a. intensity
 - b. speed
 - c. density
 - d. temperature
 - *e. frequency
46. The elements helium, neon, argon, krypton, xenon and radon are chemically non-reactive. They form a family of inert gases that are frequently used where chemical reaction is to be avoided. They are not grouped (on the periodic chart) with other nonreactive elements primarily for which of the following reasons?
- a. These elements are gases over a wide range of temperatures whereas nonreactive elements such as gold and platinum are solids at ordinary temperatures.
 - b. The boiling point temperatures increase regularly with increased atomic weight.
 - *c. The atoms of these elements have an electron structure pattern different from other known elements.
 - d. These elements were discovered one right after the other late in the nineteenth century after Mendeleef had established a period system for the elements.
 - e. Elements are grouped according to name. The names of these usually end with "on."
45. Which activity should surprise you most were you to visit a science classroom on the third planet out from the star Alpha Centauri?
- a. The teacher was lecturing about the alkaline earth metals using a periodic chart of the elements.
 - b. Students were determining the value of gravity using a simple pendulum.
 - c. Students were examining fossils of plant life.
 - *d. The temperature of the room was recorded at 72° above a zero point.
 - e. Students were determining the refractive index of diamonds the smallest of which was 1 cubic inch.

41. If one of each kind of animal alive today were to be lined up in order of increasing complexity
- a. the array would show a regular increase in size.
 - b. the array would show a regular decrease in size.
 - *c. the array would fairly well reflect the history (evolution) of animal life on earth.
 - d. about the first half of the array would include ocean dwelling animals and the more complex half would include the terrestrial animals.
 - e. it would be observed that the rate at which animals became extinct decreased as complexity increased.

42. If the structural building block of common organisms is the cell what is the parallel building block of ordinary matter?
- a. colloid
 - b. crystal
 - *c. atom
 - d. nucleus
 - e. proton

39. Which of the following is not descriptive of virus particles.
- a. They respire.
 - b. They are regular chemical compounds and for a given type are apparently of exactly the same size up to their last atom.
 - c. Outside of a living cell they can arrange themselves into regular patterns of ordinary crystals.
 - d. They form a transitional step between living and nonliving matter.
 - *e. They cannot be destroyed by ordinary physical or chemical means.

III. THINGS AND EVENTS ARE PERCEIVED IN ACCURATE PERSPECTIVE IN RELATION TO TIME AND SPACE.

22. If the entire history of the Earth were compressed into a period of one year, which event would have been most likely to have occurred on December 31?
- a. The Appalachian mountains were formed in eastern North America.
 - *b. The great lakes were formed by the receding Wisconsin glacier.
 - c. The first animals evolved from sea to land.
 - d. The dinosaurs became extinct.
 - e. The Milky Way was formed.

21. Which general statement is supported best by observable facts?
- a. Light is a wave phenomenon.
 - b. Light is a particle phenomenon.
 - *c. The features of the earth's crust are changing.
 - d. Feathers are fish scales that have changed in the evolution of fish to reptiles to birds.
 - e. The universe evolved from an exploding "superatom" about 5 billion years ago.
20. In which way is an atom of aluminum most like the solar system?
- a. Satellites of the central mass spin and revolve in elliptical orbits forming a disc.
 - b. Satellites increase in mass and velocity as they occur farther from the central mass.
 - c. Satellites occur in pairs.
 - *d. Most of an atom and the solar system are empty spaces.
 - e. There are billions of atoms and solar systems known to exist in the universe.
6. How does the weather on the first day of March usually compare with the weather on the last day of March?
- a. The weather on the first day is generally the same as the weather on the last day.
 - b. The weather on the first day is opposite the weather on the last day.
 - *c. The weather on the first day is generally colder than the weather on the last day.
 - d. The weather in March is so unsettled that no general relations have been observed.
 - e. The weather on the first day is generally warmer than the weather on the last day.
65. The density of the earth is 5.522 g/cc. The error in this statement is
- a. The density of the earth is several hundred times this value.
 - *b. 5.522 g/cc is the average density and it is possible that not one cubic centimeter of the earth weighs 5.522 grams.
 - c. The mass of the earth is constantly increasing making the value 5.522 g/cc unreliable.
 - d. The mass and volume of the earth have not been determined accurately enough to arrive at this precise a value.
 - e. Gram and centimeter measurements are not appropriate when considering a body as large as the earth.

60. The energy that warms the air in an electric oven can most certainly be traced to
- a. the burning of coal.
 - b. a nuclear fission reaction.
 - c. heat released by cooling water.
 - *d. A thermonuclear reaction.
 - e. Infra-red radiation.
59. Which would be least desirable in providing regular motion with which to standardize a clock?
- a. The rhythmic motion of the sun around the galaxy.
 - b. The rhythmic motion of a simple pendulum.
 - *c. The rhythmic motion of human heart muscles.
 - d. The rhythmic motion of electrons in house current.
 - e. The rhythmic motion of orbital electrons in atoms.
55. Which sequence is out of order?
- a. proton, atom, molecule, crystal
 - b. nucleus, cell, tissue, organ
 - *c. earth, moon, sun, milky way
 - d. core, mantle, crust, earth
 - e. lead, wood, paint, pencil
57. The element technetium (atomic number 43) does not naturally exist in any form on earth, although recently isotopes have been produced in atomic piles. The most stable isotope of technetium has a life expectancy of about a million years. In 1952, the spectrum of technetium was discovered in certain kinds of very hot stars. Which hypothesis of the following seems least warranted.
- a. Some technetium must have been formed somewhere within the last million years.
 - b. Any technetium present when the earth was formed four billion years ago has long since disappeared.
 - c. Elements are naturally made in stars.
 - d. High heat is required to produce the heavier elements.
 - *e. Planets are cooled globules of stars.
51. Environment is best described as
- a. the things within range of the human senses.
 - b. the things and events within range of the human senses.
 - c. all things and events that occur on earth and neighboring celestial bodies.
 - *d. all things and events that occur in the universe.
 - e. the immediate surroundings of living organisms.

48. A fruit model which best illustrates the depth relationship of the earth's crust to the rest of the earth:
- a. cherry to pit
 - *b. apple skin to apple
 - c. muskmelon rind to melon
 - d. orange peel to orange
 - e. peach to pit
44. The temperature of a volume of water is due to the average energies of the individual molecules. As certain of these molecules have great speeds, collectively they can spontaneously boil furiously or fly out of the container enmass and speed through the air like a bullet, while the molecules remaining in the container freeze solid. The above is
- a. false, since such a phenomenon has never been observed and reported.
 - b. false, since the individual molecules of water at 20° C. move at the same speed.
 - c. false, since the molecules do not move until the water boils.
 - *d. true, but the probability for such an event to occur is infinitely low.
 - e. true, this phenomenon can be easily demonstrated in the laboratory.
35. We know that Franklin County was at least once covered by shallow seas. The best evidence for this conclusion is that
- a. glaciers of the type covering Greenland moved into this area and apparently broke off and floated down the Scioto valley as icebergs.
 - *b. marine fish and invertebrate fossils make up much of the local bedrock.
 - c. tree ferns are common in sedimentary rock south and east of Columbus.
 - d. the Bible reports that a flood covered all the land of the earth.
 - e. the Ohio mound buildres were known to be great sailors and shell collectors.
32. Fossils are found in two different rock strata which lie as they were originally formed. In which of the following characteristics are the fossils taken from the lower stratum always different from those taken from the upper?
- a. Size
 - *b. Age
 - c. State of preservation
 - d. Structure
 - e. Abundance

31. Which is the most reasonable explanation for the downward slope of land from High Street to the Olentangy River?
- a. The slope is the result of an excavation made by the Franklin County engineers.
 - *b. The slope was cut by the Olentangy River since the last glacier.
 - c. Glaciers carved out this slope some twenty thousand years ago.
 - d. There was once an inland sea through this region, and this is what remains of an ancient bay cut by the waves.
 - e. The land has maintained this slope ever since the earth was created.

IV. REAL PROBLEMS IN CONTROLLING, PREDICTING AND INTERPRETING EVENTS IN THE UNIVERSE TRANSCEND SINGLE DISCIPLINES.

36. Microscopes are scientific instruments. They are used by
- a. Biologists
 - b. Chemists
 - c. Geologists
 - d. Physicists
 - *e. All of the above
64. A lie detector measures
- a. conscious thinking
 - b. unconscious thinking
 - c. lying
 - *d. physiological change
 - e. reaction time
38. For which of the following tasks is (are) there occasion(s) to use information in biology, physics, and chemistry.
- a. The development of low nicotine yielding tobacco plants.
 - b. The development of a safe go cart.
 - c. The synthesis of a hair dye that will not weaken the strength of the hair follicle.
 - *d. All of the above.
 - e. None of the above.
3. The weed, Equisetum arvense, takes up gold in soil rich in this metal. In order to prospect for gold using this fact one would be expected to do best who had studied
- a. chemistry, geology and physics
 - *b. geology, botany and chemistry
 - c. metallurgy, biology, astronomy
 - d. botany, zoology and map reading
 - e. mining, map reading and agriculture

47. A thorough study of the element magnesium would also be a study of

- a. chemistry (matter)
- b. physics (energy)
- c. biology (life)
- *d. all three of the above
- e. chemistry and physics

28. In the index of a science book, you find the following entries:

Water	
bacteria in	162
conservation of	126
distilled	220
electrolysis of	130
excretion of	216
expansion of	135
experiments with	325
hardness of	141
in blood	218
properties of	140
purification of	150
refraction of light by	300
weight of body to	225

To learn more about the treatment of drinking water, you should start by looking on pages

- a. 162, 141, 225
- b. 127, 216, 300
- c. 150, 140, 220
- *d. 141, 150, 162
- e. 162, 216, 218

V. MAN'S RELATIONSHIP WITH HIS UNIVERSE, AS AN OBSERVER AND AS A PART OF THE "WEB" IS PERCEIVED REALISTICALLY.

43. Science serves the graphic artist and the music composer best by

- a. providing them with improved materials and equipment with which to carry out their creative work.
- b. creating an intellectual climate where creative products are better appreciated by the public.
- *c. revealing more understanding of the universe which they can creatively interpret.
- d. discovering the genetic formula responsible for the inheritance of creative talent.
- e. increasing their life span which in turn increases their productivity.

56. The ultimate aim of science is to
- a. develop the materials and know-how that will provide man with a maximum of happiness.
 - b. provide the knowledge that will enable man to completely control his environment.
 - *c. discover interconnecting theories that will account for all phenomena.
 - d. teach people to think rationally rather than emotionally.
 - e. to provide man the means to survive after the sun will no longer support life on earth.
58. All things (minerals, kinds of rays, breeds of roses) receive names when they become known to man. The reason man attaches a symbol to each is that
- a. things can be classified best after they are named.
 - b. man naturally affixes names to new things.
 - c. man is the only species of animal with the intelligence to symbolize.
 - *d. names are time saving conveniences that aid in communication.
 - e. names identify things by describing them usually in Latin or Greek.
40. Which explanation for the origin of varying skin color seems most reasonable to you?
- a. Skin color is one way in which genes of intelligence, kindness and athletic ability express themselves.
 - b. Skin color resulted from the needs of groups of white skinned people to absorb, in varying degrees, sun light before damage was done to underlying tissues.
 - c. Varying skin color resulted from the needs of groups of dark skinned people to adapt to the areas of the earth of low solar radiation in order to provide underlying tissues with vitamin D stimulating ultra violet.
 - *d. The human species carries in its total gene pool the potential to develop a wide range of skin color. The skin color of any group of individuals may change over a period of many generations by selection, accident or natural need.
 - e. Population of humans with varying skin color have existed as long as man has existed.
61. The optical instrument that does most to add a new dimension to human vision is the
- a. camera
 - b. telescope
 - *c. spectroscope
 - d. microscope
 - e. light meter

37. A light year would be larger for Martian astronomer than it is for an Earth astronomer. This statement is chiefly
- a. True, because light travels faster in the thinner atmosphere of Mars than it does at earth.
 - b. True, because even though the velocity of light is a universal constant, the Martian day is longer than an earth day.
 - c. False, because the galaxy, Milky Way, is 100,000 light years across whether it is observed from Earth, Mars or Alpha Centauri.
 - d. False, because there is no evidence of the existence of Martian astronomers.
 - *e. True, because the time required for Mars to revolve about the sun is longer than the period of revolution for the earth.
5. What structure is of the same use to earthworms as a lung is to man?
- *a. skin
 - b. lung
 - c. nephridium
 - d. gill
 - e. mouth
1. The theory of evolution as advanced by Charles Darwin is one of the best known big ideas in science because
- a. more people have read The Origin of Species than any other book of science.
 - b. the theory of evolution is much less complex and easier to understand than the relativity theory as advanced by Albert Einstein.
 - c. since teaching and writing about evolution is forbidden by law in parts of the world, people naturally want to learn more about evolution.
 - d. Darwin introduced an entirely new idea about the origins of plants and animals.
 - *e. the ideas of evolution disagreed with long established ideas about the origins of plants and animals.

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AUTOBIOGRAPHY

I, Irwin L. Slesnick, was born in Canton, Ohio, August 5, 1926. After completing my public school education in 1943 at the Canton-McKinley High School, I enlisted in the United States Marine Corps where I served as a Japanese Language Interpreter. From Bowling Green State University I received the Bachelor of Arts and Bachelor of Science degrees in 1949. In January, 1954 I was granted the Master of Science in Zoology degree from the University of Michigan. I was awarded a du Pont fellowship for graduate study in science education at The Ohio State University for the academic year 1955-1956, a program that served as the foundation for the doctoral program now completed.

From 1949 to 1955 I held the position of science teacher at the Archbold (Ohio) High School. Since 1956 I have been employed as science instructor at the University School of The Ohio State University.