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Cubberley/Lockheed Science Project Final Report, Volume 1 - Narrative Report. A Development Program to Attain Stated Behavioral Objectives in Science: A System Approach.

Cubberley (Elwood P.) Senior High School, Palo Alto, Calif.

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This book represents the final report of the planning phase in the development of an instructional system to be implemented at Cubberley High School in the Palo Alto Unified School District. The purpose of this project is to develop a pilot science learning system in the earth/life sciences. The systems analysis approach was utilized in an attempt to avoid the traditional instructional constraints and to bring about improved science instruction. The specific techniques of systems analysis employed in this project include functions analysis, organization of project activities, criteria establishment to test design solutions, and systematic development of systems design solutions. This work was prepared under ESEA Title III contract. (BC)

CUBBERLEY/LOCKHEED SCIENCE PROJECT

VOLUME I – NARRATIVE REPORT

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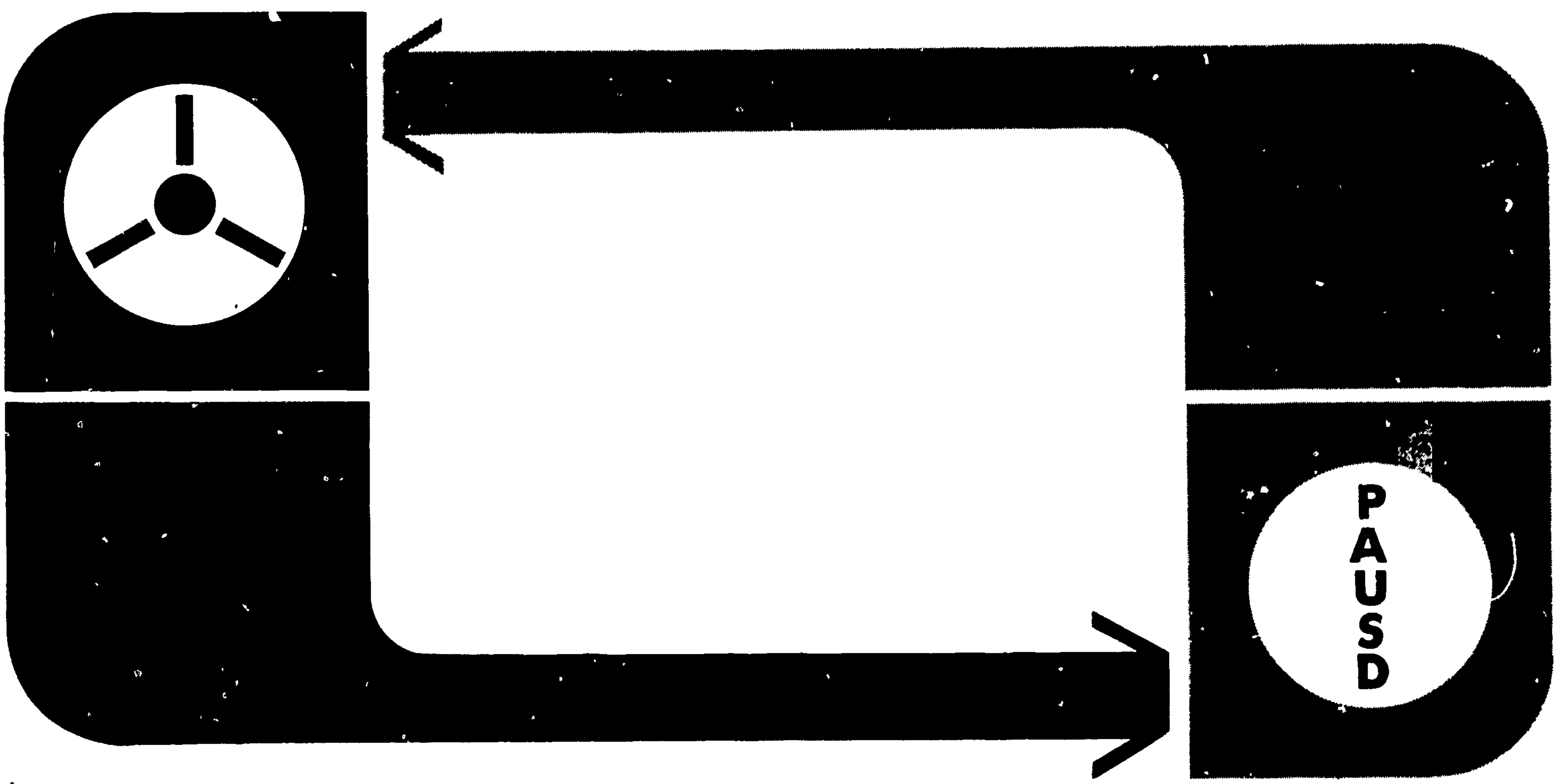

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C U B B E R L E Y - L O C K H E E D S C I E N C E P R O J E C T

(CLSP)

A DEVELOPMENT PROGRAM TO ATTAIN STATED

BEHAVIORAL OBJECTIVES IN SCIENCE:

A SYSTEM APPROACH

FINAL REPORT

PLANNING PHASE

Prepared under Grant

Number 67-3011

P.L. 89-10 Title III

Prepared at

Elwood P. Cubberley Senior High School

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Volume I

Narrative Report

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1.0 INTRODUCTION

The central purpose of the Cubberley-Lockheed Science Project is the development of a pilot science learning system, specifically in the Earth/Life sciences. Although the development of this system will benefit science instruction at Cubberley High School, it will also serve as a model of science instruction that can be replicated in other high schools, particularly within the same geographic region.

The project originated because of dissatisfaction with traditional forms of science instruction and because of the feeling that education is a relatively static entity in the midst of dynamic social and economic change. An analysis of current science instruction at Cubberley and other high schools shows it to be molded by the self-contained classroom.

This self-contained classroom organization places several limitations on the quality and nature of instruction. One is the repetitive nature of much teacher effort; a basic pattern of information giving is repeated five times per day. A second constraint is the nature of the contacts with the students; primarily the teacher meets with them as a group. Time for one-to-one interaction of teacher and student is low. One-to-one interactions must occur in the presence of the group and are difficult to conduct because of group demands. A third problem is the social distance between teacher and student caused by the administrative necessities of group management.

Because of the difficulties encountered in establishing a one-to-one relationship, the teacher tends to work with groups rather than with individuals. In doing so he directs his instructional effort to a hypothetical average student in the hope that the needs of most students will be met. Even with ability grouping, the differences in individual needs are great within classroom groups. The teacher's tendency is to use what might be termed a "shot gun" approach to the group. He aims at what he sees as a midpoint of ability and hopes that the scatter is sufficient to reach the whole group. The Project effort has been concentrated on how to break out of these traditional constraints which have molded and restricted the quality of instruction.

2.0 TECHNICAL APPROACH

In attempting to break out of traditional instructional constraints, the Cubberley-Lockheed Science Project (CLSP) is committed to utilizing the techniques of Systems Analysis to achieve improved science instruction. References to the use of systems analysis techniques applied to educational problems are frequent in the current literature; however, it is difficult to determine what exactly is meant by systems analysis, and specifically where these techniques have been utilized. For the purposes of CLSP, systems analysis is defined as that body of analytic and synthetic design technique, primarily drawn from the area of weapons systems development, which facilitate analysis and design of a system as an entity rather than in piece-meal fashion. These techniques include functions analysis, requirements analysis, trade-off studies, and cost effectiveness analysis. Specifically in CLSP these techniques have been utilized in the following areas:

- Identification of the problem. Although this sounds obvious, many studies unfortunately waste considerable time and money attacking the wrong or a poorly stated problem. In CLSP this approach has resulted in the development of a systems hierarchy model to define the problem to be studied and facilitate the development of the requirements of the system.

- Organization of project activities. Based on the proper identification of the problem, function analysis and function flow techniques were then applied to structure project activities.

- Establishment of criteria to test design solutions. Development of an effective instructional system must be based on a clear definition of the criteria to be used in measuring the system. The present study is utilizing the techniques of systems effectiveness analysis in establishing these criteria.

- Systematic development of systems design solutions. A final area of impact of systems analysis and systems engineering techniques on the project deals with the development of solutions to identified design problems. Such development of design solutions must be based on systematic trade-off analyses of alternative design solutions within the overall systems effectiveness and cost effectiveness models.

2.1 ANALYSIS OF THE PROBLEM

To facilitate the identification of the problem and the requirements of the system, a model of the immediately adjacent systems involved in science instruction has been developed. This model is shown in Figure 1. This model includes

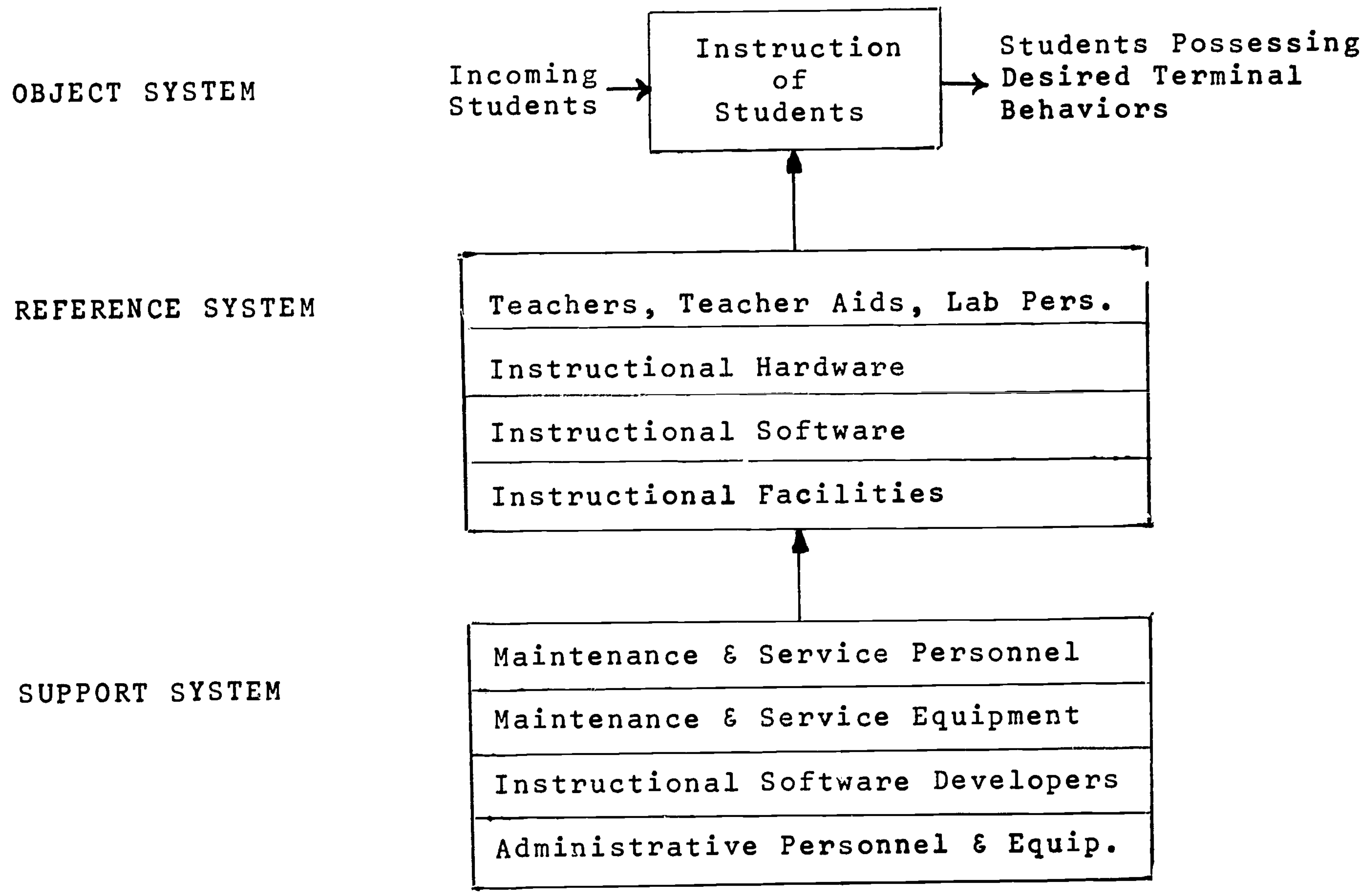

Figure 1. INSTRUCTIONAL SYSTEMS HIERARCHY

only those systems immediately adjacent to the object system and does not include all of the systems contained within the complexity of a secondary school.

At the top of the hierarchy is the "object" system which is the basic system with which we are concerned. This system is shown functionally in the model as the input of students possessing various capabilities and limitations based on their inherent abilities as affected by their unique educational and social experience. The output of this object system is the same set of students who now possess certain specified behaviors as part of their repertoire of capabilities. Analysis of this model indicates that to develop an effective instructional system we must first analyze the capabilities of the students entering the system, and second, we must develop the listing of desired terminal behavioral objectives which constitute the requirements of the system. It should be pointed out that the measure of total systems effectiveness must be accomplished at the object system level. That is, the system stands or falls on whether output students <u>do</u> or <u>do</u> <u>not</u> possess the desired terminal behaviors.

The "reference" system of the hierarchy is shown in the figure directly linked to the object system because it consists of all those resources and facilities which directly interface with the object system during the instructional process. For example, a textbook in the traditional instructional system directly interfaces with the student during instruction. However, the author or editor of the textbook does not directly interface and is, therefore, not a part of the reference system. The reference system is the one that receives the greatest attention in most projects dealing with instructional systems. Although this attention is not inappropriate, it is inappropriate to deal with the reference system in isolation from the object system.

At the base of the systems hierarchy is the "support" system. This system includes all of the resources and facilities that are not in direct interface with the student during instructional processes, but are necessary to the continued operation of the reference system. Although perhaps not as glamorous an area as those of the object and reference systems, the proper design of this support system is critical, for maintaining an instructional system.

3.0 BEHAVIORAL OBJECTIVES

3.1 DEVELOPMENT OF OBJECTIVES

The ultimate goal of education is the production of thinking individuals who can use their capacity to reason as they meet personal problems, as they contribute to the solution of socio-community problems and as they achieve vocational and professional goals.

To be an effective thinker a person must have acquired thinking skills and must also have had the opportunity to exercise these skills in problematic situations. Another element of effective thinking is a thorough familiarity with the problem area. This familiarity must include facts from the area, plus the assembly of the facts into concepts and theoretical networks.

The processes used in the attempt to educate thinking individuals can be built around the active engagement of the individuals with problem situations which involve information input, mental processing and an output or expression of the results of the mental processing. In addition, the basic skills, tactics and strategies for thinking must be acquired. They, too, can be associated with input, mental processing, and output.

Science is a major aspect of our culture which influences personal, social, and economic life. It should be a familiar area to the thinking individual. The above assertions are generally accepted as valid. By contrast, the design of the student encounter with science is a subject of much controversy.

The traditional science course provides considerable factual and conceptual information to the student. The tendency is to bombard the student with facts and concepts to an extent that limits and even blocks his mental processing. As a consequence, the public knowledge that comprises the science courses frequently does not become an effective part of the individual's private, personal knowledge and, therefore, does not become a functional part of his mental activities.

For the Cubberley-Lockheed project, we have adopted the position that a much more effective education can be built by focusing attention on the learner and by building courses around objectives that describe changes in his behavior as a thinker. The courses can be built as experiences in thinking which use the content of science as the material for thought. To provide adequate course definition and facilitate the development of instructional materials, these behavioral objectives must include definition of the measurable mental process and specification of the associated content.

A preliminary listing of candidate behavioral objectives was developed through analysis of demands built into teacher-made tests, published science tests, worksheets and laboratory activities, as well as the general scientific literature. This analysis resulted in a list of over forty behavioral objectives relative to the cognitive domain. This preliminary listing was screened to insure that all objectives were at least potentially related to future success in science courses, college courses or the life of an informed citizen.

3.2 ORDERING OF OBJECTIVES

It is impossible to develop a course of instruction unless there is some order to the objectives established for the course, in this case over forty in number. As the next step in the definition of behavioral objectives an attempt was made to structure the candidate objectives. The result of this effort was a tentative selection of the methods of science as the model for course development.

- Problem recognition
- Hypothesis formulation regarding the problem area
- Experimental tests of the hypothesis
- Report and interpretation of experimental results

A test of this model indicated that all of the identified process objectives can be subsumed under the PHER (Problem, Hypothesis, Experiment, Report) model. It is recognized, of course, that certain basic skills, e.g., discrimination, are common to each of the four phases of the model.

Although the PHER model provides a useful model of the overall structure of the course objectives, there are certain limitations on its useability in the development of instructional materials and their sequencing within the course. The problem in applying the model is two-fold; first, there is no sequencing of instructional activities other than the sequencing of the scientific method, and second, when applied to the content material a single PHER represents a unit of instruction that is too lengthy.

As a result of these problems a second model was developed which views objectives as mental skills which need to be assembled into strategic and tactical forms for attack on subordinate elements of problem situations or for an attack and complete solution of a problem.

Under this form of organization, the list of objectives need not be sequenced in any single order. Instead, they can be assembled as pairs, triplets, etc. for tactical purposes. Although they must be learned as separate skills as a first step, they must also be assembled into a higher form to become significant as part of an individual's education. A first level of student performance is, therefore, demonstration of the skills. A second level of performance becomes a relatively simple mixing of skills as a tactic for an attack on elements of a problem. Successive levels would involve a more complex mixing of the skills or of the simpler forms of tactics.

As an ultimate goal, complete acts of problem solving are identifiable as strategies composed of the tactics that the student has learned. The existence of the various tactical levels creates a connection between the complete act of problem solving as represented by the PHER model and the basic mental skills that we have identified. Table 1 contains a preliminary sampling of tactical mixes of the basic mental skills.

It is recognized that the total list of objectives is not appropriate for any single student; rather he should possess an individualized mix of objectives. This mix should be based on his aspirations, aptitudes and interests. A tentative matching of objectives and five categories of students is indicated in Figure 2. A complete listing of objectives is contained in Appendix A.

Terminal Behavioral Objectives	Student is college bound, has high aptitude and high interest in science					
	Student is college bound, high aptitude and moderate interest in science					
	Student is college bound, has moderate aptitude and interest in science					
	Student has vocational goals, moderate aptitude and interest in science					
	Student is terminal h.s. with moderate - low aptitude and interest in science					
Cognitive	Elements of thinking skills	Thinking skills	Tactics for thinking		Strategies for thinking	
			Level 1	Level 2	Level 1	Level 2
	subordinate necessary elements of thinking skills	1 thru 41 cognitive objectives: a tentative list subject to refinement and extension	assembly of 2, 3, or 4 of skills into appropriate approach to a problem element	more complex assembly of skills for tactical purposes	assembly of tactics as strategy for problem solving	high level problem solving strategies
Affective	Items 45 - 56 of tentative list					
Psycho-Motor	Items 42 - 44 of tentative list					

Fig. 2. Relationship of Objectives and Student Vocational Goals

Table 1

THINKING TACTICS

1.0 Indicate the possible effect of various qualifications or conditions on the validity of the hypothetical answer

- 1.1 State a problem to be solved [38]*
- 1.2 Formulate hypothetical answers to the problem [27]

2.0 Recall previously learned processes, directions and movements of phenomena with respect to time to find situations appropriate and analogous to a problem being studied [35]

- 2.1 State a problem to be solved [38]
- 2.2 Formulate hypothetical answers to the problem [27]
- 2.3 Recall methods or techniques used to make historical discoveries [23]
- 2.4 Recall observations which led to a generalization [18]

3.0 Use a generalization and its associated observations to make predictions about the nature of future observations

- 3.1 Recall observations which led to a generalization [18]
- 3.2 Make a prediction of the results of a given experimental procedure [33]

4.0 Relate various phenomena (structures, processes, theories)

- 4.1 Describe observed phenomena in an objective, non-teleological, non-anthropomorphic manner [31]
- 4.2 Recognize similarities and dissimilarities among two or more structures, systems, processes or theories [14]

5.0 Relate operational definitions to conceptual (theoretical definitions) and write operational definitions [37]

6.0 Make predictions based on interpolations and extrapolations of ordered data

- 6.1 Plot tabulated data of two variables [39]
- 6.2 Interpolate and/or extrapolate from the plotted data [30]

7.0 Recognize similarities and dissimilarities of parts and structures of compared organisms [14]

- 7.1 Draw observed organisms such that relevant characteristics are shown [32]
- 7.2 Label parts and structures shown in diagrams [12]

* Numbers in brackets refer to order of behavioral objectives as they appear in Appendix A.

8.0 Judge the validity of a conclusion

8.1 Recognize or identify unstated assumptions used in a reported experiment [15]
8.2 Differentiate between dependent and independent variables in the same reported experiment [7]
8.3 Differentiate between the experimental and control conditions in the same reported experiment [6]
8.4 Relate the conclusion of the reported experiment to the assumptions, variables, and conditions as described in the report

9.0 Distinguish the conclusion based on observations from associated statements that tend to support it or stem from it.

9.1 Recall observations that led to a generalization [18]
9.2 Distinguish emperical observations from value judgements that are associated with them [8]
9.3 Distinguish a conclusion from statements which support it [9]

10.0 Use the criteria and the attributes to analyze, synthesize, and criticize the terms, concepts, principles and opinions (this one could be separated into at least three equivalent tactics)

10.1 Recall criteria used to judge certain facts, principles, opinions and experimental results [22]
10.2 Recognize the attributes, properties, and relations of technical terms, concepts and principles [18]

3.3 DEFINITIONS OF COURSES

The commitment of CLSP is to work with three science courses; biology, geology and a third course that uses both earth and life science concepts.

Biology represents the least problematic situation since a national curriculum sponsored by the National Science Foundation, the Biological Sciences Curriculum Study, has defined three eminently acceptable, up to date, versions of high school biology. One reason for the development of three courses was the assumption that many different versions could be valid representations of the field of biology. We have pursued this assumption into a further step by choosing to assemble our version of a fourth course through use of materials from all three BSCS versions.

One reason for choosing to use all three versions is the utilization of local resources. As a national study, BSCS designed material so it would be generally appropriate throughout the United States. Our concern can be centered around the San Francisco Bay Region and Northern California and the utilization of the resources of these regions in a real life form of field biology. Via visual materials we can use local situations which the student can then visit during out of school hours, thus making the significance of school learnings much more apparent.

Geology, the second course, does not have a curriculum defined for high school. It is offered in only a few high schools in California. Cubberley High School has offered it for the past ten years. During that time the course has enjoyed continuous popularity with students. As a general education science course it has aroused interest and bolstered confidence so that many students choose to take a second science course. With geology, as with biology, we will deliberately use content that will allow use of regional geology for purposes of illustration. Northern California is a natural laboratory for the study of geology.

The choice of geology topics will be influenced by the fact that all ninth grade students of the school district must take a science course which uses the text and materials produced by the Earth Sciences Curriculum Project, another project sponsored by the National Science Foundation. The understanding acquired in this course will be utilized and repetition will be avoided in the geology course.

Both biology and geology serve a student clientele who have intellectual aspirations and college preparation as goals. Instruction in these courses is aimed toward a high level of competence in the tactical and strategic use of the cognitive skills we have identified as behavioral objectives.

The Earth-Life science course, by contrast, is designed for students who wish to take science solely to complete the high school graduation requirement. The criteria for use in choosing content for this course, and structuring it are much more difficult to establish than for the college preparatory courses. Our thinking at this date has produced incomplete results. Tentatively, we have said that we will select topics, wherever possible, that are man-centered, related to current social-scientific problems and are of immediate rather than future concern to the students. Again, we will utilize the natural resources of the immediate environment to make the significance of the chosen topics real in the minds of the students. In structuring the content, we will keep the complexity of concepts at a level that will allow the students to be successful, a too seldom experienced feeling for many of these students.

The following descriptions of the three courses is in terms of behaviorally oriented content objectives and the content that has been identified. These descriptions represent first steps toward complete delineation of the courses.

3.31 UNITS FOR THE GEOLOGY COURSE

1. Chemical-physical nature of matter
2. The Cosmos: Its dimensional limits, its origin and its composition
3. Physical geology of North America
4. Climatology
5. Topographic and geologic maps
6. Oceanography
7. Geologic time and geologic events
8. Physical Anthropology
9. Physical Mineralogy Laboratory

Unit 1: Chemical-physical nature of matter

Objectives

1. Student can identify the significant assumptions of modern atomic theory and how they were identified originally.
2. Student can identify situations where the assumptions of the atomic theory can be applied.
3. Students can apply their knowledge of atomic theory in problem situations that are posed to them.
4. Students can describe how elements and other natural materials are classified.
5. Students can examine specific samples of natural materials and place them in correct categories based on the examination.
6. Students can recognize relationships between the combinations of elements and other materials found in the earth's crust.

Content

- historical development of the atomic theory
- atomic structure
- periodic chart as an ordering of knowledge of the elements
- physical characteristics of elements
- chemical characteristics of elements
- combination of elements to form compounds
- basic types of compounds found in the earth's crust
- kinetic-molecular theory
- crystal forms that matter can take
- radioactivity, isotopes and their uses

Unit 2: The Cosmos: Its dimensional limits, its origin and its composition

Objectives

1. Students can describe how light and radio waves are used to provide data about the universe.
2. Students can describe the probable limits of size of the universe and its shape.
3. Students can relate conclusions about the size and shape of the universe to the data used in drawing the conclusions.
4. Students can describe the theories advanced for the origin of stars and relate the theories to data.
5. Students can use light spectra to identify elements and can describe how spectra are used to identify the chemical composition of stars.
6. Student can describe the relation of the earth to the solar system and the solar system to the galactic system.

Content

- Nature of light and electromagnetic radiations
- Light as an analytic tool for gathering information about the universe
- Origin of the universes
- Types of universes, quazars, etc.
- Analysis of the Milky Way
- Formations of stars
- Types of stars
- Theories for the origin of the solar system
- Earth's relationship to galaxies

Unit 3: Physical Geology of North America

Objectives

1. Students can use appropriate terminology in descriptions of geologic features.

2. Students can advance hypotheses about the order of geologic processes that led to the present physiography of the continent.
3. Students can identify the forces that produce present and future changes in physiography.
4. Students can infer what forces produced present physiography.
5. Students can correlate the action of geologic processes in one area with similar action in another area.
6. Students can recognize and classify the rocks and minerals found in the San Francisco Bay Region and the Sierra Nevada Mountains.
7. Students can describe the origin of rock formations and land forms of the Northern American Continent.
8. Students can use field techniques used by geologists.

Content

- Pacific Area
- Sierra Nevada area
- Columbia Plateau area
- Colorado River Plateau area
- Rocky Mountains, north and central
- Hawaiian Islands
- Great Lakes Area
- Alaska
- Appalachian area and Atlantic Coast
- Mississippi River Basin and Coastal Plain
- Basin Range area

Unit 4: Climatology

Objectives

1. Students will know the physical characteristics of the atmosphere.
2. Students will recognize and be able to interpret changes in the atmosphere caused by temperature and pressure conditions.
3. Students will describe evaporation and condensation of water in terms of temperature effects and humidity effects.
4. Students will measure weather phenomena and interpret the collected data.
5. Students will read and interpret data from weather maps.
6. Students will trace patterns of wind circulation and interpret how these patterns contribute to climatic conditions.
7. Students will trace patterns of weather data across North America and relate them to the total climatic pattern.

Content

- Weather and climate as appropriate topics for geology
- Physical relation of temperature to states of matter and kinetic energy
- Water in the atmosphere - humidity, evaporation-condensation, dewpoint
- Air pressure, measurement, and plotting on maps
- Behavior of gases, temperature effects, adiabatic cooling and heating, currents
- Winds, air masses, and wind belts
- Weather activity, reading weather maps, cloud types, storms, weather fronts
- Classification of climates, causes of variations, climatic zones, weathering and physiography
- Keeping daily records of weather data

Unit 5: Topographic and Geologic Maps

Objectives

1. Students will know the conventional symbols used on topographic maps.
2. Students will make maps.
3. Students will know the system of grid coordinates and be able to use them at a local and global level.
4. Students will interpret the contour information of topographic maps and identify land forms from the maps.
5. Students will trace erosion patterns, stream gradients and drainage patterns on topographic maps.
6. Students will interpret geologic maps to identify stratigraphic columns and to correlate geologic formations.

Content

- History of map making
- Maps as models of the physical environment
- Types of maps
- Construction of maps
- Grid coordinate systems
- Contour lines
- Drawing cross sectional profiles
- Plotting stream gradients
- Use of topographic maps to investigate the geology of an area
- Use of geologic maps to coordinate geologic formation
- The construction of stratigraphic columns

Unit 6: Oceanography

Objectives

1. Students will know the physical characteristics of sea water and oceans.
2. Students will recognize and be able to interpret the effects of temperature and density in the oceans.
3. Students can describe action of temperature and density in producing currents.
4. Students can relate ocean currents to climatic phenomena.
5. Students can describe how data on the oceans is obtained.
6. Students can describe the ocean floor and how it compares with the continents.
7. Students will know the possible relations of the oceans to man's future.
8. Students will know about changes in sea level and be able to relate these changes to possible causes.
9. Students will know about marine sediments and how they are investigated and used by geologists.

Content

- The field of ocean exploration
- Nature of sea water and its origin
- Currents - water transport
- Changes in sea level
- Topography of the ocean floor - formation of ocean basins
- Development of coastal land forms due to shore line erosion and deposition
- wave motion - types and origin
- Islands and coral atolls
- Oceans as a source of minerals

Unit 7: Geologic Time

Objectives

1. Students will identify the order of past geologic events.
2. Students will interpret data to predict the probable conditions of the earth during stages of the geologic past.
3. Students will correlate geologic history with life history.
4. Students will know the methods used to gather data on the history of the earth.
5. Students will know the methods used to interpret and date past geologic events.
6. Students will interpret and correlate the formation of some of the major features of the earth.

Content

- Theories about the pre-history geology of the earth
- Dating methods used to determine the earth's age
- Formation of early features, i.e. ocean basins and continents
- Evidences of first geologic erosional activity
- Theories about the development of living material
- Land forms and life developments through the various stages of the geologic history of the earth

Unit 8: Physical Anthropology

Objectives

1. Students will identify the characteristics of the fields of physical and cultural anthropology.
2. Students will know what is known of the early history of man and the methods used to trace this history.
3. Students will conduct personal library research into a number of cultures and report thair findings.

Content

- The lower primates
- Comparisons of Hominidae and Pongedae
- Species of prehistoric man
- Migration of man
- Beginnings of human culture
- Types of cultures

Unit 9: Physical Mineralogy

Objectives

1. Students will determine specific gravity values of mineral samples.
2. Students will identify unknown specimens through physical examination for cleavage, fracture, hardness, specific gravity and appearance.
3. Students will identify unknown specimens by use of chemical tests used along with tables of information about results of the tests.
4. Students will use the data from physical and chemical tests to infer the possible origin of the mineral.
5. Students will demonstrate use of accepted laboratory techniques as they conduct physical and chemical tests.

Content

- Measure specific gravity
- Determine streak information
- Determine hardness and arrange a scale
- Types of crystal forms
- Classes of common minerals
- Use of closed and open tubes for heat tests
- Use of charcoal block
- Use of a mineral identification booklet
- Mineral origins and source locations

3.32 THE BIOLOGY COURSE

The biology course is an evolving one, such that the full details are not known at present. We hope to offer experiences which start with the individual's existing performance relative to a given behavior and carry him toward an identified terminal performance level of that behavior. The sets of experiences (instructional packages) do not deal with a single behavior; therefore, during one chronological period the student will be progressing through the "conditions for learning" (1) for several behavioral objectives.

We have felt several severe constraints on this design; the most severe is the lack of knowledge and detailed theory about the learning process. What must a student be able to do before he can describe a conceptual model? Must he be able to describe the model before he is able to explain observed phenomena in terms of the properties (assumptions) of the model? Our initial solution was to intuitively define and order the stages of model building and then present them chronologically. We anticipated that back-transfer would establish the requisite performance level. The example called sample behavior A exemplifies our efforts. Use combined with evaluation will cause us to modify such stages and their sequencing.

Another constraint that acts on our ultimate design is the physical impossibility of construction of materials for multiple stages of multiple behaviors for a given body of content by our limited staff. We have accepted a linear sequence with optional, higher stage activities for our first trials.

Content creates its own constraints in its complexity relative to the physical science background of an incoming sophomore student, the seasonal availability of living organisms and associated experiences, and the availability of audio-visual aids at the most appropriate time from the Santa Clara County Office of Education. For these reasons we have rearranged the sequence utilized in the B.S.C.S.'s Molecules to Man (2) to one shown in the following course outline. Our rationale for such sequencing is shown here also.

Sequence of Biology Course Content

Weeks Duration	Topic Content
2	Science as Inquiry and Measurement.
2	Variety of Life (Diversity)
3	Ecology: Populations, Habitats, and Communities
2	Evolution: Two Theories
- - - - - - - -	
2	Introduction to Energy and Matter
1	Cell: Morphology and Theory
3	Systems: Energy and Transport (Form and Function)
3	Systems: Regulation (Homeostasis)
- - - - - - - -	
4	Reproduction (DNA and cell division)
3	Heredity (Gene pool)
2	Development
- - - - - - - -	
3	Adaptation: Behavior and Evolution
2	Races of Man
4	Current Topics of Biological Significance

Rationale for Biology Sequence

The approach to the study of content for the year will be made under the PHER model and an inquiry approach in the laboratory. The paragraphs that follow describe some of the rationale for the sequence and scope of the content. For convenience the units may be considered in four groups; each would represent about one quarter of the school year.

The four topics of the first quarter set the scene for the year's work. Problem recognition and forming of hypotheses introduced in the first week will be used on each subsequent unit throughout the year. The three topics that follow also set the scene for the year's work by introducing the problem of variety of life, the inter-relationships of living things and their environment, and the theory of evolution. These three topics lend themselves to interest-building field studies and laboratory investigations, consider the familiar surroundings of the student, and fit best the student's image of biology.

Since the topic of molecular biology contains more abstract concepts, provides the opportunity for fewer actual in vivo laboratory experiences, and is based to some extent on models, it is best considered during the second quarter after the student has attained some of the early behavioral objectives.

The second quarter then moves from the level of the organism to the molecular level and back to the level of the organism. Life is considered as a molecular phenomena involving matter and energy. A modern day interpretation of the cell is presented, followed by the study of the organization of cells into systems in multicellular organisms. Macromolecules, such as ATP and enzymes, are introduced as the form and function of energy and transport systems are considered. The function of hormones and other molecules in maintaining homeostasis in the regulatory systems follows.

The third quarter deals with the topics of reproduction, heredity, and development. These three topics are interdependent. They show the molecular basis for variation, continuity and similarity of life, and further develop the concepts of complimentarity of structure and function and homeostasis. Some of the topics, such as DNA, are based on models and lack practical laboratory in vivo laboratory experiments. Certain aspects of these topics lend themselves to bringing student attention back to their own lives.

The fourth quarter summarizes the theory of evolution by considering the adaptive functions of organisms. Man as a biological organism and his interaction with other organisms in the environment is studied before the significant biological problems are investigated. Although current biological problems may have been introduced at many points during the course, little opportunity can be provided for examination in depth. Students that complete a biology course in high school should be able to recognize problems of biological significance to them and should also interpret their environment through use of problem processes. Considered at the end of the year, the students bring more perspective to the problems than if considered earlier.

To show how the stages of behavior are developed throughout our sequence of content, the nature of activities relative to a terminal objective considered in each unit for two terminal objectives will be given. It is to be noted that these are not instructional objectives as they do not show the conditions or the performance level of the behavioral objectives.

Sample behavior A: To predict behaviors or capabilities of performance of a system on the basis of a conceptual model.

Stages: To list assumptions (properties) of the model.

To recall observations of natural phenomena associated with the model.

To describe the model.

To explain previously unobserved phenomena in terms of the model.

To predict behavior or capability of performance of a system on the basis of the conceptual model.

Content and associated behaviors:

Inquiry: Introduction to nature and use of observation and prediction.

Variety of Life: Introduction to simplification and organization of observed data.

Ecology: Introduction to nature of assumption and model, with macroscopic data given, assumptions identified in the quantitative mode.

Introduction to prediction, in the quantitative mode, on the basis of the model.

Evolution: The forming of generalizations (assumptions) on the basis of observed data.

Matter-Energy: Associating non-quantitative, given observations with assumptions.

Use of model to explain observed phenomena.

Use of model to predict the results of changes in the system.

Reproduction: Use of model to explain observed phenomena.

Use of model to predict the results of changes in the system.

Sample behavior B: To graph data of two variables on Cartesian co-ordinates using the horizontal axis for independent variable and the vertical axis for the dependent variable. Appropriate scale, [Legend], axis labeling, and title will be used.

Stages: To order data.

To identify the variables.

To discriminate between the dependent and independent variables.

To identify the nature of the data.

To determine the scale to be used to present data on 8 1/2" x 11", 5 squares/inch graph paper.

4.0 SYSTEMS EFFECTIVENESS

As indicated earlier, the establishment of effectiveness criteria is critical to proper systems development. Effectiveness may be considered as consisting of five components.

- Capability
- Dependability
- Availability
- Suitability
- Acceptability

Capability is the basic ability of the system to effect the desired behavioral changes in the student population, i.e. the object system. Dependability is the characteristic which describes the survivability of the system. In other words, is the system dependable in the face of known environmental obstacles and its own inherent reliability. Availability is concerned with the system being ready to use at prescribed times, i.e., scheduled class times. It involves the maintenance and supply problems for sustaining operation of the system. Suitablility is concerned with whether or not the system is compatible with existing instructional systems in the overall school context. Finally, acceptability refers to the assessment which must finally be made by school and district administration problem, particularly cost.

First priority, during the planning phase, has been given to consideration of the capability of the system in meeting the behavioral objectives for the object system of students. The discussion below is directed toward this consideration. Problems associated with the other aspects of effectiveness are discussed in Section 8, as well as the relationship of effectiveness to cost.

Establishement of capability effectiveness criteria involves three major steps which are briefly listed below.

1. Define the nature of effectiveness within the framework of the system under development.
2. Identify or develop techniques for measuring effectiveness of the system and their interrelationships.

All of these steps have been accomplished for the projected system at the conceptual level during Phase I.

Definition of the nature of effectiveness for a secondary science instructional system requires consideration of the purposes of secondary science education. Some of these considerations have been covered in the preceding section on the development of behavioral objectives. Simplistically, of course, all we need to do is to look at the object system and conclude that effectiveness is the achievement of specified behavioral objectives. The critical question is the specification of criteria for the selection of behavioral objectives. As indicated in the section on behavioral objectives students entering into the science instructional system can be grouped broadly into five categories. The five categories and their vocational goals are indicated below.

INPUT STUDENT	OUTPUT STUDENT
° High aptitude and high interest in science.	° Student prepared for follow-on courses in science at advanced secondary or college level.
° High aptitude and moderate interest in science	° Student prepared for follow-on course in advanced science at secondary level or course in allied field at college level.
° Moderate aptitude and interest in science.	° Student prepared for follow-on college level course in non-allied field.
° Moderate aptitude and interest in science; vocational goals do not include 4 year college.	° Student prepared for entry into science or allied field at paraprofessional level.
° Moderate to low aptitude and interest in science; does not plan to go to college.	° Student prepared to understand scientific development as reported in popular media.

In addition to the specific vocational goals indicated above there is a basic requirement, as previously indicated, to provide instruction in basic thinking skills which can be utilized by the students in other areas.

If we use the above scheme for defining the nature of effectiveness for the overall science course, we can then select behavioral objectives for the course appropriate to each vocational category. Effectiveness of the system then becomes the achievement of these selected behavioral objectives. The ultimate measurement of effectiveness is the degree to which the students perform at a higher level in their selected vocational endeavor than do students who receive a traditional science education at the secondary level. It is recognized that science education is only a part of the total educational experience of secondary education. If the improvement in science education is significant, however, measurable differences should be obtained in a long-term follow-up study of students exposed to the new instructional system.

Before considereing a formulation of effectiveness at the course level, it is necessary first to consider what constitutes a course of instruction. For the purposes of CLSP a course may be defined as a sequence of instructional units or packages with a common content core directed to a specified set of behavioral objectives. We may then define course effectiveness as:

E = f (Selection and Sequence of Instructional Packages) in which "f" means "a function of". This formula states in effect that, if there is in existence an unlimited number of optimized instructional packages (IPs), differences in effectiveness depend upon the selection of these packages and the sequencing of them in the course. This formulation and the discussion associated with it assumes that the necessary equipment and facilities required for conducting the course are available.

Because the above formulation of course effectiveness assumes the existence of optimized (Maximally effective) instructional packages, it is necessary to also consider the problem of defining effectiveness at the instructional package or instructional unit level. Review of the literature and experience of the CLSP staff has led to the following formulation of instructional package effectiveness:

E = f (Instructional Mode, Media, Structure, Content) in which

Instructional Mode is defined as the mix of group size and instructional technique.

Media is defined as the means for transmitting information to the student.

Structure refers to the sequencing of instructional events that leads to achievement of the instruction behavioral objective.

Content refers to the selection of materials for inclusion in the package of an illustrative, conceptual or factual nature and the accuracy and recency of such data.

In effect, what the formulation states is that if you select the optimal mode and media for presentation of information and instructional activities, if you select the best and most appropriate content material, and if you sequence the instructional events in accordance with the best information available from the learning theorists you will have an optimally effective instructional package. The measure of such a package would be the degree to which the specified behavioral objectives of the package are met by the students under instruction. These tests of achievement may be either motor skill tests, cognitive tests mediated by verbal expression, or any of a variety of measures of changes in effective behavior.

The power of the above formulation is that it defines the variables that contribute to effectiveness, and therefore can be systematically manipulated. The limitations of the formulation are simply that the presently available data from the literature is inadequate to provide reliable predictions of effectiveness for any candidate instructional system. Due to this inadequacy of available data, preliminary testing of aspects of mode and media as contributors to effectiveness has begun in Phase I.

5.0 INSTRUCTIONAL MODES

Instructional modes may be defined as the interaction between a teacher and a student or students via an instructional technique. Lecture, discussion, quiz and laboratory/field work are four basic instructional techniques that can be identified. Other techniques can be identified, but they consist of mixes of these four basic types. Selection of appropriate instructional modes is critical to the success of any instructional system since this selection is based on an understanding of the basic object system and the nature of the capabilities of the students entering that system.

5.1 INDIVIDUALIZATION

In selecting instructional modes, as in other areas of this project, criteria for selection have first been established. In the selection of modes, individualization has been the primary criteria. Individualization of educational experience assumes that the behavior to be learned and the instructional contact through which it is learned should be tailored to each student's ability. Further, individualization assumes that the major responsibility for learning rests with the student. There is ample justification in the general educational literature, as well as specifically in the literature of learning theory to justify the use of individualization as a major criteria in the selection of instructional modes. Further, the collective experience of the teaching personnel within the CLSP indicate a need for such an approach.

The degree of interaction that can occur between teacher (sometimes mediated) and the student is an important element of individualization. Interaction may involve noticeable, visual, overt student response or a passive, completely covert thought. In this discussion of group size/technique (i.e., mode), consideration will be given to the degree of observable interaction that can occur in each mix. It is assumed that the greater the degree of observable interaction that occurs, the greater the certainty that learning has occurred. In looking for an optimum mix of group size and technique, it must be kept in mind that individualization and interaction are necessary ingredients.

5.2 INSTRUCTIONAL TECHNIQUES

Lecture

Research shows that the lecture technique is used 75 to 90 percent of the time in a show-and-tell form of teaching in traditional secondary school classrooms. One-way communication predominates and avenues of interaction are virtually cut off. Individualization does not exist. Differences between students are recognized, but the lecture-large group mode can only respond to them with a diffuse "shot-gun" effort. It is impossible for ALL students to receive satisfactory instruction.

Discussion

Discussion provides many opportunities for interaction and therefore individualization. Two-way communication does exist and interactions can occur. Psychological pressure for overt interaction exists in small groups, but evidence indicates that negative pressure for overt interaction exists in groups over 12 - 15 in size. Small, flexible groups should become a preferred mode for instruction and learning activity in conjunction with individualized instruction.

Discussion under the 1/1 ratio should be advisory and consultive. Teacher and student can discuss performance, evaluation, enrichment and remedial steps at a very personal level. Teachers will have a greatly expanded opportunity to prescribe instructional involvement for each student. Discussion in the 1/10 ratio group can take place with the teacher acting as an observer, a resource, a stimulator and mediator.

Quizzes

Quizzes may be written or oral. In an individualized system the oral quiz can occur frequently enough that it may replace many written quizzes. As the role of the teacher is changed, the teacher-student contact will provide the opportunity for oral quizzing. It is evident that the maximized interaction and individualization that is possible under a 1/1 ratio will permit a much more complete teacher assessment of student performance.

Laboratory

The traditional laboratory can be replaced by an "open lab" under an individualized schedule. Maximum effectiveness can occur where students will be able to complete experiments in one session. Under the traditional program a rigid time allotment prevents the completion of many experiments in one session. An artificial, ineffective break in the experimental performance has to exist. The planned model will allow time in any necessary increment or sequence of increments demanded by the experiments when materials and media are available for the laboratory instruction.

Field Trips

Field trips, while extremely useful, still require large time increments and usually involve disruption of student involvement in other classes. Students are too often herded along in large groups where teacher-student contact is low. Interactions occur but are restricted. With innovations in the use of media, it may be possible to simulate a field trip as part of the student's classroom, laboratory or independent study involvement. With the simulated field trip as a school experience, the students can then conduct field trips on weekends.

In considering candidate group size/techniques mixes the criteria of individualization has been used. Large group sizes were eliminated because of low interaction and minimum individualization. Information normally presented via the large group lecture can be presented on a 1/1 basis if the material is mediated through some recording technique. Discussions should be limited to the 1/1 and 1/10 ratios to maximize student-student and student-teacher interactions. There should be an increasing use of oral quizzes in the 1/1 and possibly the 1/10 ratios. Laboratories will be held to a 1/1 ratio even though physically, there may be many students in the same laboratory facility.

The three instructional modes selected for test in Phases I and II are therefore:

- Individualized mediated instruction
- Small group discusssion
- Individualized laboratory

6.0 INSTRUCTIONAL MEDIA

Although there may be some requirements for hardware in functions other than that of information presentation, the primary emphasis has been placed on presentation equipment, since firm requirements for support in this area have already been established. Rather than classify instructional equipment by hardware terminology, it is more useful in the implementation of selected instructional modes to use a media classification.

For the purposes of CLSP, media are any methods or techniques for presenting stimuli to the student. Media under consideration for inclusion in the proposed system include the following categories:

- Oral (live, recorded)
- Text (traditional, programmed)
- Graphics (slides, pictures, charts)
- Three dimensional objects (models, specimens)
- Moving pictures (movies, video tapes)

During Phase I a survey of available instructional hardware was conducted. The Department of Audio Visual Instruction (DAVI) Convention was used as the starting point for this survey. Based on this initial survey, follow-up inquiries were sent to identified vendors to obtain additional information concerning detailed equipment specifications and cost.

Equipment data which has been analyzed indicates that with hardware presently available, it appears unlikely that any extensive development effort will be required in this area. Rather, the emphasis will be placed on the integration of existing hardware into an effective functioning configuration. Certain items of equipment may, however, requre modification, particularly with regard to reliability to fit into the overall system. Further, it appears that the major effort required in implementation of the system is the development of software to adequately take advantage of the available equipment.

To provide baseline data a survey was conducted of instructional hardware already available at Cubberley. In addition to simply identifying the equipment items, a survey was conducted among the science department faculty to obtain information on utilization and experience with available equipment. In general, dissatisfaction with existing hardware was primarily with the lack of software, e.g., films, for optimal use of the equipment in the classroom.

To supplement the review of instructional hardware discussed above, a survey was conducted of a number of operational and military instructional systems during Phase I. It was not the intent of this survey that an instructional system for the Cubberley situation could be lifted from another existing system, and also to identify problems that have occurred in other systems.

In attempting to match media to instructional packages or instructional events within packages, three approaches are possible:

- Perform the matching based on the experience of the staff and data available in the general literature.

- Develop new data regarding media matching through testing within CLSP.
- Permit the individual student to perform his own matching by providing alternative media for instructional events.

The first approach, appeal to the literature, is of limited utility due to the lack of data or the unique nature of the conditions under which the data were developed. The approach planned within CLSP is to develop new data through pilot testing of instructional packages that will at least identify the two or three best media for any specific instructional event. This will permit a combination of the last two approaches listed above. A preliminary matching of media to mode is shown in Figure 4. It is interesting to note that with all of the emphasis on individualization, there appears to be little effort to individualize media for the student. There is much concern over individualization of rate of learning, but little over individualization of media. It may be, for example, that certain students are functionally blind or deaf to certain mediating channels, and would achieve at significantly higher levels if given alternate routes through the instructional experience. There are, of course, time and cost constraints on how many alternative mediations can be provided to the student.

7.0 CANDIDATE INSTRUCTIONAL SYSTEMS

Rather than attempt to identify all of the possible systems that could meet the requirements for a secondary science instruction system, a decision was made early in the project to select a limited set of candidates that would provide the greatest amount of information about the range of cost and effectiveness associated with a new system. It was, therefore, decided that the list of candidates would be restricted to three systems, including the present system. The present system must be included to provide a baseline against which the new systems will be tested. The two new systems that have been selected for forther consideration include a system that makes use of the most advanced techniques in technology, i.e., dial access, computerized feedback, and a middle system which makes use of innovative instructional modes and media but does not automate a large number of the system functions. Brief functional descriptions of each of these systems is provided below.

7.1 SYSTEM A--THE BASELINE SYSTEM

The baseline system is the present science instructional system at Cubberley Senior High School. It should be pointed out that any existent instructional system is not static and a description of the system is simply the description at a single point in time. This is particularly true when the staff responsible for teaching within the system are subjected to exposure to a project such as CLSP. This means that the system as it existed during the 1966-67 academic year has been altered as a result of experience with CLSP.

The present system consists of a laboratory oriented approach within the constraints of a self-contained classroom. The instructional modes are essentially all large group versions of lecture, discussion and laboratory. A variety of media are utilized within these modes but effective utilization is constrained by the lack of effective, readily available software.

As part of the analysis of the present baseline system a survey was conducted among the science staff at Cubberley. This survey was designed to obtain data about the present instructional modes and media utilization. The results of this survey are presented below.

Mode	Number of Hours Per 5 Hour Week	
Group lecture, discussion and recitation	3.1	
Laboratory	1.5	
Small group discussion (depth study)	.4	
	5.0	Total

Media	Number of Hours Per 5 Hour Week	
Oral communication	2.1	
Graphic elaboration (slides, charts)	1.0	
Use of models or objects	1.0	
Textual material (reading, etc.)	.4	
Film presentation	.5	
	5.0	Total

7.2 SYSTEM B

The second candidate system represents a moderate step away from the baseline primarily by providing the instructional modes and supportive equipment and facilities to provide the potential for individualization. The primary instructional modes for this system consist of individualized mediated lecture, small group discussion, and individualized laboratory experience. A wide variety of media will be used in the programmed instructional packages, all under the direct control of the student.

The primary changes in the facility and equipment areas will be in the provision of small group seminar or discussion rooms, and facilities for independent study. Independent study facilities will consist of carrels which have equipment for utilizing audio tapes, motion pictures, slides, and printed media.

Handling of media materials will be manual, with checkout of materials and equipment from a central repository.

The basic unit of organization in this system is the instructional package. An instructional package may be defined as the total set of instructional software required for teaching a unified sequence of content leading to specific instructional objectives. To facilitate the development of such packages an arbitrary time limit has been set of three weeks equivalent in the self-contained classroom situation. An instructional package may require from one day to as much as three weeks for the student to complete. The instructional package must contain the following items:

- Instructional objectives
- Pre-test with rationale
- Statement of purpose
- Precis of course content
- Outline of major concepts
- Outline of teaching activities
- Content instruction requirements
- Performance criteria for completion
- Outline of student activities
- Student responsibilities
- Student class assignments
- Post test with rationale

In addition to the above, it will also contain an appropriate mix of the following item:

- Tape-slide presentations
- Programmed text
- Single concept films
- Self check evaluationa
- Small group discussion guides
- Laboratory worksheets

As can be seen from the above listing, the total package includes materials for both the teacher and the student.

7.3 SYSTEM C

The third candidate system will closely resembel System B with three major changes. Instructional modes, media materials, and instructional packages will be essentially the same. However, there will be significant changes in the following areas:

- Media materials will be made available to individual carrels through a dial access system.
- Two-way video communication will be provided between the student in the carrel and a remotely located teacher.
- Computer support will be provided to the teacher for use in planning the individualized program for each student and for scoring of tests and immediate feedback to the student.

MEDIA		MODES	
	Individual Instruction	Laboratory	Small Group Discussion
Oral	Taped		Live
Text	Programmed and Reference	Programmed Worksheets	
Graphics	Slides	Slides	Slides
Three Dimensional Objects		Models and Specimens	
Moving Pictures	Single Concept	Single Concept	

Figure 4 Preliminary Matching of Mode and Media

8.0 COST EFFECTIVENESS

8.1 GENERAL APPROACH

In performing any task whether it be a military mission, an industrial operation, or science instruction, three general areas of activity can be identified. First, we must describe the job to be done. Second, we must invent, collect or somehow generate candidate systems which have possibilities in performing that job. Third, in order to select a best system from among the candidates, we must determine how well each of them performs the job. Depending upon the final answer, it could include no acceptable system; we might find that we would have to iterate again through these steps to finally produce the desired result.

The final operation in this sequence is selection of the best system from those which are determined to be acceptable. The criterion for selection is value per dollar or cost-effectiveness. Cost-effectiveness is often expressed as a ratio of the effectiveness and the dollars required to bring about that particular level of effectiveness. Use, merely as a sample ratio, is not sufficient and sometimes can be misleading. Although the value per dollar might be high, several possible undesirable situations could be represented. For example, the cost might be extremely low for a system with unacceptable effectiveness; or the effectiveness might be extremely high, at a cost that cannot be afforded. Although the simple cost-effectiveness ratio would have labeled these as good systems, neither could be used.

Another fallacy in the use of the simple ratio is the effort to seek the greatest effectiveness for the least cost. These cannot be sought simultaneously. To expect that the least expensive system would correspond with that having the greatest effectiveness is unreasonable.

The normal approach is to evaluate on the basis of constant effectiveness or constant cost. For constant effectiveness, a prescribed level of accomplishment is used as the objective for use of the several possible candidate systems. Each must provide the level of accomplishement set. Depending upon the capability of each, different levels of resources would have to be brought to bear involving different levels of cost. The least expensive system for equal effectiveness would be the preferred system. On the other hand, for constant cost evaluation, a level of resources available would be fixed, normally expressed as budget dollars. It would then be determined that a level of effectiveness could be achieved by each of the candidate systems. The most effective system for constant cost would be the preferred system.

For the Cubberley-Lockheed Science Project, the most useful approach appears to be the constant effectiveness approach.

8.2 EFFECTIVENESS

Effectiveness is the value for having used the system. In order to properly evaluate that value, several things are needed:

1. A model to predict behavior of that system as used under a particular set of conditions,
2. System characteristics and their relationships, and
3. Basic data which would adequately describe those characteristics and relationships in order to use the prediction model.

Cost considerations should include all those chargeable to the system under study. This means not only the cost for development but also that involving procurement of the initial means to employ it and finally the costs for operating and maintaing the system through its useful life.

In the present project three basic learning systems are under study. The first, System A, is the baseline system and represents the current form of science instruction at Cubberley. Actually, as a result of Phase I efforts, changes have already been incorporated in the baseline system so that it would be considered System A_1. System A_1 will be the reference against which comparisons will be made. System B represents a moderate step away from the baseline which moves toward individualization. This is achieved through changes in instructional mode, the variety of media used and the type of facilities employed. System C is essentially like System B except for a move toward mechanization with rapid access systems and means for rapid feed-back to the student.

Each of these systems will have a characteristic effectiveness in achieving the behavioral objectives for the student. Each effectiveness will be sensitive to the detail design of the system. The current state of knowledge indicates that:

1. No models are available to predict the behavior of such a system.
2. Although some characteristics have been identified, their inter-relationships are not well enough known so that a suitable model can be developed.
3. Data describing these characteristics are not available, although some should become available as Phase II progresses.

The Phase II effort should provide much of this needed information but at this point, it appears that not nearly enough would become available to enable the development and use of sophisticated prediction.

There are several major forms which the models might assume. These include analytical math models and simulations. The math model requires a high level of knowledge concerning the inter-relationships of system characteristics and data describing them. The simulation on the other hand, can use a lower level of precision describing the inter-relationships. For Phase II, as noted above, neither of these appear as practical for predictive purposes. However, an approach to simulation is pilot run testing as planned for Phase II. With such testing, appropriate measurements can be made to select from among those systems actually tried, a suitable best system. The representation of the system or its simulation is the system itself. From these tests credible ranking should be available as well as trends in performance sensitivity to changes in each of its characteristics.

Effectiveness has five basic components which can be appropriately detailed for the purposes of analysis. They are:

1. Capability
2. Dependability
3. Availability
4. Suitablilty
5. Acceptability

Capability is the basic ability of the system to affect the behavioral change desired. Dependability is the characteristic which describes the capability as a survivable system. In other words, is the system dependable in the face of known environmental obstacles and its own inherent characteristic of reliability. Availability is concerned with the system being in hand when needed not only for the initial effort but on a continuing basis. It involves the maintenance and supply problems for sustaining operation of the system. Suitability is concerned with whether or not the system is compatible with existing instructional systems in the overall school context. Will it meet with the "social" and "political" constraints which are the norm for the school environment in which it must be used. Finally, the acceptability refers to the assessment which must finally be made by the school administration in deciding to use the system. Acceptability involves all aspects of the administration problem particularly cost.

All of these can be expressed as a probability of achievement for the individual effectiveness component. The overall P in the effectiveness equation should be treated as a product of these factors. This means that the entire system is no better than the poorest component of effectiveness. Having one or two of them high cannot make up for deficiencies in others. The level of each of these effectiveness components should be balanced, within the group.

It has been stated that models would be used to predict behavior. The description of that behavior is the measure of effectiveness. In the absence of such a model, the components should be the items measured during the pilot run tests coupled as a set of conditional components.

8.3 ANALYSIS OF COSTS

This section discusses cost analysis of alternative systems for a science program at a senior high school in the Palo Alto Unified School District. Cubberley and Gunn High Schools were used as the data base for specific estimates. Relevant cost analysis concepts, appropriate present cost categories, current costs of present programs, cost categories for new systems, and possible tradeoffs are discussed in order.

Educational systems generate three major types of costs: development costs, investment costs, and operating costs. Science instruction systems currently operated in most high schools incur primarily operating costs. However, with rapidly expanding educational technology, it is likely that many future systems will incur a larger proportion of their costs in the development and investment areas.

The time phasing of these categories of cost for a given system vary widely. Development costs are generally incurred first with perhaps some continuation during early years of actual operation. They may be spread over considerable period of time, although one to three years may be typical. Investment costs tend to impact in the relatively short period of one to two years, after which operating costs begin and extend for the life of the system. Because of this time phasing, a conceptual device is needed to assist the comparison of these differently phased costs between systems.

This study follows widespread practice in systems cost analysis and uses ten year system cost. Ten year system cost is defined as the sum of development, investment, and ten years of operating costs, all expressed in current year dollar values. This cost concept accounts for all the major cost areas, gives operating costs an appropriately heavy weight to reflect its lifetime incurrence, and yet avoids projecting so far into the future that uncertainties about what may comprise desirable practice far outweigh any apparent precision in the numbers.

The ten year span is appealing also because it is a reasonable estimate for the useful life of much of the equipment in the system. (Current accounting practice in the district depreciates science equipment at 10% per year.) Ten years may also be a reasonable estimate for the useful life of development work carried out for new systems utilizing more advanced technology.

Another important aspect of systems cost analysis is the need for consistency in cost estimating methods between systems under comparison. The need for consistency indeed outweighs the requirement for accuracy in the size of the cost estimates. Uncertainty about key values like future construction costs, teacher salaries, technological developments, etc., unavoidably imparts uncertainty to the magnitude of the final cost estimates. However, the long range planning problem is to make a choice among the available alternatives. Consistent estimating and categorization practices reduce the chance that changes in these cost factors will change the ranking of the alternatives on the basis of total system cost. The uncertainty cannot be eliminated but its influence on the choice can be held to a minimum with consistent practices applied in the same way to all systems.

The cost data needs for formulating next year's budget, in contrast to planning needs, are more stringent. However, as each year of the ten comes closer to reality better estimates can be made for budget purposes. The effects of uncertainty are not avoided by avoiding planning.

Table 2 shows cost categories for the present science instruction system. No development cost categories are shown for the present system. Those costs, even if identifiable, are sunk costs. They have already been expended and the present system could be reproduced with no expenditures for development. The incremental cost concept has been used in developing these categories. That is, only those additional costs incurred in adding a science program to an existing school have been included. (Conversely, these are the costs that could be eliminated from the school's total costs if the science program and its student period load were eliminated.) Some minor categories of variable cost have been ignored since they were so insignificant as to have no appreciable effect on the ten year cost totals.

Table 3 presents the estimates of costs for the present system in 1967 dollars. These estimates are based on cost studies done in this district for Cubberley and Gunn. Building investment is based on the cost of the total academic floor space at Gunn (adjusted upward 5% per year to reflect increasing construction costs), multiplied by the average proportion of academic floor space used by the science departments of Gunn and Cubberley. The credit for value at the end of ten years is based on a 50 year life for classroom buildings, which is conservative. Equipment investment is based on actual experience adjusted at 2% per year for price changes. Investment in books and supplies is estimated at three times annual expenditures.

Teacher salary is based on 6-3/4 full time equivalents (FTE) at the current estimated senior high school average salary in the district, including 5% employer contributed fringes. Support salary, books and supplies, support services, custodian expense, and utilities are based on estimated 1967 experience. Building maintenance is estimated to grow from 0.6% to 1.5% of building investment cost over the ten year time span. Equipment maintenance is estimated to grow from 0.6% to 1.0% of equipment investment cost over the ten year span. Total ten year system cost is $1,285,500, of which teacher salary accounts for nearly two-thirds.

Table 2

COST CATEGORIES FOR PRESENT SCIENCE PROGRAMS

<u>Investment</u>

Buildings
Equipment
Books and supplies

<u>Operations</u>

Teacher salary

Support salary
- Guidance and counseling
- Teacher aids
- Shop/lab clerk

Books and supplies
- Textbooks
- Library books
- Educational supplies

Support services

Custodial expense
- Salary
- Supplies

Utilities

Maintenance
- Building
- Equipment

For estimating costs of future systems the cost categories shown in Table 2 must be expanded to include the following considerations:

1. Initial teacher training.
2. Possible recruitment of specially trained teachers.
3. Initial student preparation, if necessary.
4. Possible scrap costs, if material must be discarded or become obsolete, as a result of initiation of the new system.
5. Impact costs in terms of additional cost or possible savings that result from the integration of the new system with the ongoing more conventional systems.
6. Continuing in-service training.
7. Continuing development of new materials and supplies as the system evolves and improves from use.
8. Evaluation costs for monitoring and assessing inauguration of such a new system.

In making a comparative evaluation of the several systems which are candidates, a decision should be made about whether or not full costs or incremental costs should be used. When full costs are considered it is necessary to aportion general costs such as those for buildings and common equipment so that an appropriate value can be charged against the system under consideration. The degree to which the various costs should be proportioned and allocated against each of the systems is sometimes quite difficult to determine. The incremental cost approach on the other hand treats only those added or reduced costs which would result from the use of a particular learning system. The problem of allocating general costs would be eliminated.

It is recommended that for future evaluation, the incremental approach be used. This certainly does not mean that all cost categories would not be considered. Each of them would be. However, the cost could be collected at a normally definable burden center for accounting such as the science department within the school or perhaps the school itself. All common costs would then be appropriately included. At this same burden center the added costs or perhaps reduced costs for the use of a particular system could then be accounted and correctly considered. The differences then in burden center costs relative to the reference system would be the basis for judging costs and a measure of preference. This, in effect, leads to a marginal analysis wherein changes in effectiveness relative to the reference system are coupled with changes in cost relative to that same reference system. Costs treated in this way should offer a more convenient and credible approach.

Table 3

TEN YEAR COSTS OF PRESENT SYSTEM
(Costs in 1,000's of 1967 Dollars)

Investment

Building	$ 371.1	
Less credit for residual value (80%)	269.9	$ 74.2
Equipment		70.0
Books and supplies		17.4

Operations

Teacher salary	$80.1/yr x 10 yr	801.0
Support salary	11.8/yr x 10 yr	118.0
Books and supplies	5.8/yr x 10 yr	58.0
Support services	1.7/yr x 10 yr	17.0
Custodial expense	5.9/yr x 10 yr	59.0
Utilities	2.6/yr x 10 yr	26.0

Maintenance:	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	
Building	2.2	2.6	3.0	3.3	3.7	4.1	4.5	4.8	5.2	5.6	38.9
Equipment	.4	.4	.5	.5	.6	.6	.7	.7	.8	.8	6.0

Total Ten Year System Cost $ 1,285.5

9.0 PHASE I TEST PROGRAM

9.1 TEST PLAN FOR MODE/MEDIA STUDY

The objective of this research was to compare the effectiveness of two methodologically different approaches to science instruction. The first approach has been designated as System A. The system can be characterized as the self-contained classroom with advanced content/behavioral objectives development. The second approach has been designated as System B. System B_1 is characterized by small group discussion and individualized lecture, laboratory, and learning rate. In addition to these two systems, the effect of a third system was also investigated. It is similar to System A_1 except that class size was reduced to less than twenty students. This third system was designated A2.

The fact that many modes and many media will influence the results of this study is apparent from the foregoing description of the three approaches to science instruction. The intent of this study is to compare the overall system effectiveness; it is not to determine the relative efficiency of any one mode/medium mix for a particular instructional objective. Persons familiar with the educational research literature are aware that the variables manipulated in this research (Systems A_1, A_2, and B_1) are too gross to yield useful data. As Lumsdaine (1963) has aptly stated, "The severe restrictions on interpretation of such a comparison arise from the lack of specificity of the instruction with which the instrument is compared; ..." (p. 594). However, before subcomponents of System B can be investigated and empirically evaluated, the over-all instructional approach certainly deserves some assessment. The preliminary assessment of System B is the purpose of this study. Lumsdaine (1963), in the same article, supported this position:

> Where the evaluation made in over-all terms is a comparative one involving two alternative instruments or presentations, the purpose may be to determine which of these two specific instruments (e.g., two specific films) to adopt. (p. 594)

A review of the literature concerning various aspects of individualizing instruction has revealed no definitive research that would permit a competent selection and/or verification of one proposed instructional system over any other. Briggs (1961) and Lumsdaine and Glaser (1960) have reported and discussed the results of self-pacing of instruction. Although no significant differences were found between self-paced and automatically paced subjects, they concluded that once the student gets used to being able to pace himself, his performance will be enhanced. Research has also been reported on the individualization of media, e.g., teaching machines, movies, tape presentations; but again the data are not directly applicable to the present research (see Lumsdaine, 1963; 1959; 1965). Research has demonstrated that small group discussion ($N \leq 12$) is often more effective than large group discussion, although these findings are not conclusive. It has been pointed out in investigations of discussion group size, that as the number of students in the group increases, so does teacher dominance (Schellerberg, 1969).

Directly relevant to the present study are the results of a pilot study run by CLSP at the beginning of the Fall, 1967, school year. This pilot study compared System A_1 to System B on teaching the "inquiry method" to biology students. The stimulus materials for that pilot study can be found in Volume II of this report. The pilot study demonstrated that although Systems A_1 and B_1 did not differ significantly on measures of time and achievement, students under System B_1 did perform at a higher level than those under System A_1 which in turn performed at a higher level than the Control group.

To summarize this brief review of literature, there is evidence, though far from conclusive, that the components of System B_1 are, singly, more effective than the components of System A_1 or A_2. The purpose of the present research is to determine whether these components assembled into instructional System B_1 are more effective than System A_1 and, by inference, System A. The findings reported in the literature review served as a basis for hypothesizing that System B_1 would prove more effective in teaching fundamental biochemistry to high school biology students than would be System A_1 or System A_2.

9.2 DEVELOPMENT OF INSTRUCTIONAL MATERIALS

The selection of fundamental biochemistry as the stimulus material for this research was based on two major considerations. The first was that biochemistry offered subject matter that was both behaviorally oriented and fact-specific in nature. The second consideration was that this unit within the course was scheduled in a sequence which allowed sufficient lead time to develop the stimulus material.

Development of the material was regulated by the requirements set forth in the Instructional Package Specification contained in this report. The stimulus material for the biochemistry unit, entitled "Matter-Energy", was developed over a two month period. The material and examinations were based upon a set of twenty instruction objectives.

These objectives specified the terminal behaviors, and the content the students were to examine during the test period, as well as the conditions under which they were to demonstrate their new behavior. The primary information source for the material was the Biological Sciences Curriculum Study's text, <u>Biological Science: Molecules to Man</u> (1963). There were four major parts to this unit of material: Introduction to Matter-Energy (film), (II) Kinetic-Molecular Model, (III) Chemical Reaction Model, and (IV) Molecules of Living Systems. A pre-test was developed for administeration prior to Part I, quizzes developed to follow Parts II and III, and a post-test was constructed to be administered following Part IV. Copies of the stimulus materials and evaluative instruments are in Volume 2 of this report.

The stimulus material was prepared for mediation as a teacher-slide presentation in Systems A_1 and A_2 and as a tape-slide presentation in System B_1. In addition to the textual materials, work sheets were developed to provide a means of student self-check and to provide immediate reinforcement to the response made to the material which immediately preceded the questions.

At the completion of development of the stimulus material, it was structured into a two and one-half week unit by the following schedule for System A_1, presentation.

DAY 1--Class:	Film/Discussion
Home:	Complete worksheet handed out in class.
DAY 2--Class:	Lecture on the Kinetic-Molecular model
DAY 3--Class:	Lecture on the Chemical Reaction model.
DAY 4--Class:	Review and discussion of the first three days.
Home:	Study for quiz.
DAY 5--Class:	Quiz
DAY 6--Class:	Laboratory--carbohydrates, fats, proteins, enzymes.
Home:	Complete laboratory assignment.
DAY 7--Class:	Lecture on carbohydrates, fats, proteins, and enzymes.
DAY 8--Class:	Lecture on enzymes. Review and discussion of days 6, 7, and 8.
Home:	Study for quiz.
DAY 9--Class:	Quiz. Begin lecture on enzymes, ATP, and fermentation.
DAY 10-Class:	Lecture on enzymes, ATP, and fermentation continued. Lecture on protein synthesis.

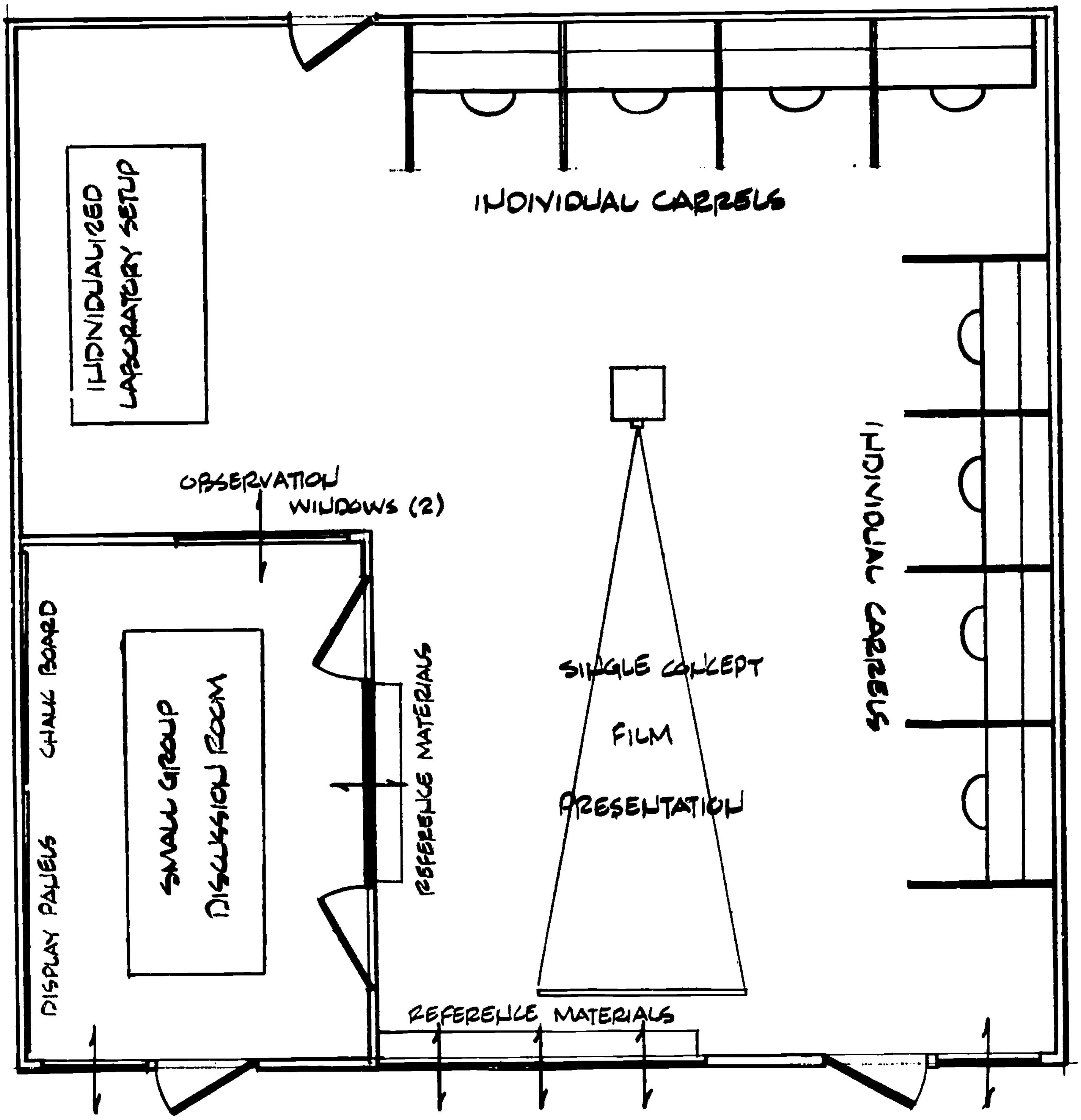

Figure 9.3.2

Schematic layout of test facility

Figure 9.3.3

This mean score on the pre-test for biology students was 7.8 while the mean score for geology students was 8.2 (N=24 and 12, respectively). [The biology subjects were randomly assigned to one of three treatments: A1, A2, or B.]

Procedures. Prior to assignment experimental treatments, all subjects received a brief description of the project and its goals. They understood that a comparison of two different instructional systems was being made. The 72 biology students were then randomly assigned into one of three groups: A1 (N=24), A2 (N=24), and B_1(N=24). From this distribution, one-half of the subjects in A1 and B_1 were randomly selected to receive a pre-test. The subjects in Group A2 did not receive a pre-test. The control group (N=24) was randomly assigned from the geology classes. One-half of the control subjects were selected at random to receive the pre-test. Considering groups A1, A2, B_1, and the controls, the distribution of subjects into treatment conditions can be summarized as shown in Table 9.4.1.

The lectures and discussions for Groups A1 and A2 were mediated by means of a teacher-slide presentation. The subjects in these two groups received the self-check questions orally from the teacher. Laboratory assignments were given to all groups via printed media. The subjects in Groups A1 and A2 proceeded through the lectures, discussions and labs at a group rate. No new information was presented during discussions.

The lectures for Group B_1 were mediated by a tape-slide presentation. The stimulus material was played on tape recorders and received on head phones. The subjects operated the slide viewers manually and coordinated the slides with the audio portion of the lectures. They were permitted to progress through the presentation at their own learning rates. The subjects were allowed to return to any part of the tape-slide lecture. They participated in small group discussions and laboratories when their self-pacing brought them to these activities. Group B_1 subjects received self-check questions and answers via a printed worksheet. As with Groups A1 and A2, Group B_1 received lab assignments via printed media and received no new information during small group discussion.

Evaluation. Over a two and one-half week period, the 74 biology students received four examinations*: (1) Pre-test, (2) Quiz 1, (3) Quiz 2, and (4) Post-test. Due to scheduling problems, the 24 geology students received only the pre-test and the post-test. The statistical analyses for this study are summarized in Table 9.4.2 and discussed below.

Quiz 1. This first part of the study consisted primarily of a comparison of Groups A1 and B_1 based on measures of achievement (Quiz 1) and time to complete the material up to Quiz 1. The statistical comparison utilized a 2 x 2 factorial design

* Subjects in Group A2 did not receive the pre-test.

in which the effect of "pre-testing" as well as "Group" were determined. In addition to this analysis, a comparison of Groups A1, A2, and B_1 was generated using the fixed model of the simple analysis of variance.

Quiz 2. The comparisons in this part of the study were identical to those described under Quiz 1. Achievement as measured by Quiz 2 and time to complete the material presented between Quiz 1 and 2 constituted the comparative data. At the completion of the second quiz, the subjects were given a questionnaire aimed at eliciting their affective responses toward System B_1(N=24). They were then returned to their regular classes to receive the last two lectures.

Post-test. The comparisons in this final part of the study were identical to those described above with two notable exceptions. First, post-test data from the Control Group was included in all analyses and, secondly, an analysis of covariance was performed. Specifically, this part of the study involved a comparison of the performance of Groups A1, A2, B_1, and the Controls based on post-test achievement data as well as a comparison of total time for Groups A1 and B_1 to complete the Matter-Energy instructional unit.

The preliminary statistical analysis for this part of the study utilized a 3 x 2 factorial design of the analysis of variance in which the effects of Group (A1, B_1, and Control) and testing (pre-test vs. post-test) were determined. An analysis of covariance, using pre-test and post-test data from Groups A1, B_1, and the Controls, was performed in support of the factorial analysis. In addition to these analyses, a comparison of Groups A1, A2, B_1, and the Control was generated the fixed model of the analysis of variance. A test was used to compare Groups A1 and B_1 on the time variable.

Table 9.4.1 Experimental Design		
Pre-test (N)	Treatment	Quizzes and Post-test (N)
12	System A1	24
12	System B	24
12	Control*	24
--	System A2	24

Table 9.4.2

Statistical Analyses

I. 3 x 2 Factorial*

	System A1	System B	Control	Total
Pre-test	12	12	12	36
No Pre-test	12	12	12	36
Total	24	24	24	72

II. Simple Analysis of Variance

	System A1	System A2	System B	Control*
N =	24	24	24	24

Total N = 96

III. Analysis of Covariance

	System A1		System B_1		Control	
	Pre	Post	Pre	Post	Pre	Post
N =	12	12	12	12	12	12

9.5 RESULTS

The findings of this research will be presented separately for each test point. The combined results will be discussed in the following section.

Quiz 1. A 2 x 2 factorial design of the analysis of variance demonstrated that subjects in Group B_1 performed equally as well as did subjects in Group A1 on a standardized test of achievement. This analysis also showed that pre-testing had no effect on the subjects' Quiz 1 performance. A simple analysis of variance demonstrated that the performance of subjects in System A2 did not differ significantly from that of the subjects in the other two groups. Table 9.5.1 summarizes the mean Quiz 1 test scores for groups A1, A2, and B_1. A maximum of 25 points was possible. In terms of percentage increases, Group B_1 showed a 6.1% increase over Group A2 and a 3.25% increase over Group A1, while Group A1 showed a 2.8% increase over Group A2.

A 2 x 2 factorial analysis of time to complete the material up to Quiz 1 revealed that subjects in Group B_1 completed the material in significantly less time than did the subjects in Group A1 ($p<.01$). This analysis is summarized in Table 9.5.2. In terms of percentage increase, the subjects in Group A1 required 15.87% more time to complete the material up to Quiz 1 than did subjects in Group B. Again, pre-testing was found to have no influence on this measure. Group A2 required an equal amount of time to complete the material as did Group A1.

Quiz 2. A 2 x 2 factorial analysis of Quiz 2 achievement scores demonstrated that the subjects in Group B_1 performed better than did the subjects in Group A1 ($p<.10$ where $F=3.96$ with 1/44 df). This analysis is summarized in Table 9.5.3. The analysis again revealed that the pre-test had no effect on Quiz 2 performance. A simple analysis of variance of achievement scores, comparing Groups A1, A2, and B_1, showed that Group B_1 performed better than Group A2 ($p<.01$). This analysis also demonstrated that Group A1 performed better than did Group A2 ($p<.10$ where $F=3.61$ with 1/66 df). The mean Quiz 2 test scores for Groups A1, A2, and B_1 are summarized in Table 9.5.1. A maximum of 20 points was possible. In terms of percentage increase, System B revealed a 33% increase over System A2 and a 15.2% increase over System A1 while System A1 showed a 15% increase over System A2.

A 2 x 2 factorial design of the analysis of variance of time to complete the material between Quiz 1 and Quiz 2 demonstrated that subjects in Group B_1 completed the material in significantly less time than did subjects in Group A1 ($p<.05$). This analysis is summarized in Table 9.5.4. In terms of percentage increase, the subjects in Group A1 required 15.6% more time to complete the material between quizzes 1 and 2 than did

Table 9.5.1

Mean Test Scores For

Quiz 1

Group / Test	A1	A2	B	Control
Quiz 1	19.83	19.29	20.47	-

Table 9.5.2

Analysis of the time to Complete the material up to Quiz 1

Source	Sum of Squares	df	Mean Square	F
System	17,633,34	1	17,633.34	33.61**
Testing	52.13	1	52.13	N.S.
Interaction	52.04	1	52.04	N.S.
Error	23,079.16	44	524.52	
Total	40,816.67	47		
**p .01				

Table 9.5.3

Analysis of Quiz 2 Achievement Scores

Source	Sum of Squares	df	Mean Square	F
System	37.16	1	37.16	3.96
Testing	9.11	1	9.11	N.S.
Interaction	6.75	1	6.75	N.S.
Error	413.42	44	9.39	
Total	466.44	41		
p .10				

Table 9.5.4				
Analysis of time to complete the material between Quiz 1 and Quiz 2				
Source	Sum of Squares	df	Mean Square	F
System	11,102.09	1	11,102.09	6.88*
Testing	1,102.09	1	1,102.09	N.S.
Interaction	1,102.08	1	1,102.08	N.S.
Error	70,991.67	44	1,613.45	
Total	84,297.92	47		
*p .05				

Table 9.5.5				
Analysis of Post-test achievement scores				
Source	Sum of Squares	df	Mean Square	F
System	2,923.69	2	1,461.85	61.01**
Testing	33.34	1	33.34	1.39
Interction	37.04	2	18.52	
Error	1,581.58	66	23.96	
Total	4,575.65			
**p .01				

Table 9.5.6				
Covariance Analysis of Post-test Achievement Scores				
Source	Sum of Squares	df	Mean Square	F
System	1,325.41	2	662.71	27.57**
Error	769.26	32	24.04	
Total	2,094.67	34		
**p .01				

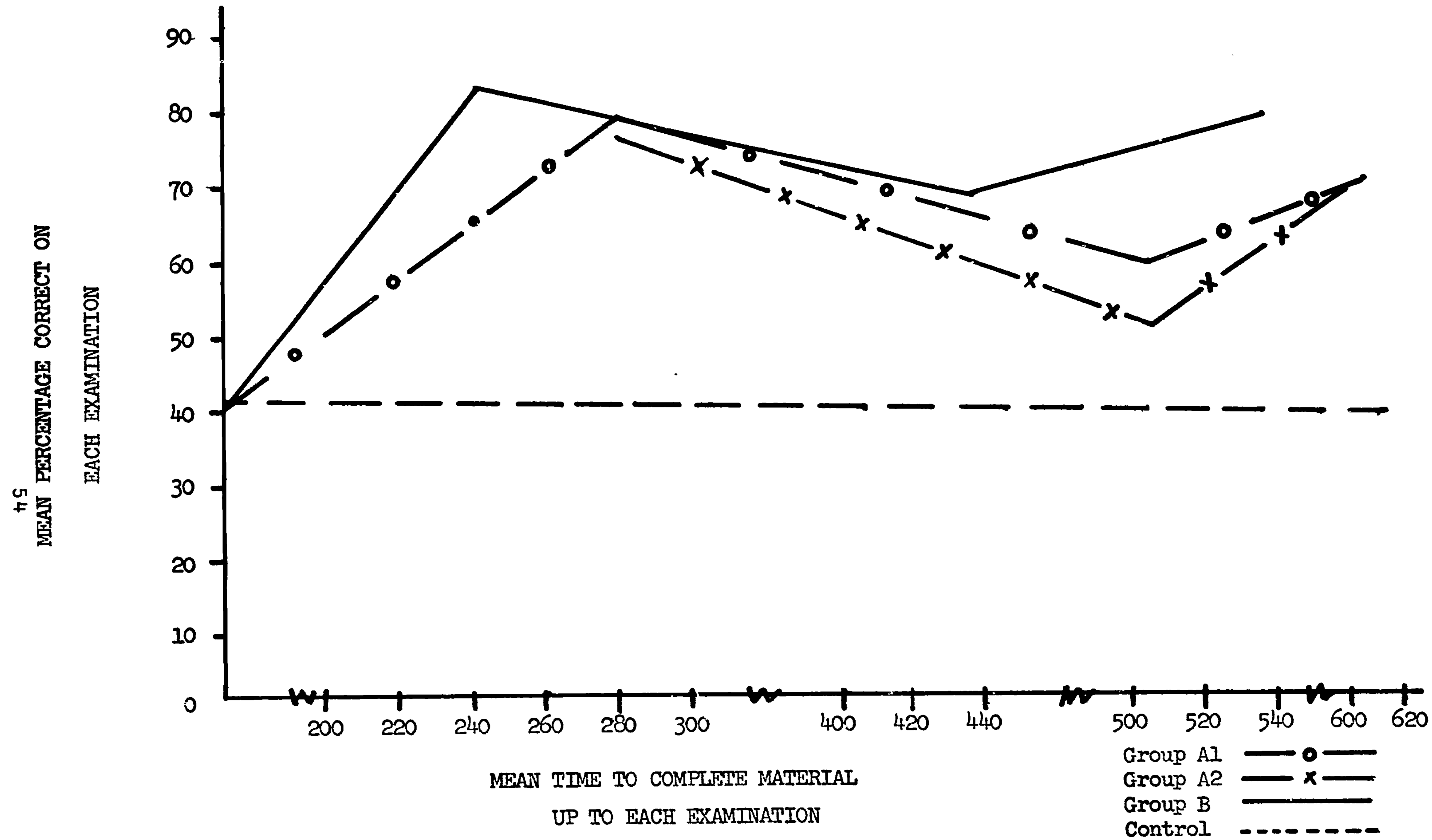

Figure 1 Graphic representation of examination scores with reference to time of testing (Time in minutes)

the subjects in Group B. Pre-testing was found to have no influence on this measure. The subjects in Group A2 required the same amount of time to complete the material as did subjects in Group A1.

Post-test. A 3 x 2 factorial analysis of the post-test achievement scores demonstrated that the subjects in Group A1 performed significantly better than did the subjects in the Control Group ($p < .01$). The analysis also revealed that the subjects in Group B_1 performed significantly better than did the subjects in Group A1 ($p < .01$) and, by deduction, they performed significantly better than did the subjects in the Control Group. This analysis also found that pre-testing had no influence over post-test scores. These findings are summarized in Table 9.5.6. A simple analysis of variance demonstrated that the post-test performance of subjects in Groups A1, A2, and B_1 was significantly better than Control Group performance ($p < .01$). This analysis also revealed that subjects in Group A1 ($p < .01$) and, by deduction, they performed significantly better than did the subjects in Group A2. Performance of subjects in Group A1 did not differ from that of subjects in Group A2 as measured by achievement on the post-test. The mean Post-test ahcievement scores are summarized in Table 9.5.1 and Figure 9.5.1. A maximum of 36 points was possible. In terms of percentage increase, the subjects in Group B_1 showed a 107.9% performance increase over the Control Group and a 12.5% increase in performance over subjects in both Groups A1 and A2. Performance of subjects in Groups A1 and A2 was identical (0% increase) and both groups demonstrated an 84.7% increase in performance over the Control Group on the post-test.

The results of t -test indicated that subjects in Group A1 required more time to complete the unit than did subjects in Group B_1 ($p < .01$). It took Group A1 15.7% more time to cover the same material as it did Group B_1. Group A2 required the same total time to complete the unit that Group A1 did.

Questionnaire. The results of the questionnaire have been listed below along with their respective questions. Frequency of scores are reported below. They refer to the students' rating of some aspect of System B_1 on a five point scale ranging from -2 to 0 to +2. A copy of this questionnaire is part of Volume II of this report. The data reported below refer to objective responses on the questionnaire. Written responses appear in section 9.6.

Compared to your regular classroom, do you feel that you learned more or less during the individualized presentation? Frequency (f) of: f(0) = 2; f (+1) = 14; f (+2) = 3.

Do you feel that the individualized presentation of the Matter-Energy Unit helped or hindered your performance on the examinations which you have taken? f(-1)=1; f(0) = 4; f(+1) = 10; f (+2) = 4.

Compared to your regular classroom, do you feel that you learned more or less during the individualized presentation? Frequency (f) of: f(0) = 2; f (+1) = 14; f (+2) = 3.

Do you feel that that the individualized presentation of the Matter-Energy Unit helped or hindered your performance on the examinations which you have taken? f (-1) = 1; f (0) = 4; f (+1) = 10; f (+2) = 4.

Compared to your regular classroom, do you feel that you were not allowed to interact enough with the other students during class? Yes 50% No 50%. On the scale below, rate your interaction with other students during individualization. f (-2) = 4; f (-1) = 6; f (0) = 6; f (+1) = 1.

Do you think that you would have learned just as much if you were given a typed copy of the materials and allowed to read it during class: Yes 0% No 100%.

Do you like or dislike the tape-slide presentation of material? Like 67% Neutral 32% Dislike 1%.

On the scale below, please rate the quality of the tape presentation. Mean: f(0) = 3; f(+1) = 8; f(+2) = 6.

Did you learn more (or less) from the small group discussion with your teacher during the individualized presentation than you normally learn during regular class discussion? f(0) = 2; f (+1) = 8; f (+2) = 7.

Did you receive more individual assistance from the teacher in learning the material in the individualized class than in your regular class? Yes 84% No 16%

Did individual assistance from the teacher help you in learning the material? Yes 88% No 12%.

On the scale below, rate your overall impression of the individualized class with comparison to your regular class. f (-1) = 1; f (0) = 0; f (+1) = 8; f (+2) = 8

9.6 DISCUSSION

The findings of this research supported the hypothesis that System B_1 would be more effective than either System A1 or System A2 in teaching basic bio-chemistry to high school biology students. The data reported in the preceding section indicated that, in general, Group B_1 resulted in both higher achievement and less required class time than did either Group A1 or Group A2. This was interpreted to mean that individualized lecture and laboratory combined with small group discussion and self-pacing is a more effective method of teaching a fact-specific, concept oriented unit such as biochemistry than is the large group lecture, laboratory, and discussion of the self-contained classroom (Group A1). Furthermore, this research indicated that the often suggested solution of reducing the student-teacher ratio to below 20 to 1 in order to improve education (Group A2) is no more effective than the existing system (Group A1). To summarize, the data indicated that "the whole is at least as great and is probably greater than the sum of its parts".

However, before discussing each study separately, an implicit assumption should be made explicit. That assumption is that System A1 is at least equally effective as a teaching system as System A. The rationale for comparing System A1 with System B_1 is based on the fact that our instructional system is not static and can be defined only with reference to a point in time. Thus, at the time of this research, System A did not exist. This fact can readily be understood if one considers that the instructional content must be held constant. System A simply did not have the same instructional objectives and consequent software as did System A1 or B_1.

Quiz 1. This portion of the study indicated that while Groups A1, A2, and B_1 did not differ in terms of achievement, the subjects in Group B_1, proceeding at their own pace, were able to complete the same material in significantly less time. Perhaps the absence of any differences in achievement could be attributed as much to the relative difficulty of the first quiz as to the treatments themselves. A comparison of the mean scores for the three groups on Quiz 1 indicated that the examination might not have been complex enough to elicit achievement differences.

Quiz 2. The results of this part of the study support the overall findings of this research. With respect to the time required to complete the material between Quiz 1 and Quiz 2, Group B_1 utilized significantly less time than did Group A1. Group B_1 also proved to be superior to both Group A1 and Group A2 in terms of achievement as measured by the second quiz. Furthermore, the findings of this study indicated that the subjects in Group A1 performed at a higher level than did the subjects in Group A2 ($p < .10$). At the .10 level of confidence, this finding may be interpreted as either chance or significant difference. Based on the results of the post-test, this finding was considered chance. This data does not support the contention expressed by some educators that a reduction of the student-teacher ratio is the needed panacea for effective education.

Post-Test. The findings of this study serve to amplify and make more definitive the data obtained in the first two parts of this study. All three parts demonstrated that Group B_1 required significantly less time to complete the Matter-Energy unit than did Groups A1 and A2. The data from this study also clarified the trend in achievement scores obtained from the first two quizzes. The two preceding quizzes suggested that Group B_1 produced higher achievement than Group A1; the post-test indicated a difference in achievement, significant beyond the .01 level of confidence. This finding was supported further by the data from the control group and an analysis of covariance. Finally, Groups A1 and A2 showed no difference in achievement on the post-test.

Several additional topics implied by the findings of this research but not readily apparent in the preceding discussion deserve mention. First, if the assumption that System A1 is at least as effective as System A is accepted, then the comparison of System B_1 with A1 can be considered a conservative approach. In other words, a comparison of System B_1 with System A might be expected to reveal even larger differences in terms of time and achievement. Secondly, after Quiz 2, the subjects in Group B_1 were returned to their regular classes (System A1) to receive the last two lectures. These lectures represented the maximum in conceptual difficulty of the Matter-Energy material. These last two lectures were based on and required a substantial understanding of the preceeding material. The findings of the third study, then, give evidence that this conceptual foundation was best supplied to Group B_1. Furthermore, the results suggest that even a partial implementation of System B_1 would result in more effective education. The data also suggest that System B_1 can be readily implemented in the existing educational system in gradual increments without being a detriment to the on-going education. Perhaps future research will indicate that a combination of System A1 and B_1 will yield the most effective educational system.

One last point remains to be considered before reviewing the findings of the questionnaire. Was the data influenced more by a "Hawthrone Effect"* than by the treatment of Group B_1? Certainly to deny that initially Group B_1 had any Hawthorne like-effect at all would be to overgeneralize. However, several factors lead to a general rejection of this possibility. First, this was not the first time the students had been exposed to System B_1. Secondly, every student in the research project was made aware that they were receiving an "experimental" treatment so, if anything, this effect was spread over all the subjects. And, finally, the experiment lasted two and a half weeks. During that time subjects in Group B_1 reported monotony during instruction. This certainly does not suggest the Hawthorne Effect.

<u>Questionnaire</u>. The data derived from the questionnaire supported the findings reported above. The subjects in Group B_1 felt that they had received a better education than they would have through System A1. They felt that the small

*Feeling that subject, as an individual, is importantmotivates him to a higher level of effect.

group discussions, particularly ($N \leq 10$) were more beneficial than System A1 type discussions. They also preferred the individual attention that the instructor was able to give them in Group B_1. As one subject commented:

> I found the individual work to be a lot less pressing than class. It seems that a class is always one day behind schedual [sic], while in individual work you make your own schedual, but to your own individual capabilities. By setting my own pace, I was never bored nor lost. The amazing thing is, with all the deadlines released and pressure removed, I still finished in line with the rushed and pushed class. I had far fewer headaches than my peers in the class, yet I got at least, if not more, out of it.

However the results of the questionnaire point up two significant problems associated with System B_1. The first problem is that Group B_1 tends to isolate the students from each other. The second is that Group B_1, especially the tape-slide presentation, can be monotonous. As several students commented. "Although the individualized class was well-run and interesting, I much prefer to be with people more of the time. It gets monotonous." "It was perfect except for the solitary confinement."

Future Research. In the Introduction to this research report it was pointed out that systems comparisons could be justified as a decision making tool. This statement reflects the purpose of the present investigation. Future research should concern itself with an analysis of the specific modes and media available for incorporation into System B . More particularly, research should be concerned with verifying a model for matching media and mode to behavioral and instructional objectives. This project has developed such a model. Perhaps when commonalities and mixes between mode and media have been identified for various types of learning situations (eg. Gagne's hierarchy of learning), the monotony reported by the subjects in the present study will be diminished significantly or disappear altogether. In addition to generating mode, media, and learning mix data, an effort must be extended to discovering aspects of System B_1 that would alleviate the isolation problem identified in the questionnaires. This objective might be accomplished through increasing the number of small group discussions and by increasing the number of laboratory assignments. The feeling of isolation might also be reduced through more adequate human engineering design of the study carrels. Human engineering work space and motivational studies are needed before any carrel design can be accepted for incorporation into System B_1.

Conclusions.

- Preliminary systems effectiveness data indicates that individualized instruction involving individual lectures and labs with small group discussions ($N \leq 10$) and self-pacing is superior to the existing science instruction system at Cubberley High School.
- The suggestion that science instruction can be enhanced by reducing the student-teacher ratio was rejected based on the findings of this research.
- Student questionnaires indicated that although System B_1 was more effective than the existing system (A1), this system presented problems of isolation and monotony.
- Equipment specifications for an individualized instruction system must take into strict account such factors as hardware reliability and maintainability.

10.2 EFFECTIVENESS

Based on limited tests of effectiveness of Systems A1 and B, which were conducted during Phase I it is anticipated that System B would be more effective than System A1 in achieving the specified instructional and terminal behavior objectives of the courses. An accurate prediction of the amount and significance of the difference is not possible with the limited data available. It is further hypothesized that System C would be more effective than System B, again by an unpredictable increment. This increment would largely be due to the fact that teachers would be unburdened from many time consuming tasks which would permit larger investments of time in one-to-one interaction with the students.

11.0 SELECTION OF PHASE II SYSTEM

Due to a lack of comprehensive data the selection of system(s) for further study in Phase II was of necessity judgmental in nature. The final decision was to include both System A1 and System B in the field test pilot program. The fundamental reasoning in this selection is as follows.

1. System B as the middle system, in both cost and effectiveness, would provide the maximal amount of data regarding the relative effectiveness of candidate instructional modes and media.

2. The inclusion of System A1 provides an alternate treatment control group in the pilot program with relatively little additional expenditure of funds. This results from the fact that preparation of the materials for System B includes the preparation of most of the materials for System A1.

3. System C was not included in Phase II plans as a system to be tested emperically primarily because of cost considerations. It was to be included in the analysis planned for Phase II. During Phase II it will be possible to test many of the aspects of System C in the test of System B. Further it will be possible to develop comprehensive and realistic cost estimates for System C which might permit establishing System C as the eventual instructional system which might be achieved through a series of incremental improvements of System B.

12.0 DEVELOPMENT OF PHASE II SYSTEM SPECIFICATIONS

The final activity carried out in Phase I prior to the preparation of the final report was the development of the specifications for Phase II. These specifications are contained in Volume III of this final report. These specifications were based on the analyses carried out in various activities of Phase I, the results of the Phase I test program, and special reviews of the existing educational and human engineering literature. Because Phase II represents one step towards an operational instructional system, these specifications are preliminary in nature and shaped by certain facility and cost limitations of the Phase II program. It is planned that they will be modified and updated as a result of the Phase II test program.

13.0 EXPECTATIONS AND RESULTS

As indicated earlier in this report, all first phase objectives of the Project have been completed. The area of greatest difference between original plans and obtained results is in the analysis of cost-effectiveness.

Fortunately, the variance was both negative and positive. On the negative side, it had been anticipated that sufficient data was available from the general literature to permit an acceptable definition of an effectiveness model for secondary science education. Project activities during Phase I, however, indicate a significant number of data gaps in the direct relationship of such parameters as modes and media to effectiveness, and an almost total lack of data regarding mixes of these parameters as they relate to effectiveness. As a result of these findings, increased emphasis will be placed on data collection to fill these gaps during Phase II to supplement the data accumulated during Phase I. This collection process will be carried out primarily as a part of the evaluation program, which is discussed in Section 10 of Volume III of this report.

On the positive side, it was feared originally that the costs associated with any new science instruction system would be of such magnitude that implementation might be impossible. Based on the results of the planning phase, it now appears quite reasonable to implement such a system in a planned evolution from the present system, within existing cost constraints. This is partially due to the availability of off-the-shelf hardware capable of meeting requirements established by the Project.

14.0 IMPACT OF PROJECT ON SCHOOL

The most immediate impact of the Project during the planning phase is through those classroom teachers who have been active in the Project. Their involvement has caused them to modify their current teaching. By examining the instructional process as a system, techniques have been identified and implemented that are particularly applicable to teaching Life and Earth sciences.

One of these techniques is the simulated field trip. By means of 35 mm color slides and 8 mm motion pictures, students are taken on "field trips" within a 200 mile radius of Palo Alto. The phenomena observed can be related to the formal concepts of the course to emphasize reality. This is particularly true if students have already visited the locations, or if they can make family excursions to the trip sites. To cement the learning during actual visits, tape recordings can be made that instruct on where to go and what to look for.

Another form of instruction is the use of brief, animated, motion picture film clips. In the past the teacher, too often, has had to resort to word descriptions. The Project has opened the way to a use of animated visual presentation that can be carefully sequenced into the effort to build concepts that require animated mental pictures.

A third area of instructional technique concerns the laboratory experience. The Project teachers regard the direct experience of the laboratory as a vital part of science teaching. They also recognize that it is time consuming. The expansion of available instructional techniques to include tailor-made slides and motion pictures has raised the question of how much laboratory time is needed? Many experiments require learning of manipulative techniques. The use of visuals can be substituted for the parts of experiments that require time consuming techniques. Also, via time lapse photography, lengthy experimentation can be compressed into brief time periods. Mixing the direct experience that does not require elaborate technique with the visual record of the more complex phases of experiments holds potential for a better utilization of student time and also provides the means for doing so. This idea is not new, but the opportunity offered under the auspices of the Project is new. It is the first time that the involved classroom teachers have had the means and the time to tailor-make visual materials for use in their teaching.

The Project represents a commitment to the attainment of behavioral objectives in science. The impact on teacher behavior, however, has been profound. Teachers on the Project have acquired a realistic picture of the monumental task of designing instruction so that it moves students toward a set of specified terminal behavioral objectives. In spite of the magnitude of the task, they consider it to be a necessary and important objective.

15.0 IMPACT OF THE PROJECT ON OTHER AGENCIES

Because of the nature of the first phase of the Project, i.e. planning, the impact of the Project on other agencies has come primarily from the dissemination program. An operational phase of the Project would greatly expand the involvement of other schools and agencies in the region. Details of the dissemination program are discussed in the next section.

16.0 DISSEMINATION PROGRAM

16.1 INSTRUCTIONAL SYSTEM SURVEY

As a part of Phase I a survey was made of some significant instructional systems throughout the United States. These were associated with twelve school districts and military installations. This survey was used not only for identifying the progress of other innovative instructional systems, but also for disseminating information about the Cubberley-Lockheed Science

Project. To facilitate this process a brief brochure was prepared outlining the objectives and approach of the Project.

16.2 VISITORS

Briefings of visitors to the Project office were accomplished using the materials which are described in the next section. In addition to a number of local personnel, visits were made by members of the Kettering Foundation and by schools in the Los Angeles, California, Seattle, Washington, and Rochester, New York areas.

16.3 FORMAL PRESENTATIONS

A series of formal presentations were made by Project personnel to professional meetings and conventions. Included among these presentations were the Bay Section Curriculum Conference of the California Teacher's Association, a regional meeting of the California Association of Secondary School Administrators, and the Southwest Regional Conference of the National Science Teachers Association.

These presentations featured a set of 35 mm slides which explained the objectives, approach, and accomplishements of the Project.

16.4 INTERIM REPORT

An interim report covering the Project activities was published in September. This report has been made available to over a hundred members of the regional and national educational community.

16.5 PROJECT WORKSHOP

An information workshop was held on the fourteenth and fifteenth of December, 1967. Invitations were extended to two hundred educators in the San Francisco and northern California areas. Although the workshop was scheduled for a total period of two days, each conferee participated for only one half day. Activities scheduled for this workshop were based on the findings of the Phase I effort with regard to optimum instructional modes. The attendees witnessed a tape-slide briefing on the Project, followed by learning experiences in student carrels followed by small group discussions.

17.0 CONTINUATION PLANS

One of the motivating factors within the Cubberley faculty that led to the development of the original proposal for this project, was the recognition of the need for a science learning center. At the same time it was anticipated that local bond funds would become available for the construction of such a center. In the normal course of events the specifications for the center, the "educational specifications", would be prepared by a committee of the faculty during their "free" time and would represent modest improvements on existing facilities. Although Palo Alto is not an impoverished school district, research and development money is not available to finance anything more sophisitcated than the "free" time approach.

The original Title III, planning proposal was conceived, therefore, as a joint venture between the Palo Alto Unified School District and the United States Office of Education. The idea of this approach was that Federal funding would be used for the development of innovative systems approaches to science education that would then be used as guidelines in preparing plans for the new science learning center. Because these approaches should be useable by other schools and districts, they would be developed in modular form, adaptable to the unique situations of other schools. The end result of such an approach would be beneficial to both the local school district and the national educational community.

As a result of the planning Phase, it has become apparent that an extended time span is required for adequate testing as part of the development of the proposed system. Although there are local funds available for a more modest level of continued testing and evaluation of the system in the operational stages, supplemental funds from outside agencies are vital in the early development stages of the system. The loss of Federal funds at the conclusion of Phase I will seriously impact the continued development of an effective instruction system in secondary science. This impact will be felt in several ways:

- The present Project team will be dissolved through the return of the teacher members of the staff to full time teaching loads and the cessation of contracted support from Lockheed. This loss will affect not only the availability of personnel to work on the problem, but will also severely reduce the momentum of the Project and the opportunity to use the Project developed skills of the staff.

- Because of the above losses there will be a significant delay in the overall program with a consequent slippage of the operational system well into the seventies.

- Plans for the science learning center must be prepared regardless of the status of the Project, so that only inputs to planning will be from Phase I data without the data and verification of concepts that could result from a Phase II, thus losing the laboratory exemplary aspects of the new facility.

- Finally, and most important, the dissemination process to other districts and schools will be seriously hampered. The primary effects of the Phase I funding will be restricted to a single school district and a single school.

18.0 PLANNING PHASE BUDGET

Total cost	$ 174,650
Total Non-Federal Support	67,750
Total Federal Support under Title III, P.L. 89-10	106,900

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APPENDIX A: TERMINAL BEHAVIORAL OBJECTIVES

This section contains the original listing of terminal behavioral objectives, in process form, for the Earth/Life science courses. The numbers used for these objectives are cross-references in the organization models presented in Section 1.3.2.

Cognitive Behavioral Objectives

1. To choose the appropriate tool for quantitative measurement or observation.
2. To choose appropriate authority for sources of data.
3. To summarize main ideas from oral, written, visual and combination presentations.
4. To differentiate between dependent and independent variables from a description of a controlled experiment or a problem to be subjected to experimentation.
5. To differentiate between empirical observation and value judgments.
6. To differentiate between experimental and control groups from a description of a controlled experiment or a problem to be subjected to experimentation.
7. To differentiate a conclusion from statements of evidence which support it.
8. To recognize a connection between observed phenomena and a verbal description of the phenomena.
9. To identify structures or parts of structures shown in schematic diagrams.
10. To relate portions of a written paragraph describing a process with a set of sequential, schematic diagrams that represent the process.
11. To recognize similarities and dissimilarities among two or more structures, systems, processes or theories.
12. To identify unstated (implicit) assumptions in reported experiments.
13. To express an abstraction by stating an illustration or examples.
14. To recognize and/or identify an appropriate term, concept, or principle as encompassing a given phenomena.
15. To recognize and/or identify the attributes, properties, or relationships of a technical term, concept, or principle.
16. To recall observations which led to a generalization.
17. To associate historical discoveries or philosophies with the scientist to whom it is attributed.
18. To relate schematic diagrams with prior experience to be able to identify a process or recall attributes of a process.
19. To recall conventional criteria by which facts, principles, opinions and experimental results are judged.

20. To recall methods or techniques used to make historical discoveries.
21. To recognize relevant problems to be investigated.
22. To describe an appropriate control for a proposed experimental procedure.
23. To state a hypothesis in an "if..., then..." form.
24. To formulate more than one testable hypothesis for a statement of theory.
25. To form a verbal statement of generalization from a set of data.
26. To form a mathematical statement as a generalization from sets of data.
27. To interpolate or extrapolate from data.
28. To describe observed phenomena in an objective, non-teleological, non-anthropomorphic manner.
29. To describe observed organisms such that relevant characteristics are noted.
30. To make a prediction of the results of a given experimental procedure.
31. To support a logical argument with available, recalled data.
32. To recall and order processes, directions, and movements of phenomena with respect to time.
33. To interpret the relationship expressed in symbolic forms to verbal forms and vice-versa.
34. To form denotative or operational definitions.
35. To state problems to be solved.
36. To describe the relationship between two variables.
37. To describe the relationship between three variables.
38. To express mathematically, a verbal statement and vice-versa.
39. To organize, in a reportable form, investigative activities.
40. To plan controlled experiments with one dependent variable.
41. To recognize relevant observations which support or deny a hypothesis.

Perceptual--Motor Behavioral Objectives

42. To manipulate tools to measure quantities or to observe phenomena to desired degrees of accuracy.
43. To plot tabulated data of two or three variables on Cartesian coordinates, with appropriate scale, legend, and title.
44. To draw observed phenomena such that relevant characteristics are shown.

Affective Behavioral Objectives

45. To increase reliance on scientific sources for data.
46. To attempt to identify causes of physical and biological phenomena through experimentation.
47. To be aware of social phenomena as being subject to scientific study.

48. To be aware of the "frontier" between unknowns, tenable hypotheses and well-established theories.
49. To be willing to read accounts of scientific activities in common news media.
50. To be willing to perform minor research activities.
51. To be willing to consult scientific authorities.
52. To enjoy working with living organisms or aspects of the physical environment.
53. To become involved in social problems, scientific issues, and controversial issues.
54. To wish to continue science education.
55. To be ready to revise judgments and to change personal behavior when new evidence emerges.

APPENDIX B: ORDERING OF OBJECTIVES

It is impossible to develop a course of instruction unless there is some order to the objectives established for the course, in this case over forty in number. As the next step in the definition of behavioral objectives an attempt was made to structure the candidate objectives. The result of this effort was a tentative selection of the scientific method as the model for course development. Essentially the scientific method may be described as consisting of four phases:

- Problem recognition
- Hypothesis formulation regarding the problem area
- Experimental tests of the hypothesis
- Report and interpretation of experimental results

A test of this model indicated that all of the identified process objectives can be subsumed under the PHER (Problem, Hypothesis, Experiment, Report) model. It is recognized, of course, that certain basic skills, e.g., discrimination, are common to each of the four phases of the model. The listing of terminal behaviors and their location in the PHER model are contained in Fig. 3.

Although the PHER model provides a useful model of the overall structure of the course objectives, there are certain limitations on its useability in the development of instructional materials and their sequencing within the course. The problem in applying the model is two-fold; first, there is no sequencing of instructional activities other than the sequencing of the scientific method, and second, when applied to the content material a single PHER represents a unit of instruction that is too lengthy. As a result of these problems a second model was developed which views objectives as mental skills which need to be assembled into strategic and tactical forms for attack on subordinate elements of problem situations or for an attack and complete solution of a problem.

Problem Recognition

Level 1 To recognize relevant problems to be investigated (24)

To state problems to be solved (38)

Level 2 To relate schematic diagrams with prior experience to be able to identify a process or recall attributes of a process (21)

To relate portions of a written paragraph describing a process with sequential, schematic diagrams (13)

To recall (order) processes, directions, and movements of phenomena with respect to time (35)

Hypothesis Formulation

Level 1 To state a hypothesis if an "if-then" form (26)

To formulate more than one testable hypothesis for a state of theory (27)

Level 2 To differentiate between experimental and control groups from a description (6)

To differentiate between dependent and independent variables from a description (7)

To relate schematic diagrams with prior experience to be able to identify a process or recall attributes of process (21)

To describe observed phenomena in an objective, non-teleological, non-anthropomorphic manner (31)

To make a prediction of the results of a given experimental procedure (33)

To write denotative or operational definitions (37)

Experimental Test

Level 1 To plan and execute experiments with one dependent variable (43)

To recognize relevant observations which support or deny a hypothesis (44)

To recall methods or techniques used to make historical discoveries (23)

To describe an appropriate control for a proposed experimental procedure (25)

Fig. 3 PHER Model of Behavioral Objectives (Sheet 1 of 3)

Experimental Test (Continued)

Level 2 To choose the appropriate tool for quantitative measurement or observation (2)

To manipulate tools to measure quantities or to observe phenomena (3)

To recognize phenomena during observation as described verbally (10)

To label structures or parts of structures shown in schematic diagrams with correct names (12)

To recall methods or techniques used to make historical discoveries (23)

To describe an appropriate control for a proposed experimental procedure (25)

To form a mathematical statement of generalization about sets of data (29)

To describe observed organisms such that relevant characteristics are shown (32)

To write denotative or operational definitions (37)

Report and Interpretation

Level 1 To recall observations which led to a generalization (19)

To interpolate and or extrapolate from data (30)

To report on investigative activities in an organized, conventional form (42)

To distinguish empirical observation from value judgment (8)

To distinguish a conclusion from statements which support it (9)

Level 2 To label structures or parts of structures shown in schematic diagrams with correct names (12)

To relate portions of a written paragraph describing a process with sequential, schematic diagrams (13)

To recognize similarities and dissimilarities among two or more structures, systems, processes or theories (14)

Fig. 3 PHER Model of Behavioral Objectives (Sheet 2 of 3)

Report and Interpretation (Continued)

Level 2 To recognize unstated assumptions used in reported experiments (15)

To translate (simplify) an abstraction by stating an illustration or example (16)

To recognize an appropriate term, concept, or principle as encompassing a given phenomena (17)

To recognize the attributes, properties, or relations of technical terms, concepts or principles (18)

To recall observations which led to a generalization (18)

To associate historical discoveries or philosophies with the scientist to whom it is attributed (20)

To relate schematic diagrams with prior experience to be able to identify a process or recall attributes to the process (21)

To recall conventional criteria by which facts, principles, opinions and experimental results are judted (22)

To form a verbal statement of generalizations about sets of data (28)

To support a logical argument with available (recalled) data (34)

To recall (order) processes, directions, and movements of phenomena with respect to time (35)

To interpret (translate) the relationship expressed in symbolic forms to verbal and vice versa (36)

To express (translate) mathematically a verbal statement and vice versa (41)

To plot tabulated data of two variables with appropriate scales, legend, and title (39)

To plot tablulated data of three variables with appropriate scale, legend and title (40)

Fig. 3 PHER Model of Behavioral Objectives (Sheet 3 of 3)