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THE USE OF AN ADVANCE ORGANIZER IN TEACHING SELECTED CONCEPTS OF ECOLOGICAL SYSTEMS.

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REPORTED IS THE DETERMINATION OF THE RELATIVE EFFECTIVENESS OF THREE LEVELS OF ABSTRACTION (VERBAL, SKETCH, MECHANICAL MODEL) IN THE USE OF THE CONCEPTUAL SCHEME OF EQUILIBRIUM AS AN ADVANCED ORGANIZER APPLIED TO INSTRUCTION WITH REFERENCE TO ECOLOGICAL SYSTEMS. LESSONS WERE TELEVISED TO CONTROL THE INSTRUCTION OF PUPILS IN GRADES 7 AND 9. THE DESIGN INCLUDED A PRETEST, THE TEACHING OF NINE LESSONS, AND A POST-TEST AT THE COGNITIVE LEVELS OF (1) KNOWLEDGE, (2) COMPREHENSION, AND (3) APPLICATION. THE POST-TEST WAS GIVEN TWICE--FIRST, TO DETERMINE CONCEPT ATTAINMENT IMMEDIATELY FOLLOWING INSTRUCTION AND SECOND, TO DETERMINE CONCEPT RETENTION SIX WEEKS LATER. INDICATED WERE THAT (1) AT THE COMPREHENSION LEVEL THE USE OF MECHANICAL MODELS AS THE REFERENCE TO THE ORGANIZER WAS SIGNIFICANTLY SUPERIOR TO VERBAL REFERENCE OR THE USE OF SKETCHES, (2) SIGNIFICANTLY HIGHER MEAN TEST SCORES WERE EARNED IN GRADE 9 THAN IN GRADE 7, AND (3) A SIGNIFICANT DECREASE IN MEAN SCORES EARNED BY PUPILS IN GRADE 9 OCCURRED AT THE KNOWLEDGE LEVEL BETWEEN THE TIME OF THE FIRST POST-TEST AND THE SECOND (RETENTION) POST-TEST--A SMALL BUT STILL SIGNIFICANT DECREASE OCCURRED IN BOTH GRADES AT THE COMPREHENSION LEVEL--AND NO SIGNIFICANT DECREASE OCCURRED AT THE APPLICATION LEVEL. THE EVALUATION INSTRUMENT IS AVAILABLE IN PRACTICAL PAPER NO. 3 OF THE CENTER. (DS)

THE USE OF AN ADVANCE ORGANIZER IN TEACHING SELECTED CONCEPTS OF ECOLOGICAL SYSTEMS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

UNIVERSITATIS WISCONSINENSIS SIGILLUM
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RESEARCH
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Technical Report No. 42

THE USE OF AN ADVANCE ORGANIZER IN TEACHING SELECTED CONCEPTS OF ECOLOGICAL SYSTEMS

By Henry J. Triezenberg

Report from the Science Concept Learning Project

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PREFACE

Contributing to an understanding of cognitive learning by children and youth --and improving related educational practices--is the goal of the Wisconsin R & D Center. Activities of the Center stem from three major research and development programs, one of which, Processes and Programs of Instruction, is directed toward the development of instructional programs based on research on teaching and learning and on the evaluation of concepts in subject fields. The staff of the science project, initiated in the first year of the Center, has developed and tested instructional programs dealing with major conceptual schemes in science to determine the level of understanding children of varying experience and ability can attain.

For this study nine televised lessons on ecological systems were presented to students in Grades 7 and 9 following presentation of an advance organizer, the conceptual scheme of equilibrium, at three levels of abstraction--verbal, sketch, mechanical model. Pupils who had received instruction using the mechanical model had more positive attitudes toward the series of lessons than did pupils in the other two groups. Significant differences in posttest scores occurred between grades as well as among ability groups within grades. In addition, at the ninth-grade level, significant decreases in scores over a six-week period following instruction occurred only at the knowledge and comprehension levels; there was no significant decrease at the application level. The pretest on equilibrium and posttests of knowledge, comprehension, and application of concepts of ecological systems are available in Practical Paper No. 3 of the Center.

Herbert J. Klausmeier
Director

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ABSTRACT

The purpose of this study was to determine the relative effectiveness of three levels of abstraction (verbal, sketch, mechanical model) in the use of the conceptual scheme of equilibrium as an advance organizer applied to instruction with reference to ecological systems. Lessons were televised to control the instruction of pupils in Grades 7 and 9. The experimental design included a pretest, the teaching of nine lessons, and a posttest at three cognitive process levels: knowledge, comprehension, and application. The pretest was used to determine the pupils' knowledge of the conceptual scheme of equilibrium and their ability to apply it to ecological concepts. The posttest was given twice: (1) to determine concept attainment immediately following instruction and (2) to determine concept retention six weeks later. Significant differences were identified by utilizing the Analysis of Variance technique with the pretest data and the Repeated Measures Analysis of Variance technique with the posttest data. When appropriate, the Newman-Keuls procedure was utilized as a post hoc test.

On the pretest, pupils of high ability earned significantly higher mean scores than pupils of average ability and pupils of average ability earned significantly higher mean scores than pupils of low ability. The difference between Grades 7 and 9 was not significant. Pupils of average and high ability in both grades earned mean pretest scores on the concept of static equilibrium that were higher than a minimum acceptable mean score of 15 percent above chance.

In the posttest data it was found that:

1. At the comprehension level the use of working models as the reference to the organizer was significantly superior to verbal reference or the use of sketches. There were no significant differences due to these treatments at the knowledge or application levels.

2. In both grades the pupils of high ability earned significantly higher test scores than pupils of average ability and in Grade 9 pupils of average ability earned significantly higher test scores than pupils of low ability at the knowledge, comprehension, and application levels. In Grade 7 pupils of average ability earned significantly higher test scores than pupils of low ability only at the knowledge level. These results were not unexpected in view of the pretest results.

3. Significantly higher mean test scores were earned in Grade 9 than in Grade 7 at the knowledge level by all groups of pupils, at the comprehension level by pupils of high ability, and at the application level by pupils of high and average ability.

4. A significant decrease in mean scores earned by pupils in Grade 9 occurred at the knowledge level between the times when the posttest was

given to measure attainment and when it was given to measure retention; a smaller but still significant decrease occurred in both grades at the comprehension level, and no significant decrease occurred at the application level.

The minimum acceptable criterion of 15 percent above chance was applied to the mean posttest scores earned by each grade-ability-treatment group on each ecological concept and the successful groups were identified.

A survey of the attitude of the pupils indicated that they considered the lessons interesting, enjoyable, and educational, but quite difficult. The rank order of the treatment groups in a comparison from the lowest to the highest positive attitude of pupils was: verbal, sketch, and model.

I
THE NATURE AND BACKGROUND OF THE PROBLEM

INTRODUCTION

The transmission of knowledge between generations is a fundamental process in education and a necessary process for the growth of science. Bruner (1960) has suggested that a good way to transmit knowledge is to point out its structure, that is, how things, phenomena, or ideas are related logically and meaningfully. Relations may be hierarchical, in which some structural elements are subsumed under more generalized categories and other elements are associated at the same level of generalization. In processes of teaching and learning, according to Watson and Cooley (National Society for the Study of Education, 1960, p. 300), the logical "structure of the subject" and the "readiness of each individual pupil" are brought together.

To maximize such a congruence, Ausubel (1963) has suggested a subsumption model for processes of teaching and learning. Ausubel's subsumption model suggests that central unifying ideas of a discipline should be taught first and that less inclusive ideas be related clearly and logically to the unifying ideas by subsumption. Central unifying ideas or conceptual schemes thus become advance "organizers." An advance organizer is a concept stated in terms already familiar to the learner, to which the learner can logically relate new facts and concepts by subsumption (Ausubel, 1963). The organizer is more inclusive and abstract than the familiar or unfamiliar concepts; it may be a conceptual scheme. The conceptual scheme of equilibrium is a unifying idea that has been used in the teaching of ecology. Assuming that such a unifying idea is to occupy the central place of an advance organizer in the curriculum, how should it be presented? Is verbal reference sufficient or should more concrete levels of stimuli be used, such as sketches or actual working models to illustrate conditions of equilibrium when teaching concepts related to ecological systems?

THE PROBLEM

The problem is to determine the relative effectiveness of three levels of abstraction (verbal, pictorial, working model) in the use of the conceptual scheme of equilibrium as an advance organizer when applied to instruction with reference to ecological systems in Grades 7 and 9 as indicated by tests at three cognitive process levels.

BACKGROUND IN THE HISTORY OF SCIENCE EDUCATION

The study of the relationships of living things and their environments has long been recognized as an essential part of the K-12 science curriculum, but it has suffered from a lack of organization almost as long. When science education began in the United States with the public academies in about 1750, didactic writings were used to guide observations of natural phenomena. The didactic writers presented natural history in various degrees of logical organization, and some attempted to teach "in terms of a general process whereby the individual gradually acquires the ability to synthesize experience into increasingly complex hierarchies of ideas which give him some measure of control over new experience [Underhill, 1941, p. 28]." But as the school readers were developed about 1825, these books neither encouraged observation nor demonstrated the logical relations of science. The directed observation of natural phenomena was restored with the advent of object teaching about 1860. Among others, Wilbur S.

Jackman advocated use of a conceptual structure of science in directing student observations for the nature study movement:

> In the process of living, during the conscious hours there is a continual effort, first, to interpret these psychic results [mental images]—that is, to refer them to the proper material source; and, second, to organize them—that is, to discover by what relations they are associated.... The process of education is the systematized attempt to economize this effort [National Society for the Scientific Study of Education, 1904, p. 18].

> The mathematics in connection with science work naturally divides itself into two parts. These are, first, what pertains to the collection of accurate data, and second, that which pertains to comparisons necessary in making generalizations....
>
> After the data have been collected by means appropriate to the nature of the subject and the capacity of the child, the work of comparison begins. This is the fruitful, the really educative part of the work. The collection of data gives skill and requires nicety in manipulation, it is disciplinary, but it is not educative in a broad sense. It does not give the broad concepts that come only from comparing results so collected [Jackman, 1893, p. XXIV, XXV].

> True nature-study, therefore, is natural science, and its methods are strictly scientific.
>
> It is not here sought to establish merely an identity of terms. Failure to recognize the true relation of different parts of the subject has helped to emphasize the break that is already too pronounced between the elementary and the higher schools....Every step taken should be a substantial preparation for the next throughout the course from the kindergarten to the university [National Society for the Scientific Study of Education, 1904, p. 14].

The importance of conceptual schemes of science in determining the content of a K-12 curriculum was probably appreciated to a greater extent by another leader of the nature study movement, E. R. Downing, who wrote:

> Some unifying concept must be introduced or the course of study becomes fragmented, resulting in a series of uncoordinated efforts that lose their cumulative effect. In a course aiming to develop thought power this unifying factor would best be a series of logically related ideas or a dominant concept [Downing, 1907, p. 194].

Another school of thought advocated a sentimental approach and eventually declined, though it left an indelible public impression about which conservation advocates should beware:

> It would appear that at least two distinct ideas are masking under the name of nature-study. The first verges on the sentimental. Its aim is to waken in the child the proper emotional attitude toward nature. It has in mind more the child's feelings and sympathies. The other regards more the child's intellect, the necessity of training him to observe accurately and to think clearly....
>
> The advantages in having a thoroughly systematized line of nature-work with carefully selected materials properly apportioned to the various grades are evident. If the work is planned with the aim of having gradually developed certain fundamental principles by the time the course has been concluded, certainly the child, although unconscious of the fact, has been grounded in proper habits of thought that no amount of desultory observation could have developed. If his investigations have been directed along carefully selected lines he loses none of the joys of discovery which are reckoned so highly by the advocates of nature-study, and yet in the end he will get a cumulative effect of evidence which will be of the greatest value to him [Guyer, 1908, p. 112, 117].

This study is made from the latter point of view as the one which offers the most viable alternative for serious and sequential study to the child's long-term personal, social, and academic benefit.

Authors of the 31st yearbook of the National Society for the Study of Education (1932) valued the inclusion of nature study as a means of developing habits of thoughtful observation and also recommended a continuous unified program aimed at giving an understanding of significant ideas in science. They listed 38 generalizations to provide a logical structure for science curricula. Thus, further impetus was provided for an organized curriculum. Sufficient research was not available to show how the generalizations could be used to determine content, nor did research in science education help indicate the grade-placement of concepts.

> We must determine what are the most worth-while specific objectives to be accomplished in science-teaching, the minimal essentials and their proper grade-placement. Ever since science was introduced into the school curriculum, we have been trying to solve this problem by the trial-and-error method. As always it has proved a method wasteful of time and energy. It has reached no satisfying conclusions in over a hundred years. We must attack the problem by the scientific method and get an adequate fact basis for our judgments [Downing, 1925, p. 99].

Most research of the 1920's and the 1930's was concerned with the child's readiness and interests. This emphasis is reflected in Curtis' Digests of Investigations in the Teaching of Science (Curtis, 1926-39) and in the 46th yearbook of the National Society for the Study of Education (1947). The Progressive Education Association, while making important contributions in some areas, neglected efforts to use transfer from broad principles in favor of wide experience in problem solving with novel situations. Transfer was only allowed in situations similar to previous experience. The primary idea then was to bring the child's general needs in contemporary society together with child development instead of bringing logical structure of the subject together with the readiness of the pupil (Progressive Education Association, 1938).

But "contemporary society" changes as a human being changes from a child to an adult, and in the modern world the needs of a child are not the needs of the adult. The accelerating progress of science in the 1940's and 1950's rapidly ushered in the atomic age, the plastic age, the automation age, the biological control age, and the space age. Pertinent facts in the curriculum were rapidly superseded. If the curriculum was to be organized for long-term viability, greater emphasis would have to be placed on concepts and less on facts. Such increased emphasis on the logical structure of science received impetus through committees funded by the National Science Foundation to organize science curricula in the light of modern developments. Conceptual schemes illustrated by models were used to organize some of these curricula, e.g., concepts of light involving particles and waves in the curriculum of the Physical Science Study Committee (1960), and concepts of chemical equilibrium by moving particles in the Chemical Education Material Study (1963). The Biological Sciences Curriculum Study writers (Biological Sciences Curriculum Study, 1963a, pp. 453, 454) were to utilize nine "unifying themes" in organizing the curriculum but these "unifying themes" were implicit not explicit in the texts that were produced. Nonetheless important contributions to the teaching of ecology were especially made by the BSCS Green Version (Biological Sciences Curriculum Study, 1963b). The idea of equilibrium is one of the conceptual schemes recommended in the National Science Teachers Association publication Theory into Action (1964). Most science curriculum movements in the 1950's and 1960's have attempted to utilize the logical structure of science in developing a serious and sequential curriculum for long-term viability.

The present study is timely for two reasons. The first pertains to the civic importance of the study of ecology in the schools as reflected by a recent report of the Special Commission on Weather Modification for the National Science Foundation:

> Man is becoming so numerous and his influences on his environment so profound that he cannot consider himself free to heedlessly or improvidently exploit the air, water, land, and growing things of this earth. He no longer lives under the constant threat of a wilderness but, instead, is changing his environment and, therefore, must plan for its conservation and development.
>
> With advances in his civilization man has learned how to increase the fruit of the natural environment to insure a livelihood. The main problems which now threaten his future are:
>
> 1) large-scale, catastrophic warfare;
> 2) providing sustenance for a rapidly increasing population;
> 3) waste disposal and environmental change accompanying the discharge of matter into the atmosphere, open waters, and subterranean spaces.
>
> Recognizing these circumstances of human activity, it is fortunate that growing knowledge of the natural world has given him an increasing awareness

of the changes that are occurring in his environment and also hopefully some means for deliberate modification of these trends [1965, p. 7].

The second basic reason for the timeliness of this study is related to the present realization of the utility of concepts in directing curricula as reflected in a recent article in The Science Teacher:

> Concepts are important not only because they are the warp and woof of science, but also because they provide the possessor with a means of coping with the development of knowledge in the future.... The formation of concepts or conceptual schemes is one method of classification which results in such economical use of human intelligence [Pella, 1966, p. 31].

This study is designed to provide some information concerning the degree of stimulation desirable in emphasizing a curriculum-directing concept.

BACKGROUND IN THE NATURE OF SCIENCE

Science is concerned both with a logical structure of facts and concepts that describe nature and with the processes by which the structure is obtained. Science education is rightly concerned with the transmission of both aspects of science between generations. While recognizing the fundamental importance of transmitting knowledge of the processes of science, this paper is not concerned with that function of science education. Rather, the major concern is with the function of transmitting from generation to generation a logical structure of facts and resultant concepts that describe nature. Hence, it is imperative that we consider the importance of such a logical structure in the scientific enterprise.

For purposes of definition and discussion in this paper, a logical structure of science represents its formal organization as conceived by expert scientists. Admittedly, there may be several such structures and each may include both facts and concepts. By facts we mean observables or percepts. In a logical structure, facts are related by and to concepts. Concepts represent conscious relations between facts or between ideas: they may be generalized ideas.

> It grows from a comparison. It has seized a likeness between two unlike appearances; for the apple in the summer garden and the grave moon overhead are surely as unlike in their movements as two things can be. Newton traced in them two expressions of a single concept, gravitation; and the concept (and the unity) are in that sense his free creation. The progress of science is the discovery at each step of a new order which gives unity to what had long seemed unlike....
>
> The poem or the discovery exists in two moments of vision: the moment of appreciation as much as that of creation; for the appreciator must see the movement, wake to the echo which was started in the creation of the work. In the moment of appreciation we live again the moment when the creator saw and held the hidden likeness....
>
> And we test the concept....by its implications. That is, when the concept has been built up from some experiences, we reason what behavior in other experiences should logically flow from it [Bronowski, 1965, pp. 15, 19, 35].

"Science is not concerned with <u>things</u>; it is concerned with <u>ideas</u>, although those ideas often are ideas about things. And those ideas are <u>created</u> by men's minds [Roller, 1960, p. 16]." According to Lachman (S. Lachman, 1960, p. 25) these generalized ideas not only embody the broad findings of science, but they also guide further quest. A basic assumption of this paper is that conceptual schemes in a student's mind are useful in guiding his quest for knowledge and understanding in the classroom.

> In short, the pattern we perceive when we note "a fact" is organized and interpreted by a whole system of attitudes and thoughts, memories, beliefs, and learned constructs. It is thought that gives us eyes.
>
> ...in the course of time, despite great innovation and revolutions, there accumulates in science a set of internationally acceptable, basic, and fairly enduring conceptual schemes [Holton and Roller, 1958, pp. 240-41, 215].

Granting the fundamental importance of conceptual schemes in the logical structure of science, it is possible to overemphasize the formal structure of science in the classroom and neglect the processes by which it was formed. As a result, the pupils receive a false impression of science as a static, authoritative endeavor. In science, "new concepts arise from experiments and observations, and the new concepts in turn lead to further experiments and observations [Conant, 1951, p. 37]." In schools, concepts and conceptual schemes should guide student discovery in the laboratory as well as in the classroom.

> Concepts are not found as such in nature; they are evoked in the human mind by nature. Experience cannot warrant concepts "true" or "false", only appropriate or inappropriate. Concepts prove themselves as tools prove themselves [Nash, 1963, p. 17].

Part of the art of teaching is to help students recognize situations in which a concept can apply and where it cannot. Students of the sciences need be aware of concept limitations as well as strengths, and activity in the processes of science helps them to realize this awareness. Westmeyer (1965) has noted that modern science concepts such as gravity, light, evolution, atomic orbitals are great myths; myths which are the real power of science and which enable us to relate more and more observables to one another but myths that we should not hesitate to discard or improve when the evidence warrants.

> To too great an extent we associate this noble word [science] with the mechanical, deterministic, physical science of fifty years ago....the science of today deals with concepts that involve abstractness, imagination, the beauty of conciseness, and at the very core of the subject something which can properly only be called faith ....
>
> We are determined ... to respect the abilities of science at the same time that we realize its limitations, to know enough about science so as to be able intelligently to meet the responsibilities of modern citizenship [Weaver, 1957, p. 365].

Didactic presentation of only the logical relations of science without taking into account the strengths and limitations of its processes has the inherent danger of becoming authoritarian. An authoritarian perspective is as alien to the nature of science as it is to the nature of students, prohibiting their independent thinking as well as their enjoyment of the scientific process. If we only reward acceptance of an authoritative statement of the logical relations of science in the schools, students will be careful not to reason. This implies that we must determine whether the facts and concepts being presented are commensurate with the student's level of thinking--with his psychological structure. It implies also that we are obligated to present not only the strengths but also the limitations of a conceptual scheme, illustrating where the conceptual scheme applies and where it does not.

Assuming that we should transmit the logical structure of science from one generation to the next, it follows from our discussion of the strengths and limitations of science that we are transmitting a dynamic, ever-changing structure. If we wish to teach for long-term goals, therefore, we must organize classroom activity around those basic principles in the nature of science which are of greatest generality and endurance. The basic principles are often abstract but models are sometimes useful mediators between abstract principles and concrete experience; they are essential components in the nature of science.

> . . . we might now visualize science as an arch resting on two pillars, observations and experience, with conceptualization and abstraction supported in between. . . .
>
> This feature of the human mind, this thirst for concreteness, characterizes not only the frequent preoccupation with mechanical models within science itself, but also the most primitive type of common sense explanation . . . .
>
> In its most general sense, "to explain" means to reduce the unfamiliar to the familiar . . . [Holton and Roller, 1958, pp. 225, 226, 227].

The utility of such models, both in science and in education are evident in the following quotation from Rosenblueth and Wiener:

> No substantial part of the universe is so simple that it can be grasped and controlled without abstraction. Abstraction consists in replacing the part of the universe under consideration by a model of similar but simpler structure. Models, formal or intellectual on the one hand, or material on the other, are thus a central necessity of scientific procedure....
>
> A material model is the representation of a complex system by a system which is assumed simpler and which is also assumed to have some properties similar

> to those selected for study in the original complex system. A formal model is a symbolic assertion in logical terms of an idealized relatively simple situation sharing the structural properties of the original factual system.
>
> Material models are useful in the following cases. a) They may assist the scientist in replacing a phenomenon in an unfamiliar field by one in a field in which he is more at home. They may thus have important didactic advantages. . . . b) A material model may enable the carrying out of experiments under more favorable conditions than would be available in the original system . . . . Sometimes the relation between the material model and the original system may be no more than a change of scale, in space or time. . . .
>
> All scientific problems begin as closed-box problems, i.e., only a few of the significant variables are recognized . . . . The setting up of a simple model for a closed-box assumes that a number of variables are only loosely coupled with the rest of those belonging to the system. The success of the initial experiments depends on the validity of that assumption [1945, pp. 316, 317, 319].

Models should be used with discretion; they are analogies, not reality.

> Since a successful model enables us to predict the future outcome of sets of events, the model is sometimes assumed to be a literal description of reality. For example, it might be argued that the kinetic theory predicts the behavior of gases and since a gas must be composed of something, why not the molecules pictured by the model [R. Lachman, 1963, p. 87]?

Lachman answers the latter question by saying that there could be several models serving the same class of events, not one. To give a faithful picture of the nature of science, perhaps we should use more than one model for the same class of events, pointing out the strengths and weaknesses of each. Such models may conflict, as described in the following quotation.

> So the later conflict in quantum physics between the behavior of matter as a wave and as a particle is a conflict between analogies, between poetic metaphors; and each metaphor enriches our understanding of the world without completing it [Bronowski, 1958, p. 64].

In the basic story line of the didactic presentations in this experimental project, the conceptual scheme of equilibrium is carefully revealed; then the conflicting concept of succession is introduced. Strengths and limitations of the conceptual scheme of equilibrium for 'ecological systems' are clearly revealed. Using the classification of concepts proposed by Pella (1966), the idea of equilibrium in an ecosystem is a theoretical concept and the process of succession within an ecosystem is a correlational concept. Models illustrate conditions of equilibrium and their disruption, mediating between the theoretical concept and concrete experience.

BACKGROUND IN PSYCHOLOGY

The theoretical basis for the use of a conceptual scheme as an advance organizer is found in Ausubel's subsumption theory.

> Two important criteria determine whether new learning is potentially meaningful. The first criterion—nonarbitrary relatability to relevant concepts in cognitive structure . . . is a property of the material itself. . . .
>
> The second important criterion determining whether learning material is potentially meaningful—its relatability to the <u>particular</u> cognitive structure of a particular learner—is more properly a characteristic of the learner than of the material <u>per se</u> [Ausubel, 1963, p. 23].

Characteristics of the learner and of the material are brought together as the learner subsumes new material under conceptual schemes that already exist in his cognitive structure.

> Precise and integrated understandings are, presumably, more likely to develop if the central, unifying ideas of a discipline are learned before more peripheral concepts and information are introduced; if the limiting conditions of general developmental readiness are observed; if precise and accurate definition is stressed, and emphasis is placed on delineating similarities and differences between related concepts; and if learners are required to reformulate new propositions in their own words [Ausubel, 1963, p. 21].

When presented in this fashion, key concepts become advance organizers that promote meaningful learning and retention.

> One important variable affecting the incorporability of new meaningful material is the availability in cognitive organization of relevant subsuming concepts at an appropriate level of inclusiveness to provide optimal anchorage. . . .
>
> Since it is highly unlikely that at any given stage in the learner's differentiation of a particular sphere of knowledge we can depend on the spontaneous availability of the most relevant and proximate subsuming concepts, the most efficient way of facilitating retention is to introduce appropriate subsumers and make them part of cognitive structure prior to the actual presentation of the learning task. The introduced subsumers thus become advance "organizers" or anchoring foci for the reception of new material. In effect, they provide an introductory overview at the appropriate level of conceptualization [Ausubel, 1963, pp. 28, 29].

The problem here as stated previously is: If a conceptual scheme is to occupy the central place of an advance organizer in the curriculum, to what extent should it be emphasized? Is verbal reference sufficient or should we use more concrete levels of stimuli such as sketches or actual working models to illustrate conditions of equilibrium and their relation to ecology?

A qualifier for the advance organizer is that it must be "at the appropriate level of conceptualization [Ausubel, 1963]." Hence before the relative effectiveness of the three levels of abstraction (verbal, sketches, models) can be ascertained, we must determine the relative achievement of various grade and ability groups in concepts of equilibrium related to 'ecological systems' so that we know whether the materials themselves begin at an appropriate level of conceptualization—data relating to this problem must be evaluated first. With respect to postulated stages of child development (Inhelder and Piaget, 1958), it is recognized that some students may be at the concrete stage of development, but that others may be at the abstract stage in cognitive development, particularly with respect to concepts of 'ecological systems.' Since learners at the concrete stage theoretically cannot meaningfully understand verbally expressed propositions, concrete props in the form of models and sketches of models were used in two treatment groups to aid them in understanding the generalized applicability of the conceptual scheme of equilibrium to concepts of 'ecological systems.' Furthermore, according to Ausubel (1963), the existing cognitive structure is the major factor affecting not only meaningful learning but also retention. Retention should be included if we are to answer the problem of determining the relative effectiveness of three levels of abstraction (verbal, pictorial, working model) in the use of the conceptual scheme of equilibrium as an advance organizer when applied to instruction with reference to 'ecological systems' at Grades 7 and 9 as indicated by tests at three cognitive process levels. It is assumed that cognitive process levels can be differentiated according to categories outlined in the Taxonomy of Educational Objectives (Bloom, 1956) and that items can be written to measure student achievement in these categories. Three of the categories were used and these are defined as follows:

1. Knowledge:

   Knowledge as defined here includes those behaviors and test situations which emphasize the remembering, either by recognition or recall, of ideas, material or phenomena.
2. Comprehension:

   Three types of comprehension behavior are considered here. The first is translation which means that an individual can put a communication into other language, into other terms, or into another form of communication. . . .

   The second type of behavior is interpretation which involves dealing with a communication as a configuration of ideas whose comprehension may require a reordering of the ideas into a new configuration in the mind of the individual. . . .

   The third type of behavior to be considered under comprehension is extrapolation. It includes the making of estimates or predictions based on understanding of the trends, tendencies or conditions described in the communication.
3. Application:

   A problem in the comprehension category requires the student to know an abstraction well enough that he can correctly demonstrate its use when specifically asked to do so. "Application," however, requires a step beyond this. Given a problem new to the student, he will apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation [Bloom, 1956, pp. 62, 89, 90, 120].

In other words, according to Bloom, the application category includes the comprehension category plus the ability to recall and recognize the correct abstraction to be applied. Experimental procedures and an experimental design are required which consider the child's level of maturity as defined by grade and general mental ability, abstract to concrete levels of stimulus intensity for the advance organizer, and achievement and retention measured by tests at three cognitive process levels.

II
REVIEW OF RELATED STUDIES

The formulation of experimental procedures designed to answer the problem posed in this study would be impossible without reliance on the research of other investigators. Selected research literature can be classified into four areas of investigation: (1) the conceptual maturity of the learner, (2) the construction of tests to measure cognitive process levels, (3) advance organizers, and (4) degree of abstraction.

CONCEPTUAL MATURITY OF THE LEARNER

The ability of children with varied intellectual and physical maturity to conceive and utilize ideas has been of interest to science educators especially since Piaget was "rediscovered." Two basic methods of determining this ability are illustrated in an early study (Craig, 1927) that had considerable influence on science education: (1) consult children and (2) consult adults. In the second category, Craig consulted educated laymen and authoritative source books of science. Surveys have been used by many other investigators to determine concepts that are useful for learners at differing levels of maturity. The test of concept utility in science education, however, is in the first category—consulting children. Craig evaluated children's questions in science to determine the concepts in which they were most interested. Other investigators have developed methods for testing conceptual development in children by individual interviews or by written questions. The work of Piaget in individual interviews with children is well known and his cooperative effort with Inhelder was most useful in the present study (Inhelder and Piaget, 1958). They found that although children have certain rough intuitions about the notion of equilibrium at a very early age (5-7 years) it is not until early adolescence (11-15 years) that children subjugate what is real to what is possible; that they think beyond the real situation in which they may see what is happening in a system that is in an equilibrium condition, to a possible situation in which they can think what is likely to happen. At adolescence, according to Inhelder and Piaget, children can proceed in their thinking by deduction along multiple dimensions from hypotheses to empirically real situations. Adolescents can think formally in terms of an idealized system even though children at a much earlier age can think intuitively about a system and can consider a single factor operative in a balance system when they do not have to think simultaneously about a possible change in another factor.

Other investigators have been concerned with the problem of whether pupils could generalize at all (Croxton, 1936) and whether training in elementary science should be restricted to observation and the development of interest. Croxton presented demonstrations of eight minutes duration to pupils from Kindergarten through Grade 9 inclusive. The experiment tested the pupils' ability to formulate and apply a principle, for example, the principle of balance. In demonstration of this principle, four different weights were used and children were given an opportunity to see how many ways a "teeter" could be balanced using only two weights at a time. In the test the pupils were supplied with diagrams of a weight on one side of a teeter and were asked to indicate on these diagrams where various weights should be placed to make the "teeter" balance. It was not until Grade 7 that 50% of the pupils were successful in formulating and applying this principle. With data from four such generalization experiments Croxton concluded that children at all levels were able to generalize but the superiority of junior high school pupils in consistency of application indicated that their increased achievement may have been due to more than just added experience.

Deutsche (1937) employed a group method with written (essay) questions to evaluate Piaget's types of causal thinking and stages of development. Pupils were asked to explain eleven demonstrations in Form I of the test and to explain twelve verbally presented situations in Form II. For example, in a demonstration of teeter-totters pupils were asked to explain why a large block on one end would balance two small blocks on the other end. The adequacy of the answers was rated by a panel of judges along an arbitrary scale from 0 - 7 and the mean quantified scores were computed within chronological age groups. On the above demonstration as well as on the total score the greatest increase in quantified scores occurred between the ages of 11 and 12 although gradual increases were noted from ages 8 to 14. Deutsche also found that the percentage of answers that could be classified as "logical deduction" increased especially between the ages of 10 and 14 and that this increase was greater on the verbal form of the test than on the demonstration form. The percentage of correct "logical deduction" responses was less on the verbal form than on the demonstration form before age 11 and greater after age 11. Thus while Deutsche concluded that causal thinking apparently does not develop by stages but by a gradual process, the development in terms of thinking by "logical deduction" did appear in her study to be more rapid from ages 10 to 12 or from 12 to 14 than from ages 8 to 10. Deutsch's conclusion of a gradual development of the reasoning processes rather than by stages was confirmed by King (1965) who, incidentally, found that more than 50% of the children at nine years of age answered correctly a question like that given as an example used by Croxton.

Ausubel and Schiff (1954) sought a more experimental method of investigating causal thinking in children than the "traditional" one of asking children to explain natural phenomena and using judges to place the explanations into categories of causal thinking. They demonstrated a teeter-totter to children of Grades Kindergarten, 3, and 6 which worked on one of two principles:

> . . . (a) a relevant principle according to which that side of the teeter-totter which was longest always fell when the supporting pins were removed; and (b) an irrelevant principle, according to which that side on which a red block (as opposed to a green block) was placed was invariably made to fall. In each case the child after an initial demonstration was asked to predict which side would fall until learning as measured by a criterion of three successive correct predictions took place. All of the subjects were presented with both types of learning problems, half of them being presented with the problems in one order and the other half in the reverse order [p. 111].

From the data collected, the investigators concluded:

> The ability to learn a relevant causal sequence and to inhibit the learning of an irrelevant causal sequence increases with age. Rate of growth of this ability is greater between the ages of eight to 11 than between the ages of five to eight. From this experiment it cannot be ascertained whether the maturational effect is attributable to increased incidental experience with teeter-totters, to growth in reasoning ability, or to both. At the kindergarten level, children are able to learn the irrelevant relationship as readily as the relevant relationship [p. 122].

From the research reviewed thus far, it is apparent that at their age in Grade 7 most children (1) have a rudimentary concept of equilibrium and (2) are gradually but rapidly growing in their ability to think in an abstract and formal way about an idealized equilibrium condition involving possibilities apart from those which confront them.

Of further interest to educators is the problem of the age at which pupils can be taught to apply a particular principle or a concept to a particular situation. Read (1958) has summarized the results of more than twenty studies in which pupils were given a twenty-minute demonstration-exposition of a single principle during which time they were not allowed to speak and after which time they were given a written test with 17-25 items. A judgment was made that in order to spend a reasonable amount of time teaching a principle in a classroom, at least 50% of the class would have to evidence their ability to use the principle effectively in a test situation. The investigators whose work was summarized by Read found that both grade level and mental ability were factors affecting the distribution of scores. A prediction was made on the basis of these studies that future investigators will find that many basic science principles can be taught at lower grade levels than is traditional, that more investigations will be needed in Grades 7 to 9, and that able elementary school pupils can benefit from a study of formal science. If this is true how will serious and sequential study by a pupil be affected?

Will pupils retain their ability to apply basic principles? A long range study reported by Tyler (1933) and Wert (1937) indicates that for college zoology students at least the ability to apply principles is not only retained but enriched by added experience. Equivalent forms of examinations that included four categories of recall, one of interpreting new experiments, and one of applying principles to new situations were given as a pretest, as a final exam for the course, and—for students who elected no further zoology—one, two, and three years after the termination of the course. In the three years after the termination of the course students retained only part of what they learned in the four categories of recall, but increased slightly in the ability to interpret new experiments and increased by half of the gain achieved during the course in the ability to apply principles to new situations.

Is there an apparent duplication of effort to develop understandings of basic principles at the junior high, senior high, and junior college levels and is there a difference in the extent to which these understandings are developed at these levels? To answer this question, Johnson (1965) constructed a 50 item test designed to measure the ability to recall and to apply 27 selected principles of physics. The test was administered to 11 general science classes, 12 high school physics classes, and 8 physical science survey classes. Johnson concluded that the pupils who have completed general science will likely profit from a course in physics, that pupils who have completed ninth-grade general science are not likely to greatly increase their understandings of these principles in a physical science survey, and that a major effort to develop functional understandings of the principles used in that study should be made at the junior high school level.

CONSTRUCTION OF TESTS TO MEASURE COGNITIVE PROCESS LEVELS

To what extent is it possible to measure the intellectual processes of the recognition and recall of information, the interpretation of new experiments, and the application of principles to new situations? Reference has already been made to studies by Tyler, Wert, and Johnson based on the assumption that this was possible. Pollach (1963), to determine the "relationships between tests of intelligence and reading and levels of concept development in terms of a hierarchy of understanding defined as knowledge, comprehension, and application," formed operational definitions of these levels and constructed tests to measure them based on the science content of a single film. Analyzing the results of administration to fifth-grade pupils by comparing correlations, Pollach concluded that the abilities tested by the application test showed little difference in relation to intelligence from the abilities tested by the knowledge test and that subject-matter knowledge was a better predictor of test success than test scores in reading or intelligence. Pollach found difficulty in sorting his items into a hierarchy and questioned the effectiveness of such categorization.

Howard (1943) defined item complexity for a panel of judges who were asked to rate his items:

> For some items the mental processes may be of a higher order than for other items. One item may require the recall of but one specific bit of information, the answer coming almost automatically, if it is known. . . . . Another item may be much more complex, requiring the recall and interrelating of a considerable web of information. . . . . Items may be found that are intermediate. . . . . One may then think of the test items as graded along a scale of complexity from those requiring the simplest recall to those requiring the greatest complex of recall and interaction of ideas [p. 2].

Six "expert" judges rated 180 items from the Cooperative General Science Test, Form 1937, as corresponding to five intervals of a "complexity continuum" from simple to complex as did six "good" and six "poor" students who were college sophomores. Howard found:

> . . . that persons well acquainted with the content of a test can reliably rate the items along a scale of complexity; that the reliability of the complexity values obtained is directly related to the rater's knowledge of content; and that the degree of estimated complexity is

inversely related to the student-raters' knowledge of content [p. 25].

Judging from the results of an administration of this test to over 1000 students from six colleges and universities, Howard concluded that expert judgment of the complexity of items appeared to be independent of item difficulty.

A test of science "comprehension" for Grades 4, 5, and 6 was reported by Nelson and Mason (1963). This test had 60 items arranged into eight blocks each of which centered

> around the interpretation of a situation, the application of scientific principles or theory in accounting for what has happened, and analysis of the situation as a basis for arriving at a solution to the problem inherent in the situation presented [p. 323].

The chief concern was "to measure the degree of understanding of an idea rather than the memorized meaning of a term [p. 323]." The test was given as a pretest early in the school year, requisite background information was given to treatment groups classified according to the emphasis given to critical thinking by teachers, information was tested for by unit tests throughout the year, "A Test of Science Comprehension" was given again at the end of the year. Significant differences were found among the mean scores earned by the treatment groups on the "comprehension" test.

For purposes of definition and communication a committee of college and university examiners classified educational objectives related to the cognitive domain in a taxonomy with six major divisions: knowledge, comprehension application, analysis, synthesis, and evaluation (Bloom, 1956). The first three of these cognitive process levels were defined in Chapter I. An assumption was made that examiners could "divide the cognitive objectives into subdivisions from the simplest behavior to the most complex [p. 15]" and that test items could be written to measure the "intended student behaviors." Although the taxonomy has been widely circulated and has not been superseded by a more definitive work, neither has it been extensively used to standardize the classification of items measuring the results of educational research. Anderson (1965) used the first four levels to determine whether students' abilities to use these cognitive processes were developed to a different extent when the curriculum produced by the Chemical Education Materials Study as opposed to a "traditional" curriculum was used. The test consisted of a reading passage on chemical reactions with a subtest of multiple choice items for each process to be measured. There were five months between separate administrations of the test as pretest and posttest. She reported, "Factor analyses tend to support the hierarchical nature of the <u>Taxonomy</u>."

Kropp and Stoker (1966) conducted an extensive research project to test educators' assumption that the taxonomy structure was verifiable. Four tests, each with six subtests corresponding to the six cognitive process levels, were constructed and administered to approximately 1600 pupils in each of Grades 9, 10, 11, and 12. Each test consisted of a reading passage that presented content from a particular discipline with items testing that content. The content, selected for probable interest, ease of comprehension, and unfamiliarity to the pupils, dealt with social science ("Lisbon Earthquake" and "Stages of Economic Growth") and science ("Atomic Structure" and "Glaciers"). The tests included 20 four-choice items related to each of the first four levels, five free-response "Synthesis" items, and 10 free-response "Evaluation" items. Kropp and Stoker found that complexity and difficulty were partly similar and that:

> The hypothesis of inverse relationship of mean performance and taxonomic level was generally supported. For the social science forms, means for all grades were in the predicted order. For the science forms there was a systematic reversal of means on the Synthesis and Evaluation subtests.
>
> The simplex analyses offered some support to the hypothesis of hierarchical structure. For all analyses of the social science forms for grades ten, eleven, twelve, and all grades combined, the hypothesized order was the best order in terms of simplex order. For one science form at all grade levels, the same order of variables led to simplical structure and it was different from the hypothesized order. It placed Evaluation between Knowledge and Comprehension.
>
> On the basis of these results, the conclusion was drawn that there was a clear tendency for the empirical data to

support the imputed hierarchical structure of the taxonomy [pp. 167-168].

USE OF CONCEPTUAL SCHEMES TO GUIDE INSTRUCTION

Since in this experimental project the conceptual scheme of equilibrium was used as an "organizer" to direct instruction related to ecological systems, it seemed appropriate to review research which related the influence of an emphasis on conceptual schemes, principles, or concepts in teaching with performance on tests of the higher cognitive processes. Owens (1951) sought

> (1) to study the relationship between the ability of high school pupils to recognize scientific principles in test situations and the ability to apply these principles to problematic situations, and (2) to study the effects of directed teaching on the ability of these pupils to apply scientific principles to new situations, not previously employed in the teaching of the understanding of the principle [p. 207].

Ten principles common to biology and chemistry were selected for emphasis to three biology and two chemistry "experimental" classes while matched groups were designated as "control" groups. Teaching units were constructed to present the ten principles in the context of each discipline. Two tests based on these principles were constructed: (1) to measure the ability of pupils to recognize scientific principles and (2) to measure the ability of pupils to apply scientific principles to new situations. The tests were given as pretests followed by eight weeks of instruction and the same tests were given as posttests. The control and experimental groups were given identical instruction but, in addition, the experimental group was encouraged to state applications and relations of scientific principles to everyday living, read additional references, and solve additional problems. Owens concluded that the pupils had a greater ability to recognize scientific principles than to apply them to new situations, that there was a significant difference favoring the experimental group in the ability to recognize and to apply scientific principles to new situations, that pupils with above-average ability scored higher on both tests than pupils with below-average ability, and that there was no statistical difference in the achievement between boys and girls on the tests.

Kastrinos (1964) compared the relative effectiveness of two instructional procedures in the development of the ability of pupils to "think critically." A "textbook-recitation group" used a laboratory emphasis on drawing and labeling parts. A "principles-critical thinking group" used a problem-type laboratory emphasis with lists of concepts and principles and homework involving problem recognition, critical evaluation of data, organization of information, and awareness of "the scientific method." No significant difference in gains of factual material was found between the two groups. The "principles-critical thinking group" was significantly superior in the interpretation of data, in the "Kastrinos Critical Thinking Test," and in the "Novak Problem Solving Test." The gain in problem solving was proportional to intelligence. Kastrinos concluded that critical thinking functions at a lower level in interpretation of data and at a higher level in problem solving.

Meridith (1962) compared the effectiveness of two organizations of subject matter in high school physical science. His experimental group developed and studied subject matter related to an energy transformation concept while the matched control group studied a textbook-defined survey of physical science. The STEP Science Form 2A was used as a pretest and Form 2B was used as a posttest of problem solving ability while the Cooperative General Achievement Test Science Forms YZ and XX were used as pretest and posttest respectively of knowledge of science facts and principles. The results of t tests of significance were that (a) the experimental group was significantly superior to the control group in problem solving and (b) there was no significant difference in developing knowledge of science facts and principles. Meridith concluded that conceptually related science content is more suitable for instruction in problem solving than is the more usual topical presentation of science content.

Anderson et al. (1956) studied the effectiveness of using biology films and emphasis on principles illustrated in the films. A control group with no specified film instruction consisted of 22 schools; an experimental group using specified films consisted of 14 schools; and an experimental group using specified films with emphasis on principles covered in each film before and after the showing consisted of 11 schools. The Nelson Biology Test was used, Form Am as a pretest at the beginning of the school year and Form Bm as a posttest at the end of the school year. With pretest scores and IQ scores held constant by covariance and adjustment, no significant difference was found among the posttest mean scores of the three groups. When grouped by IQ however, a sign test of the differences indicated that the high ability group shown films with principles stressed gained significantly more than the other two high ability groups. A similar but less marked trend appeared among the low ability groups. In a re-examination of the same data, Smith and Anderson (1958) regrouped pupils into a high (IQ of 115 or above) ability group and a low (IQ of 90 or below) ability group, classified most of the test items into "fact-type" and "principle-type" items, and rescored the papers. "Principle-type" items involved "knowledge of some biological principle." No significant difference due to instructional method existed on the "fact-type" subtest, however a significant difference existed on the "principle-type" subtest in both ability groups favoring the "films-with-principles-stressed" method.

Wittrock (1964) has reviewed psychological theory and empirical research on the learning by discovery hypothesis and related it to literature on concept learning and problem solving. In one of his own studies Wittrock gave to 292 college students one of four treatments related to a task of deciphering codes: (1) encoded item plus answer plus rule, (2) item plus rule, (3) item plus answer, and (4) item only. He found that the group receiving rules and answers achieved the greatest initial learning of a few answers but that the group receiving the items with only the rules achieved the greatest transfer to new examples of these same rules. He concluded that an intermediate amount of direction produced the greatest retention in transfer but the maximum direction produced the greatest initial learning. Noting that in almost all the studies reviewed the experimentor rather than the subject maintained control of the sequence and arrangement of stimuli, Wittrock stated some tentative conclusions:

> The first is that the conclusions are related to the type of dependent variable which is sampled. When initial learning of a few specifics is the criterion, highly directed procedures seem to be most effective, or as effective as any other approach. When transfer to new instances of the same, few previously learned concepts is the criterion, guidance toward the concepts or generalizations is probably the most effective type of procedure [p. 59].

The principles previously learned in an area apparently aid in directing discovery in new contexts both in and out of school and the more direction of this kind given the pupil by the teacher the more effective will be the pupil's discovery of new relations in that area but not with respect to other principles.

> In terms of the results from the empirical research, the curriculum projects which present carefully sequenced and hierarchically organized material and which require the learner to verbalize his own generalizations are defensible because they retain the feeling of self discovery and combine it with an efficient program of direction aimed at transfer [p. 61].

Suchman (1966) in reviewing seven years of research into the inquiry process as manifested by intermediate grade children said that in order to obtain meaning from an encounter with the environment one must employ some form of "organizer" that serves to select out and pattern certain aspects of the encounter. According to Suchman, an organizer can be memory of a prior encounter or a previously formed generalization or conclusion. The teacher must decide whether to allow children to invent and test their own organizers or to engineer conceptual schemes into the children's thinking as the "proper ways of interpreting encounter."

> Only an autonomous mediation function can operate in response to the shifting data-gathering and theory-modifying requirements of inquiry. Any attempt to intervene, such as programing data input or instructing the inquirer to utilize certain organizers tends to convert the process from pure inquiry into some form of externally manipulated learning [p. 184].

According to Suchman, the same kinds of organizers are useful in didactic teaching but the distinction is that in didactic teaching the teacher decides what organizers to use, not the learner. "As a result the process and the resulting cognitive gains should match more closely the teacher's goals than the pupil's, providing the teacher is skillful [p. 187]." Available research indicates that organizer ideas are useful in discovery, inquiry training, and didactic exposition.

Butts (1963) confronted a high interest class after school hours with science phenomena related to four concepts—displacement, inertia, "action-reaction," and "depth-pressure" —with four experiences of common relationship for each. Using a sign test and a line of least squares technique he found that children do not understand only from manipulation of data in a science experience, that they do not improve in conceptual understanding between concepts, and that they experience an orderly improvement between experiences of the same concept only with some prior knowledge. Butts concluded that pupils do not arrive at concepts by independent organization of their perceptions but that they need some direction.

Ausubel (1960) hypothesized that learning and retention of unfamiliar ideas and facts would be facilitated if some direction were given the learner by providing an organizer in advance of the instruction. The organizer is a highly inclusive and generalizable concept available in the learner's cognitive structure under which can be susumed less inclusive subconcepts and informational data. In learning, subconcepts are progressively differentiated from the organizing concept and in forgetting, they are assimilated by the organizing concept. The learning material was a 2500-word essay dealing with the metallurgical properties of plain carbon steel, chosen for its unfamiliarity to the 120 college senior undergraduate subjects. A test was constructed with 36 multiple-choice items covering principles, facts, and applications. Introductory passages of 500 words were given to an experimental group and to a matched control group 48 hours before and immediately before giving them the learning material for five minutes each time. The experimental introduction emphasized "major similarities and differences between metals and alloys, their respective advantages and limitations, and the reasons for making and using alloys." The control introduction "consisted of such historically relevant background material as the historical evolution of the methods used in processing iron and steel." Both groups studied the essay on steel for 35 minutes and took the test 3 days later. The experimental group earned a significantly higher mean test score than the control group. Ausubel attributed the positive influence of advance organizers on the learning and retention of unfamiliar facts and ideas to two factors:

> (a) the selective mobilization of the most relevant existing concepts in the learner's cognitive structure for integrative use as part of the subsuming focus for the new learning task, thereby increasing the task's familiarity and meaningfulness; and (b) the provision of optimal anchorage for the learning material in the form of relevant and appropriate subsuming concepts at a proximate level of inclusiveness [p. 271].

LEVELS OF ABSTRACTION

A difficulty which may occur in the use of advance organizers in didactic exposition is that by reason of their inclusiveness and generality they may be too abstract to be meaningful to the learner. The problem is particularly acute in the study of ecological systems since these systems are often large and have indefinite boundaries. Rockcastle (1956) proposed that microclimates "be studied by school children in a way that will make concrete on a small scale what they learn in an abstract way about weather, climate, and ecology on a large scale." A portable "Kleinklima Kit" was used for field studies related to heat exchange and air movement. Rockcastle concluded that the study of microclimates "will provide a sound background of direct experiences for the abstractions which must of necessity follow in any advanced study." In Section I it was pointed out that analogous models are often used in science to mediate between direct experience and abstract principles. Little research has been done, however, on the use of models in science education. Scott (1964) studied the use of analogies in introductory college chemistry textbooks published from 1930 through 1960. An analogy was defined as a resemblance from which one may reason.

> The use of analogy in the explanation of phenomena was shown to be applicable in the teaching of chemistry on the premise that concrete imagery is more helpful than abstraction. Conclusions drawn from analogical arguments were shown to be probable rather than certain [p. 4948].

Analogies were used to guide the development of a hypothesis. Scott noted a significant increase in analogy usage over the 30 year period and found that current analogies could be classified as (1) verbal, (2) mechanical, and

(3) mathematical. Logical justification for using analogy as a teaching technique was synthesized from a number of authoritative statements concerning analogy, and guidelines were given to indicate the limitations of analogies. Beeler (1955) tested the hypothesis that several aspects of the use of analogy in science writings for children have changed during the years. Although he found an average of 41 analogies per book, the hypothesis was not supported by the evidence.

Pella and Ziegler (1967) determined "the relative effectiveness of the use of static and dynamic mechanical models in teaching elementary school children the theoretical concept the particle nature of matter" and "whether subjects of elementary school age use acceptable models in explaining their observations of selected physical changes [p. 1]." They found that pupils in Grades 2 through 6 "can learn to use this theoretical model as a result of appropriate instruction" but that the dynamic mechanical model "was not significantly superior to the static mechanical model as an instructional aid in teaching the use of the model the particle theory of matter in explaining physical phenomena to children in Grades 2 - 6 [p. 45]."

Very little research could be located which determined the specific effects of various levels of abstraction in the use of visual illustrations for either general or specific educational objectives. Travers et al. (1964) produced a monograph to bring together the research and theory related to audiovisual information transmission and to point out the implications this information might have for educational practice. Information from the environment is compressed by an instructor or by the receiver. "Precompression" by an instructor is advantageous in that it "permits a rational decision to be made concerning what is to be retained and what is to be eliminated, while compression by the nervous system involves at least some rather arbitrary processes [p. 9.04]." This is at variance with those who would emphasize the value of realism in transmitting information but is in accord with operation of the human nervous system. At higher levels of the nervous system a categorizing process occurs. One of three implications made by Travers et al. from this research and theory for the design of audiovisual materials is:

> Second, the quest for realism and the emphasis on realism which has characterized the audiovisual field emerges as the worship of a false god. While one cannot deny that educational materials must help the learner to perform transactions with a real world, the conclusion does not follow that realism should be the aim of teaching displays. Man does not transact his affairs with the environment by responding to the vast wealth of detail which physical processes transmit to his senses, but rather is he highly selective in the information which he uses and the cues to which he responds. A learning process which involves the presentation of that information derived from the environment which is of value to him, may well provide a much better learning procedure than a realistic presentation which includes a vast and overwhelming complexity of irrelevant detail. The learner may ultimately have to learn to discriminate the relevant cues within the context of a realistic situation, though the internally occurring compression process may eliminate the need for learning. For example, a line drawing of the wiring of a television receiver is much more effective in transmitting information useful in assembling a kit than is a faithful photographic reproduction. The line drawing indicates at a glance the important features involved in wiring while the photograph requires careful study before the essential features can be sorted out from irrelevant features produced by shadows and shading. The commentary in many films is necessary only to help the viewer sort out the relevant from the irrelevant in the video presentation. Perhaps the study of the geometry of the circle should not begin with round plates, wheels, and tables, but with the circle itself, which establishes a category into which these various objects can be placed. The circle also includes that aspect of each of the objects named which is likely to transmit much of the information to the perceiver, for boundaries tend to be major information carriers [pp. 9.17, 9.18].

Dwyer (1967) compared "the relative effectiveness of three types of visual illustration sequences used in the instruction of university freshmen about the human heart [p. 253]." The three types of visual illustration sequences were (1) abstract linear representations, (2) detailed, shaded drawings, and (3) realistic photographs. The relative effectiveness of these three types was related to four dependent variables purporting to measure four "desired types of learnings": (1) knowledge of terminology (fill-in questions), (2) knowledge of the location of anatomical parts (pupils were to draw and label a heart), (3) transfer of learning (identification of the numbered parts on a three-dimensional model of the heart), and (4) comprehension (multiple-choice items). Comprehension items required the reorganization of information and "a thorough understanding of the heart, its parts, its internal functioning, and the simultaneous processes which occur during the systolic and diastolic phases [p. 256]." The "Drawing Test" had 18 items; the other tests each had 20 items. Scores on a 36-item physiology pretest were used as the adjusting variable in the analysis of covariance to evaluate the relative effectiveness of the various treatments. There were three treatment groups corresponding to the three types of visual illustration sequences and a control group consisting of students who were only shown the terminology with the oral presentation. On the total of all tests and on the drawing test the abstract linear representations and detailed shaded drawings were superior; on the heart model test the abstract linear presentation was superior; on the terminology test the abstract linear representations and detailed shaded drawings were both superior to realistic photographs but the oral presentation was as good as any; and on the comprehension test the various presentations were equally effective.

III
PROCEDURE

SELECTION OF CONCEPTS AND TEACHING METHODS

The selection of the concepts and the development of teaching methods included in the experimental program involved the study and utilization of a number of resources.

I. Books Reviewed
   A. Nine elementary school science series.
   B. Six science sourcebooks for the elementary teacher.
   C. Four junior high school series.
   D. Nine textbooks for junior and senior high school science.
   E. Twelve science sourcebooks for the secondary school teacher.
   F. Three college textbooks in ecology.
   G. Sixteen miscellaneous ecology references.

II. Audiovisual Materials Utilized
   A. Eight 16 mm. motion picture films referring to the concept of equilibrium and to ecological systems.
   B. Selected 35 mm. slides from the University of Wisconsin Plant Ecology slide collection.
   C. Selected specimens from the plant collection of the University of Wisconsin Botany Department greenhouses.

III. Conferences with Experts
   A. Eight science educators knowledgeable in the area of concepts of equilibrium and ecological systems.
   B. Twenty ecologists and conservation specialists who reviewed the lessons and concepts selected.

The experimental program involved the use of three levels of stimuli in the utilization of the concept of equilibrium as an advance organizer. The relative effectiveness of the three levels of stimuli was to be tested by utilizing three treatment groups.

Treatment 1: The concept of equilibrium was presented verbally.
Treatment 2: The concept of equilibrium was presented verbally supplemented by sketches of appropriate models.
Treatment 3: The concept of equilibrium was presented verbally supplemented by appropriate mechanical models.

The three aspects of equilibrium utilized in each treatment were, in the order of presentation: (1) static equilibrium as exemplified with a beam balance; (2) dynamic equilibrium as found in a closed system that involved evaporation and condensation; and (3) adjustment within a closed system that is thermostatically regulated.

Selection of the concepts proceeded concurrently with the selection and design of the models to be used. The concepts resulting from the selection procedure were:

I. Static Equilibrium
   The magnitudes of forces acting in opposing directions are related to a condition of static equilibrium within the limits of tolerance for the system.
II. Dynamic Equilibrium within Factors of the Ecosystem
   Rates of opposing actions within ecological factors are related to conditions of dynamic equilibrium in the system.

III. Dynamic Equilibrium between Biotic and Abiotic Material
The rates of absorption and release of matter and energy (the abiotic factors of an environment) by populations are related to a condition of dynamic equilibrium for the system. Specific populations exist in an equilibrium condition with abiotic factors within a range of tolerance.

IV. Dynamic Equilibrium with Reference to Populations
A population exists in a condition of dynamic equilibrium when the rates of birth and death within that population are equal. Specific populations exist in equilibrium conditions with associated populations when matter and energy are transferred between them.

V. Homeostasis
Homeostasis is the self-regulating adjustment of several interacting relationships in a system tending toward a steady-state dynamic equilibrium.

VI. Succession within the Ecosystem
Succession is a sequence of events within an ecosystem that has a predictable pattern of community changes disrupting an equilibrium condition over time. Some of these events are related to the presence of organisms themselves and some to cultural changes.

The concepts were presented within a series of nine videotape lessons, with primary emphasis on Concepts II, III, IV, and VI. Titles of the lessons were:

No. 1. Introduction
No. 2. Populations and Their Limiting Factors
No. 3. Energy Transfer
No. 4. Solar Energy and Populations
No. 5. Water and Populations
No. 6. Ecosystems in the Soil
No. 7. Associated Populations
No. 8. Succession in Populations
No. 9. Culture in the Ecosystem

Lesson No. 1 included the definitions of the basic terms to be used and an overview of the series. This lesson was identical for each of the three treatment groups. Lessons No. 2 through No. 9 were produced in three forms corresponding to the three treatments, hence, the total number of videotapes was 25. The ecological concepts presented to the three treatment groups were identical; only the references to the advance "organizer" varied. Each pupil was given a study guide for each lesson to help him note the essential concepts being presented.

TOOL FOR RESEARCH IN DIDACTIC METHODOLOGY

The primary purpose of this study was to compare the relative effectiveness of three levels of stimuli (verbal, sketch, model) with respect to a cognitive organizer for didactic materials in ecology. In order to investigate this problem it was necessary to provide uniform and consistent teaching procedures for three groups of students at the same time. The medium of instruction selected was a Mobile Video Distribution System owned by the R & D Center. This video system appeared to be an ideal tool permitting accurate comparison of the three levels of stimuli for four reasons:

I. Classroom input can be accurately controlled, effectively nullifying a teacher presentation variable.
II. The didactic presentation can be distributed to a large number of students at the same time.
III. A variety of source materials can be assembled in a studio but not in a classroom.
IV. Classroom input can be replicated at various grade levels and in various schools.

In addition to the usual storage and transportation characteristics, the Mobile Video Distribution System included:
—thirteen RCA Victor Lyceum television receivers with 23-inch screens for classroom use,
—three Ampex 660 videotape recorders that made it possible to transmit via coaxial cable three programs simultaneously,
—a Hallicrafters Citizens-band transmitter-receiver for emergency wireless communication with one or more of twelve Hallicrafters Model CB-6 transceiver units in the classrooms, and
—a Blonder-Tonque video camera to permit live broadcasting through the system.

Figure 1 is a picture of the videotape equipment mounted in the driver-operator compartment of the truck. Figure 2 illustrates the classroom use of the television receivers. The equipment in effect constitutes three broadcast stations, permitting broadcast of

FIGURE 1

TRANSMISSION EQUIPMENT OF MOBILE VIDEO DISTRIBUTION SYSTEM

FIGURE 2

PUPILS UTILIZING TELEVISED LESSON AND STUDY GUIDE
IN THE CLASSROOM

three lesson tapes with different didactic methods through a closed circuit on Channels :2, 4, and 6 simultaneously.

PRODUCTION OF VIDEOTAPE LESSONS

Television lessons were produced with the aid of the instructional television staff on WHA-TV at the University of Wisconsin during the spring and summer of 1966. The following procedures were used:

I. As the content was developed, two lessons were taught in an interview fashion to individual seventh- and ninth-grade students sampled from various ability groups and their effectiveness was subjectively evaluated.

II. These lessons were recorded as pilot lessons in the studio and were evaluated by the Science Concept Group at the R & D Center.

III. The production of the final lesson series to be used in the experiment was based upon the results of the evaluation noted in II, the resources noted on page 18, and the production resources of the Instructional Television group at WHA-TV.

IV. The televised lessons, study guides, equipment, and preliminary testing instruments were evaluated during a trial run.

TESTING INSTRUMENTS AND ANALYSIS

I. Testing Instruments for Evaluating Pupil Achievement in Terms of the Knowledge, Comprehension, and Application Levels of Selected Concepts

A. Tests for a Trial Run

1. A 40-item multiple-choice multiple-response test was devised and administered to 105 sixth-grade students who saw the first three lessons during the trial run.
   a. Four questions concerned introductory definitions.
   b. Thirty-six questions were equally apportioned among the six principal concepts of the series.
   c. The thirty-six questions included equal numbers of questions in the knowledge, comprehension, and application cognitive process levels (Bloom, 1956). There were two questions per concept for each level.
2. The item format of the 40-item, four-choice test was revised, resulting in 160 yes-no response items. This revised test was administered to the same students after they had viewed all the lessons in the series.

B. Analysis of Trial Run Data

Digitek answer sheets with test data from the trial run were processed and IBM cards were punched by the Wisconsin Testing Center; then the data were analyzed with the Generalized Item Analysis Program (GITAP, Baker, 1966). Item statistics produced in this analysis were utilized in the final test revision.

C Revised Tests

The tests, as finally revised and used in the experimental run, had the following characteristics.

1. There were two tests: a pretest and a posttest (Triezenberg, 1968).
   a. The pretest consisted of 54 items equally distributed among six concepts of the series. It was designed to measure the pupils' knowledge and understanding of the concept of static equilibrium and their ability to utilize this concept as a first order cognitive organizer.
   b. The posttest consisted of 60 items. It was designed to measure attainment at the termination of instruction. The same instrument was used to measure retention six weeks later. Items were equally distributed among knowledge, comprehension, and application cognitive process levels. The number of items related to each concept corresponded roughly to the proportion of time used to teach that concept. Consequently, the numbers of questions per concept in this test were not equal. Also, this test did not include items concerning the concept of static equilibrium; it included

items testing only the concepts pertaining directly to ecology.

2. Test items were written in a single-response, four-choice objective style. Correct responses were distributed as equally as possible among the four choices for all the items on each test.

II. Survey of Pupil Attitude toward 'Ecological Systems'

A. An Attitude Survey was constructed as a means of measuring the opinions of pupils regarding the series and was administered on the day of the final lesson.

1. Attitude items were written to elicit a single response from among five choices: Yes, Maybe Yes, No Opinion, Maybe No, and No.
2. Attitude stems were statements of opinion.
3. Eight of the stems in this instrument were designed to eliminate from the list those pupils who habitually responded to a given choice without reading the stem. Some of these stems were: "Series was interesting" vs. "series was dull," "series was easy" vs. "series was difficult," "enjoyed series" vs. disliked ... series" and "study guide helped ... " vs. "study guide hindered ... "
4. Three other stems were related to student attitude toward learning by television and three were related to their attitude toward the teacher in this series.
5. The stems of each of these groups were scattered throughout the test.

B. Pupil comments on the 'Ecological Systems' series were solicited.

SELECTION OF THE SAMPLE

Criteria used in selecting the school for the experimental sample were:

I. Seventh- and ninth-grade pupils must be in the same building.
II. There must be at least 180 pupils per grade.
III. The school officials must be willing to permit a random assignment of pupils to treatment classes for the duration of the experiment.

Characteristics of the district served by the selected school were as follows:

I. The area of the district is 459.5 square miles.
II. There are just under 10,000 people residing in the school district.
III. More than 50% of the public school enrollment lives outside the municipal boundaries.

The student sample was selected and assigned to rooms according to treatment in the following steps:

I. Tests of general mental ability were administered to Grades 7 and 9. Form A of the Henmon-Nelson Test of Mental Ability was administered to the seventh grade and Form B of the same test was administered to the ninth grade.
II. The seventh and ninth grades were each divided into three ability groups. The scores from the Henmon-Nelson tests were obtained as IQ scores from the school, and class lists with pupils ordered according to IQ scores were prepared. Pupils were then grouped within each grade as follows:

A. Low: 73 - 99 inclusive
B. Average: 104 - 111 inclusive
C. High: 115 - 140 inclusive

The upper and lower limits of these IQ groups were selected to provide approximately equal numbers of pupils in each ability group of each grade; the resulting numbers in each group were: 7L - 61, 7A - 61, 7H - 63, 9L - 59, 9A - 63, and 9H - 63. Pupils not in these grade-ability groups and pupils with known gross differences in educational background were assigned to a separate nontreatment group.

III. The three treatment groups were formed.
A table of random numbers was used to assign pupils within each ability group at each grade level to each of the three treatment groups.
IV. Experimental classes were organized for each grade by treatment. Experimental treatment classes included pupils from all three ability groups. There were two classes at each grade

level for each treatment with about 30 pupils per class. The ninth-grade pupils viewed the lessons during the first 45-minute period in the morning and the seventh-grade pupils viewed then during the second period.

V. Final sampling was done by random exclusion.
Pupils whose absences prevented their full participation in the experiment were eliminated from the sample and the treatment group sizes were equalized by random exclusion. The final sample consisted of 270 pupils, 15 in each treatment group of each ability level in each grade.

ANALYSIS OF EXPERIMENTAL DATA

Digitek answer sheets were processed as described previously by the Wisconsin Testing Service. The analyses of these data were carried on with the aid of the 1604 computer at the University of Wisconsin Computing Center (UWCC) utilizing the following procedures and programs.

Item Analyses

The Generalized Item Analysis Program (GITAP) was used in the treatment of Pretest and Posttest data. The Reciprocal Averages Program (RAVE) was used with data from the Attitude Survey (Baker, 1966).

Analysis of Variance

The Analysis of Variance Program (ANOVA, Jennrich, 1961) was used to determine significance among the variables of an ability x grade design for the pretest (Table 1).

TABLE 1

EXPERIMENTAL DFSIGN FOR PRETEST

Grade	Ability		
	Low	Average	High
Seven			
Nine			

For posttest data a treatment x ability x grade x test event "Repeated Measures" design (Winer, 1962, pp. 337-344) was used with the repeated measures only on the test event (Table 2). Significant interactions between factors and test events were analyzed (Winer, pp. 310, 311) with the One-Way Analysis of Variance Program (ONEWAY1, Minich, 1966). Newman-Keuls Procedures (Winer, 1962, pp. 80-85, 309) were performed to locate the sources of significant differences identified by the analyses of variance.

Concept Analysis

Mean attainment test scores for each concept were calculated for each grade-ability-treatment group. A minimum acceptable attainment test mean score of 15% above chance was used as a criterion for judging whether or not pupils of the specified grade, ability, and treatment groups could be taught a concept utilizing the methods employed here.

TABLE 2
REPEATED MEASURES EXPERIMENTAL DESIGN FOR POSTTEST

			Test Event	
			Attainment	Retention
Treatment	Ability	Grade		
Verbal	Low	Seven		
		Nine		
	Average	Seven		
		Nine		
	High	Seven		
		Nine		
Sketch	Low	Seven		
		Nine		
	Average	Seven		
		Nine		
	High	Seven		
		Nine		
Model	Low	Seven		
		Nine		
	Average	Seven		
		Nine		
	High	Seven		
		Nine		

IV
RESULTS

PRETEST

The pretest was given six days prior to the initiation of instruction. Treatment of the data using the Analysis of Variance technique under a 3 x 2 (Ability x Grade) design indicated (Table 3) that:

I. significant differences existed among the mean scores earned by the ability groups,
II. significant differences did not exist between the mean scores earned by the grades, and
III. the interaction of these factors was not significant.

Inspection of the cell means of scores earned on the pretest reported in Table 4 reveals that pupils of low and average ability in Grade 7 earned higher mean scores than pupils with comparable ability in Grade 9 and pupils of high ability in Grade 9 earned a higher mean score than pupils of high ability in Grade 7; however, these grade level differences were not significant. Since there was no significant interaction, the significant differences noted among levels of ability may be generalized over grade levels. It is noted in Table 5 that the mean scores earned by pupils of average ability were significantly greater than the mean scores earned by pupils of low ability and that the mean scores earned by pupils of high ability were

TABLE 3

ANALYSIS OF VARIANCE FOR PRETEST SCORES

Source of variation	df	MS	F
Ability (A)	2	1387.66	82.40*
Grade (G)	1	.37	< 1
GA	2	33.97	2.02
Within Cell	264	16.84	

* $p < .05$

TABLE 4

PRETEST MEAN SCORES ARRANGED ACCORDING TO ABILITY AND GRADE

Grade	Low	Ability Average	High
Seven	15.58	19.67	22.29
Nine	14.64	19.04	23.62

TABLE 5
PRETEST - NEWMAN-KEULS PROCEDURE FOR ABILITY GROUP MEAN SCORES

		Low	Average	High
Ability Group		Low	Average	High
Ordered Means		15.11	19.36	22.96
		Low	Average	High
Differences	Low	0	4.25*	7.85*
Between	Ave.		0	3.60*
Means	High			0
r			2	3
$q_{.95}(r, 120)$+			2.80	3.36
$q_{.95}(r, 120)\sqrt{\frac{MS_{error}}{g \cdot n}}$			1.21	1.45

g=number of grades
n=number of pupils/cell
+ nearest conservative table value to $q_{.95}(4, 264)$
*p < .05

Table 6
ANALYSIS OF VARIANCE FOR KNOWLEDGE SCORES

Source of Variation	df	MS	F
Between Subjects			
Treatment (T)	2	11.27	< 1
Ability (A)	2	975.61	81.57*
Grade (G)	1	244.02	20.40*
TA	4	10.07	< 1
TG	2	.84	< 1
AG	2	19.32	1.62
TAG	4	7.80	< 1
Subjects w. groups [error (between)]	252	11.96	
Within Subjects			
Test Event (E)	1	79.35	19.69*
TE	2	2.92	< 1
AE	2	2.12	< 1
GE	1	16.02	3.98*
TAE	4	4.09	1.01
TGE	2	.84	< 1
AGE	2	11.54	2.86
TAGE	4	1.22	< 1
E x subj. w. groups [error (within)]	252	4.03	

*p < .05

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significantly greater than the mean scores earned by pupils of either low or average ability.

POSTTEST

Knowledge Level

Treatment of the data using the Analysis of Variance technique under the repeated measures design indicated (Table 6) that:

I. significant differences did not exist among the mean scores earned by the treatment groups,

II. significant differences existed among the mean scores earned by the ability groups,

III. significant differences existed between the mean scores earned by the grades,

IV. significant differences existed between mean scores earned on the test events,

V. the grade x test event interaction was significant, and

VI. all other interactions were not significant.

Inspection of the cell means in Table 7 reveals that: (1) the high ability model treatment groups earned consistently but not significantly higher mean scores than the high

TABLE 7

KNOWLEDGE MEAN SCORES ARRANGED ACCORDING TO TREATMENT, ABILITY, GRADE, AND TEST EVENT

Treatment	Ability	Grade	Test Event Attainment	Test Event Retention
	Low	Seven	5.33	4.80
		Nine	6.40	4.93
Verbal	Average	Seven	6.47	6.67
		Nine	9.73	7.93
	High	Seven	10.00	8.87
		Nine	11.67	10.47
	Low	Seven	5.47	5.80
		Nine	7.47	6.60
Sketch	Average	Seven	7.60	7.73
		Nine	9.53	8.00
	High	Seven	9.93	8.87
		Nine	10.73	10.80
	Low	Seven	6.47	4.87
		Nine	6.33	4.60
Model	Average	Seven	6.80	7.33
		Nine	9.60	8.00
	High	Seven	10.33	9.67
		Nine	12.13	11.47

ability sketch or verbal treatment groups; (2) in each grade the average ability groups consistently earned higher mean scores than corresponding low ability groups, and high ability groups consistently earned higher mean scores than corresponding average ability groups; (3) Grade 9 mean scores were consistently higher than corresponding Grade 7 mean scores in the average and high ability groups; and (4) mean scores earned when the test was given to measure retention were generally lower than respective mean scores earned on the test when it was given to measure attainment. It is noted in Table 8 that the mean score earned by the average ability group was significantly greater than the mean score earned by the low ability group and that the mean score earned by the high ability group was significantly greater than either of the mean scores earned by the low and average ability groups.

Because a significant interaction existed between the grade factor and the test event, it was appropriate to locate the significant differences between the grades for each administration of the test and vice versa. For this purpose, the one-way analysis of variance technique was used.

I. Across Grades
   A. Test Given to Measure Attainment
      Mean scores earned by pupils in Grade 9 were significantly greater than mean scores earned by pupils in Grade 7 (Table 9).
   B. Test Given to Measure Retention
      Mean scores earned by pupils in Grade 9 were significantly greater than mean scores earned by pupils in Grade 7 (Table 10).

TABLE 8

NEWMAN-KEULS PROCEDURE FOR ABILITY GROUP MEAN SCORES AT THE KNOWLEDGE LEVEL

Ability Group		Low	Average	High
Ordered Means		5.76	8.02	10.41
		Low	Average	High
Differences Between Means	Low	0	2.26*	4.65*
	Ave.		0	2.39*
	High			0
r			2	3
$q_{.95}(r, 120)$+			2.80	3.36
$q_{.95}(r, 120)\sqrt{\frac{MS_{error}}{g \cdot t \cdot e \cdot n}}$			.72	.87

g=number of grades
t=number of treatments
e=number of test events
n=number of pupils/cell
+ nearest conservative table value to $q_{.95}(r, 252)$
$*p < .05$

TABLE 9

KNOWLEDGE LEVEL ATTAINMENT TEST EVENT
ANALYSIS OF VARIANCE ACROSS GRADES

Source of Variation	d.f.	MS	F
Between Grades	1	192.53	17.29*
Within Grades	268	11.13	

*p < .05

TABLE 10

KNOWLEDGE LEVEL RETENTION TEST EVENT
ANALYSIS OF VARIANCE ACROSS GRADES

Source of Variation	d.f.	MS	F
Between Grades	1	67.50	5.68*
Within Grades	268	11.89	

*p < .05

II. Across Test Events
   A. Grade 7
      Significant differences did not exist between the mean scores earned when the test was given to measure attainment and when it was given to measure retention (Table 11).

TABLE 11

GRADE SEVEN KNOWLEDGE SCORES
ANALYSIS OF VARIANCE ACROSS TEST EVENTS

Source of Variation	d.f.	MS	F
Between Test Events	1	12.03	2.99
Within Test Events	252	4.03	

   B. Grade 9
      Mean scores earned on the test when it was given to measure attainment were significantly greater than when it was given to measure retention (Table 12).

TABLE 12

GRADE NINE KNOWLEDGE SCORES
ANALYSIS OF VARIANCE ACROSS TEST EVENTS

Source of Variation	d.f.	MS	F
Between Test Events	1	83.33	20.68*
Within Test Events	252	4.03	

*p < .05

Comprehension Level

Treatment of the data using the Analysis of Variance technique under the repeated measures design indicated (Table 13) that:

I. significant differences existed among the mean scores earned by the treatment groups,
II. significant differences existed among the mean scores earned by the ability groups,
III. significant differences existed between the mean scores earned by the grades,
IV. significant differences existed between the mean scores earned on the test events,
V. the ability x grade interaction was significant, and
VI. all other interactions were not significant.

It is noted from Table 14 that the mean score earned by the model treatment group was significantly greater than the mean scores earned by either the verbal or sketch treatment groups. Inspection of the cell means in Table 15 reveals that: (1) except for the mean scores of the low and average groups of Grade 7 on the test when given to measure attainment, the average ability groups consistently earned higher mean scores than corresponding low ability groups and high ability groups consistently earned higher mean scores than corresponding average ability groups; (2) Grade 9 mean scores were consistently higher than corresponding mean scores at

TABLE 13

ANALYSIS OF VARIANCE FOR COMPREHENSION SCORES

Source of Variation	df	MS	F
Between Subjects			
Treatment (T)	2	45.07	4.22*
Ability (A)	2	721.55	67.56*
Grade (G)	1	160.07	14.99*
TA	4	23.57	2.21
TG	2	.04	<1
AG	2	53.22	4.98*
TAG	4	7.66	<1
Subj. w. groups [error (between)]	252	10.68	
Within Subjects			
Test Event (E)	1	25.79	6.97*
TE	2	4.18	1.13
AE	2	6.81	1.84
GE	1	1.25	<1
TAE	4	5.16	1.39
TGE	2	1.30	<1
AGE	2	3.64	<1
TAGE	4	5.39	1.46
E x subj. w. groups [error (within)]	252	3.70	

*p < .05

TABLE 14

NEWMAN-KEULS PROCEDURE FOR TREATMENT GROUP MEAN SCORES AT THE COMPREHENSION LEVEL

Treatment Group		Verbal	Sketch	Model
Ordered Means		6.52	6.66	7.45
		Verbal	Sketch	Model
Differences Between Means	Verbal	0	.14	.93*
	Sketch		0	.79*
	Model			0
r			2	3
$q_{.95}(r, 120)$+			2.80	3.36
$q_{.95}(4, 120)\sqrt{\frac{MS_{error}}{g \cdot a \cdot e \cdot n}}$			.68	.82

g=number of grades
a=number of ability groups
e=number of test events
n=number of pupils/cell
+ nearest conservative table value to $q_{.95}(r, 252)$
*p < .05

TABLE 15

COMPREHENSION MEAN SCORES ARRANGED ACCORDING TO TREATMENT, ABILITY, GRADE, AND TEST EVENT

Treatment	Ability	Grade	Test Event Attainment	Test Event Retention
	Low	Seven	5.80	5.20
		Nine	5.07	5.13
Verbal	Average	Seven	4.73	5.33
		Nine	7.00	6.07
	High	Seven	7.40	7.47
		Nine	9.93	9.13
	Low	Seven	4.87	3.93
		Nine	6.20	4.47
Sketch	Average	Seven	6.20	6.73
		Nine	7.13	6.80
	High	Seven	7.67	7.20
		Nine	8.67	10.07
	Low	Seven	5.80	4.73
		Nine	5.53	4.80
Model	Average	Seven	7.13	6.00
		Nine	7.73	6.47
	High	Seven	8.93	8.87
		Nine	11.93	11.47

Grade 7 in the average and high ability groups; and (3) mean scores earned when the test was given to measure retention are generally lower than respective mean scores earned on the test when it was given to measure attainment.

Because a significant interaction existed between the ability and grade factors, it is appropriate to examine the effect of ability at each grade level and vice versa. The Newman-Keuls Procedure was used for this purpose (Table 16).

I. Across Ability Groups
   A. Grade 7
      1. Pupils of high ability earned a significantly higher mean score than pupils of either average or low ability.
      2. A significant difference did not exist between pupils of average and low ability.
   B. Grade 9
      1. Pupils of high ability earned a significantly higher mean score than pupils of either average or low ability.
      2. Pupils of average ability earned a significantly higher mean score than pupils of low ability.

II. Across Grades
   A. Low Ability Group
      A significant difference did not exist between Grades 7 and 9.
   B. Average Ability Group
      A significant difference did not exist between Grades 7 and 9.
   C. High Ability Group
      Grade 9 earned a significantly higher mean score than Grade 7.

III. Across Grade and Ability
   Pupils of high ability at Grade 7 earned a significantly higher mean score than pupils of average ability at Grade 9.

Application Level

Treatment of the data using the Analysis of Variance technique under the repeated measures design indicated (Table 17) that:

TABLE 16

NEWMAN-KEULS PROCEDURE FOR MEAN SCORES OF GRADE-ABILITY INTERACTION AT THE COMPREHENSION LEVEL

		Grade-ability Groups					
		7L	9L	7A	9A	7H	9H
Ordered Means		5.06	5.20	6.02	6.87	7.92	10.20
		7L	9L	7A	9A	7H	9H
Differences between means	7L	0	.14	.96	1.81*	2.86*	5.14*
	9L		0	.82	1.67*	2.72*	5.00*
	7A			0	.85	1.90*	4.18*
	9A				0	1.05*	3.33*
	7H					0	2.28*
	9H						0
r			2	3	4	5	6
$q_{.95}(r, 120)+$			2.80	3.36	3.69	3.92	4.10
$q_{.95}(r, 120)\sqrt{\frac{MS_{error}}{t \cdot e \cdot n}}$			.96	1.16	1.27	1.35	1.41

+ nearest conservative table value to $q_{.95}(r, 252)$
* $p < .05$

TABLE 17
ANALYSIS OF VARIANCE
FOR APPLICATION SCORES

Source of Variation	df	MS	F
Between Subjects			
Treatment (T)	2	7.12	< 1
Ability (A)	2	543.61	59.61*
Grade (G)	1	325.11	35.65*
TA	4	15.35	1.68
TG	2	7.06	< 1
AG	2	55.98	6.14*
TAG	4	9.10	< 1
Subj. w. groups [error (between)]	252	9.12	
Within Subjects			
Test Event (E)	1	.54	< 1
TE	2	8.26	2.39
AE	2	3.06	< 1
GE	1	2.82	< 1
TAE	4	1.94	< 1
TGE	2	1.05	< 1
AGE	2	7.91	2.29
TAGE	4	4.20	1.22
E x subj. w. groups [error (within)]	252	3.45	

*$p < .05$

I. significant differences did not exist among the mean scores earned by the treatment groups,

II. significant differences existed among the mean scores earned by the ability groups,

III. significant differences existed between the mean scores earned by the grades,

IV. significant differences did not exist between the mean scores earned on the test events,

V. the ability x grade interaction was significant, and

VI. all other interactions were not significant.

Inspection of the cell means in Table 18 reveals that: (1) the high ability model treatment groups earned consistently but not significantly higher mean scores than the high ability sketch or verbal treatment groups; (2) except for the mean scores of the low and average groups of Grade 7 on the test when given to measure retention, the average ability groups consistently earned higher mean scores than respective low ability groups and high ability groups consistently earned higher mean scores than respective average ability groups; (3) Grade 9 mean scores were consis-

TABLE 18

APPLICATION MEAN SCORES ARRANGED ACCORDING TO TREATMENT, ABILITY, GRADE, AND TEST EVENT

Treatment	Ability	Grade	Test Event Attainment	Test Event Retention
	Low	Seven	5.00	5.40
		Nine	5.27	5.40
Verbal	Average	Seven	5.67	4.87
		Nine	7.27	7.40
	High	Seven	7.07	7.73
		Nine	9.67	7.80
	Low	Seven	5.20	4.40
		Nine	5.87	6.00
Sketch	Average	Seven	6.20	6.00
		Nine	7.87	7.33
	High	Seven	6.80	6.67
		Nine	10.40	9.60
	Low	Seven	4.33	5.47
		Nine	4.47	4.80
Model	Average	Seven	5.93	5.47
		Nine	7.47	7.60
	High	Seven	7.40	8.33
		Nine	10.60	11.07

tently higher than respective mean scores at Grade 7 in the average and high ability groups; and (4) most of the mean scores earned on the test when given to measure retention were higher than respective mean scores earned on the test when given to measure attainment.

Because a significant interaction existed between the ability and grade factors, it is appropriate to examine the effect of ability at each grade level and vice versa. The Newman-Keuls Procedure was used for this purpose (Table 19).

I. Across Ability Groups
  A. Grade 7
    1. Pupils of high ability earned a significantly higher mean score than pupils of either average or low ability.
    2. A significant difference did not exist between the mean scores earned by pupils of average and low ability.
  B. Grade 9
    1. Pupils of high ability earned a significantly higher mean score than pupils of either average or low ability.
    2. Pupils of average ability earned a significantly higher mean score than pupils of low ability.

II. Across Grades
  A. Low Ability Group
  A significant difference did not exist between the mean scores earned by pupils at Grades 7 and 9.
  B. Average Ability Group
  Pupils at Grade 9 earned a significantly higher mean score than pupils at Grade 7.
  C. High Ability Group
  Pupils at Grade 9 earned a significantly higher mean score than pupils at Grade 7.

III. Across Grade and Ability
A significant difference did not exist between the mean scores earned by pupils of average ability at Grade 9 and pupils of high ability at Grade 7.

TABLE 19

NEWMAN-KEULS PROCEDURE FOR MEAN SCORES OF GRADE-ABILITY INTERACTION AT THE APPLICATION LEVEL

		Grade-ability Groups					
		7L	9L	7A	7H	9A	9H
Ordered Means		4.97	5.30	5.69	7.33	7.49	9.86
		7L	9L	7A	7H	9A	9H
Differences	7L	0	.33	.72	2.36*	2.52*	4.89*
	9L		0	.39	2.03*	2.19*	4.56*
between	7A			0	1.64*	1.80*	4.17*
	7H				0	.16	2.53*
means	9A					0	2.37*
	9H						0
r			2	3	4	5	6
$q_{.95}(r, 120)$+			2.80	3.36	3.69	3.92	4.10
$q_{.95}(r, 120)\sqrt{\frac{MS_{error}}{t \cdot e \cdot n}}$			.89	1.07	1.17	1.25	1.30

t=number of treatments
e=number of test events
n=number of pupils/cell
+ nearest conservative table value to $q_{.95}(r, 252)$
*$p < .05$

SURVEY OF ATTITUDE

For purposes of test validity the Survey of Attitude concerning Ecological Systems did not include an indentification of the individual student. This sample, therefore, is not exactly the same as the student sample for the tests of the cognitive domain. The room number and hence the grade and treatment were the only forms of identification and classification permissible. The numbers of pupils in each grade-treatment group were: seven-verbal—52, seven-sketch—50, seven-model—48, 9-verbal—51, 9-sketch—47, and 9-model—49. The numbers of pupils who chose each response in each item were tabulated (Table 20). Similar items and pairs of opposites have been unscrambled from the instrument order as indicated by the item numbers and placed together for the convenience of the reader. The final weights listed were the optimum weights for each choice within each item for this group of pupils as calculated with the Reciprocal Averages program. The summary given in Table 20 reveals that:

I. pupils responded positively to the idea of learning by means of a television system,

II. most pupils thought the series was interesting and not dull,

III. pupils were more evenly divided in their opinion as to whether the series was easy or difficult, that is, more pupils thought it was not easy than thought it was easy; however, the group was quite evenly divided on whether the series was difficult,

IV. most pupils enjoyed the series,

V. most pupils thought the study guides aided their learning process, and

VI. most pupils reacted positively to the communicative ability of the teacher of the series.

A summary of data from the Survey of Attitude is given in Table 21 by grade-treatment group. The mean scores revealed here are the means for each grade-treatment group computed with the optimized weights given for each item. The rank order of the treatment groups is Model > Sketch > Verbal in both grades although differences are more pronounced in Grade 9.

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TABLE 20
SUMMARY OF STUDENT RESPONSES ON SURVEY OF ATTITUDE TOWARD ECOLOGICAL SYSTEMS

	Final Weights	Yes	Maybe Yes	No Opinion	Maybe No	No
1. Can learn from TV	44211	189	63	23	11	11
2. Like to learn from TV	54321	123	72	44	24	33
12. Would again try to learn by TV	54321	134	43	43	26	48
3. Series was interesting	53211	151	70	51	10	13
9. Series was dull	13245	21	26	49	64	135
4. Series was easy	55433	24	46	74	57	94
8. Series was difficult	33445	63	53	65	45	67
6. Enjoyed series	54311	130	61	65	16	21
10. Disliked material in series	12245	22	28	59	52	134
15. Study guide helped learning	54221	169	55	34	11	19
16. Study guide hindered learning	23235	21	15	42	44	164
5. Learned much from series	54321	104	84	57	29	20
11. Teacher taught much in series	54312	129	67	42	12	40
7. Teachers can teach by TV	54321	137	54	47	25	31

TABLE 21
TEST MEAN SCORES FOR GRADE-TREATMENT GROUPS ON SURVEY OF ATTITUDE

	Treatment		
Grade	Verbal	Sketch	Model
Seven	50.92	53.32	53.50
Nine	49.61	52.09	55.08

CONCEPTS MEASURED BY THE PRETEST

Items in the pretest and in the posttest can be identified as testing specific concepts. In the pretest there were nine items testing each of six concepts proposed for the series of lessons. Inspection of Table 22 reveals the following information with respect to pupil achievement in each concept on the pretest.

Concept I The magnitudes of forces acting in opposing directions are related to a condition of static equilibrium within the limits of tolerance for the system.

Pupils of low and average ability in Grade 7 earned higher mean scores than pupils of similar ability in Grade 9, and pupils of high ability in Grade 9 earned a higher mean score than pupils of high ability in Grade 7.

Pupils of average and high ability in both grades earned mean scores above the minimum acceptable level of 15% above chance.

Concept II Rates of opposing actions within ecological factors are related to conditions of dynamic equilibrium in the system.

Pupils of low ability in Grade 7 earned a higher mean score than pupils of low ability in Grade 9, and pupils of average and high ability in Grade 9 earned higher mean scores than pupils of similar ability in Grade 7.

Only the pupils of high ability in Grade 9 attained a mean score above the minimum acceptable level of 15% above chance.

Concept III The rates of absorption and release of matter and energy (the abiotic factors of an environment) by populations are related to a condition of dynamic equilibrium for the system. Specific populations exist in an equilibrium condition with abiotic factors within a range of tolerance.

Pupils of low and average ability in Grade 7 earned higher mean scores than pupils of similar ability in Grade 9, and pupils of high ability in Grade 9 earned a higher mean score than pupils of high ability in Grade 7.

Only the pupils of high ability in Grade 9 attained a mean score above the minimum acceptable achievement of 15% above chance.

Concept IV A population exists in a condition of dynamic equilibrium when the rates of birth and death within that population are equal. Specific populations exist in equilibrium conditions with associated populations when matter and energy are transferred between them.

TABLE 22

PRETEST MEAN SCORES ON EACH CONCEPT
ARRANGED ACCORDING TO GRADE AND ABILITY

Ability	Grade	Concept I	II	III	IV	V	VI
Low	Seven	3.53	2.58	2.71	2.11	2.42	2.22
	Nine	3.49	2.47	2.53	2.36	2.36	1.44
Average	Seven	5.04*	2.60	3.27	3.24	3.04	2.49
	Nine	4.73*	2.69	3.09	3.22	3.16	2.16
High	Seven	5.82*	3.18	3.31	3.51	3.76*	2.71
	Nine	5.96*	3.84*	3.69*	4.00*	3.60*	2.53

*15% or more above chance

Pupils of average ability in Grade 7 earned a higher mean score than pupils of average ability in Grade 9, and pupils of low and high ability in Grade 9 earned higher mean scores than pupils of similar ability in Grade 7.

Only the pupils of high ability in Grade 9 attained a mean score above the minimum acceptable achievement of 15% above chance.

Concept V Homeostasis is the self-regulating adjustment of several interacting relationships in a system tending toward a steady-state dynamic equilibrium.

Pupils of low and high ability in Grade 7 earned higher mean scores than pupils with similar ability in Grade 9, and pupils of average ability in Grade 9 earned a higher mean score than pupils of average ability in Grade 7.

Pupils of high ability in both grades earned mean scores above the minimum acceptable achievement of 15% above chance.

Concept VI Succession is a sequence of events within an ecosystem that has a predictable pattern of community changes disrupting an equilibrium condition over time. Some of these events are related to the presence of organisms themselves and some to cultural changes.

Pupils of low, average, and high ability in Grade 7 earned mean scores that were higher than mean scores earned by pupils of similar ability in Grade 9.

None of the groups earned mean scores above the minimum acceptable achievement of 15% above chance.

CONCEPT ATTAINMENT AS MEASURED BY THE POSTTEST

In the posttest there were 15 items measuring Concept II, 18 items measuring Concept III, 12 items measuring Concept IV, 3 items measuring Concept V, and 12 items measuring Concept VI. Because of the small number of items measuring Concept V, it will be omitted from the discussion. Considering each of the other groups of items measuring a specific concept as a concept test, the mean scores earned by the different groups when the test was given to measure attainment can be observed relative to the minimum acceptable criterion established previously.

Concept II Dynamic Equilibrium within Factors of the Ecosystem (Table 23)

High ability groups in both grades, the average ability group in Grade 7 that received the sketch treatment, and the average ability groups in Grade 9 that received the sketch and the model treatments attained the minimum acceptable mean score of 15% or more above chance.

Average ability groups consistently earned higher mean scores than corresponding low ability groups, and high ability groups consistently earned higher mean scores than corresponding average ability groups.

Groups of pupils at Grade 9 consistently earned higher mean scores than corresponding groups of pupils at Grade 7.

Concept III Dynamic Equilibrium between Biotic and Abiotic Material (Table 24)

High ability groups in both grades and average ability groups in Grade 9 that received the sketch and the model treatments attained the minimum acceptable mean score of 15% or more above chance.

Average ability groups consistently earned mean scores that were equal to or greater than the mean scores earned by the corresponding

TABLE 23
MEAN ATTAINMENT TEST EVENT SCORES FOR CONCEPT II ARRANGED ACCORDING TO TREATMENT, ABILITY, AND GRADE

Ability	Grade	Treatment Verbal	Sketch	Model
Low	Seven	4.13	4.13	4.13
	Nine	4.93	5.40	4.27
Average	Seven	4.33	6.13*	5.53
	Nine	5.60	6.40*	6.33*
High	Seven	6.93*	6.20*	6.67*
	Nine	8.80*	7.53*	8.47*

*15% or more above chance

low ability groups and, except for the pupils in Grade 9 who received the sketch treatment, the high ability groups consistently earned mean scores that were greater than the mean scores earned by the corresponding average ability groups.

Pupils of average and high ability in Grade 9 earned higher mean scores than pupils of similar ability and treatment in Grade 7.

TABLE 24
MEAN ATTAINMENT TEST EVENT SCORES FOR CONCEPT III ARRANGED ACCORDING TO TREATMENT, ABILITY, AND GRADE

Ability	Grade	Treatment Verbal	Sketch	Model
Low	Seven	5.47	5.00	5.53
	Nine	5.27	5.73	4.47
Average	Seven	5.60	5.80	5.53
	Nine	6.60	8.33*	7.13*
High	Seven	7.40*	7.40*	7.27*
	Nine	9.20*	8.27*	10.73*

*15% or more above chance

Concept IV Dynamic Equilibrium with Reference to Populations (Table 25)

Pupils of high ability in both grades and pupils of average ability in Grade 9 that received the verbal treatment attained mean scores above the minimum acceptable achievement.

Except for pupils of low and average ability in Grade 9, the model treatment groups consistently earned higher mean scores than the corresponding sketch or verbal treatment groups.

Average ability groups consistently earned higher mean scores than corresponding low ability groups, and high ability groups consistently earned higher mean scores than corresponding average ability groups in both grades.

Groups of pupils at Grade 9 consistently earned mean scores that were equal to or greater than the mean scores earned by corresponding groups at Grade 7.

TABLE 25
MEAN ATTAINMENT TEST EVENT SCORES FOR CONCEPT IV ARRANGED ACCORDING TO TREATMENT, ABILITY, AND GRADE

Ability	Grade	Treatment Verbal	Sketch	Model
Low	Seven	3.00	2.87	[illegible]
	Nine	3.00	4.13	[illegible]
Average	Seven	3.67	[illegible]	[illegible]
	Nine	5.93*	[illegible]	4.47
High	Seven	5.13*	[illegible]	[illegible]
	Nine	6.27*	6.87*	[illegible]

*15% or more above chance

Concept VI Succession within the Ecosystem (Table 26)

Pupils of high ability in Grade 9, pupils of high ability in Grade 7 who received the model treatment, and pupils of average ability in Grade 9 who received the model treatment attained the minimum acceptable mean score of 15% or more above chance.

Except for pupils in Grade 9 of low ability the model treatment groups consistently earned higher mean scores than respective sketch or verbal treatment groups.

Except for the pupils in Grade 7 who received the verbal treatment, the average ability groups achieved higher mean scores than the corresponding low ability groups, and without exception the high ability groups earned greater mean scores than corresponding average ability groups.

Groups of pupils at Grade 9 achieved mean scores equal to or greater than the mean scores achieved by corresponding groups at Grade 7.

SUMMARY OF RESULTS

Analysis of Variance

The significant differences [illegible] between factor levels were independent of other factors.

TABLE 26
MEAN ATTAINMENT TEST EVENT SCORES FOR CONCEPT VI ARRANGED ACCORDING TO TREATMENT, ABILITY, AND GRADE

Ability	Grade	Treatment Verbal	Sketch	Model
Low	Seven	2.87	2.93	2.80
	Nine	2.87	3.60	3.00
Average	Seven	2.53	3.47	3.80
	Nine	4.47	4.07	5.47*
High	Seven	3.80	4.67	5.47*
	Nine	5.33*	5.73*	6.53*

*15% or more above chance

A. Treatment
Knowledge: no significant difference between Model, Sketch, and Verbal
Comprehension: *Model > Sketch or Verbal
Application: no significant difference between Model, Sketch, and Verbal

B. Ability
*High > Average > Low on pretest, on the posttest knowledge level, and except between groups 7L and 7A on the posttest comprehension and application levels.

C. Grade
Pretest: no significant difference between Grades 7 and 9
Posttest knowledge: *9 > 7
Posttest comprehension: *Group 9H > 7H (*7H > 9A, *9A > 7L or 9L)
Posttest application: *Group 9H > 7H, *Group 9A > 7A

D. Test Event
Knowledge: *Attainment > Retention at Grade 9 (The decrease between attainment and retention events at Grade 7 was not significant.)
Comprehension: *Attainment > Retention
Application: Differences between attainment and retention test events were not significant.

Attitude

Pupil attitude was definitely positive toward television as a medium of instruction, toward this series of lessons as being both interesting and enjoyable, toward the use of a study guide, and toward the teacher of the series. Pupils felt this series of lessons was not easy but quite difficult. Rank order of the treatment groups was Model > Sketch > Verbal in each grade.

Concept Attainment

Pretest: 7 > 9 except high ability on Concepts I—IV, average ability on Concepts II and V, and low ability on Concept IV. Acceptable achievement: Concept I: 7A, 7H, 9A, 9H; Concepts II, III, IV: 9H; Concept V: 7H and 9H; Concept VI: none.

Posttest on Concepts II, III, IV, and VI: Acceptable achievement is indicated by * in the table below.

Treatment: Model > Sketch or Verbal on Concept IV except groups 9L and 9A and on Concept VI except group 9L

Ability: High ≥ Average except Grade 9-sketch groups on Concept III and Average ≥ Low except Grade 7-verbal groups on Concept VI.

Grade: 9 ≥ 7 on all concepts in all groups except low ability groups on Concept III.

		Treatment: Verbal				Sketch				Model			
	Concept	II	III	IV	VI	II	III	IV	VI	II	III	IV	VI
Ability	Grade												
Average	Seven					*							
	Nine			*		*	*			*	*		*
High	Seven	*	*	*		*	*	*		*	*	*	*
	Nine	*	*	*	*	*	*	*	*	*	*	*	*

V
CONCLUSIONS

The conclusions drawn from this study pertain to the population from which the sample was taken and to the method of televised instruction used for the didactic presentation.

I. If in Grades 7 and 9 it is desired to use the conceptual scheme of equilibrium as an abstract cognitive "organizer" in teaching ecological systems at the comprehension level of understanding, the use of working models for reference to the organizer is superior to verbal reference or the use of sketches. The use of models is not significantly superior at the knowledge and application levels.

II. When the methods of instruction and tests as described are used in teaching ecological systems in Grades 7 and 9, pupils of high ability earn significantly higher test scores than pupils of average ability and in Grade 9 pupils of average ability earn significantly higher test scores than pupils of low ability. In Grade 7 pupils of average ability earn significantly higher test scores than pupils of low ability only at the knowledge cognitive process level.

III. The didactic presentation as used in this study produces higher mean test scores in Grade 9 than in Grade 7 at the knowledge level for all pupils, at the comprehension level for pupils of high ability, and at the application level for pupils of high and average ability.

IV. A significant decrease in mean scores earned by pupils in Grade 9 occurs at the knowledge level between the times when the posttest is given to measure attainment and when it is given to measure retention, a smaller but still significant decrease occurs in both grades at the comprehension level, and no significant decrease occurs at the application level. Pupils at Grade 9 retain the information learned at the application level better than at the comprehension level and they retain the information learned at the comprehension level better than at the knowledge level.

V. The attitude of pupils is positive toward the use of television as a medium of instruction, in this series of lessons as being both interesting and enjoyable, toward the use of a study guide, and toward the communicative ability of a television teacher; however pupils felt that this series of lessons was quite difficult. The rank order of treatment groups in a comparison from the highest to the lowest positive attitude of pupils is model, sketch, and verbal.

VI. When the minimum acceptable achievement criterion of 15% above chance is applied to the mean scores earned by each grade-ability-treatment group on each concept, the following conclusions are noted.

A. Concept I, "the magnitudes of forces acting in opposing directions are related to a condition of static equilibrium within the limits of tolerance for the system," was understood by pupils of average and high ability in Grades 7 and 9 prior to the beginning of instruction. For these pupils the concept can serve as a useful introduction to the conceptual scheme of equilibrium.

B. Concept II, "rates of opposing actions within ecological factors are related to conditions of dynamic equilibrium in the system," can be taught to pupils of average ability in Grade 9 when the teaching method involved utilizes sketches or models, to pupils of average ability in Grade 7 when the method utilizes sketches, and to pupils of high ability in Grades 7 and 9 when the method employed utilizes any one of the three procedures.

C. Concept III, "the rates of absorption and release of matter and energy (the abiotic factors of an environment) by populations are related to a condition of dynamic equilibrium within limits of tolerance for the system," can be taught to pupils of average ability in Grade 9 when the teaching method involved utilizes the sketch or model treatment, and to pupils of high ability in Grades 7 and 9 when the method employed utilizes any one of the three procedures.

D. Concept IV, "a population exists in a condition of dynamic equilibrium when the rates of birth and death within that population are equal," can be taught to pupils of average ability in Grade 9 when the teaching method involved utilizes verbal references to the conceptual scheme of equilibrium, and to pupils of high ability in Grades 7 and 9 when the method employed utilizes any one of the three procedures.

E. Concept VI, "succession is a sequence of events within an ecosystem that has a predictable pattern of community changes disrupting an equilibrium condition over time which may be related to the presence of organisms and to cultural changes," can be taught to pupils of average ability in Grade 9 and pupils of high ability in Grade 7 when the teaching method involved utilizes models, and to pupils of high ability in Grade 9 when the method employed utilizes any one of the three procedures.

Generally the concepts taught in this experimental project are appropriate for pupils of average ability in Grade 9 and for pupils of high ability in Grades 7 and 9. The information reported in this paper does not lend itself to broad implications for use by science educators; it does imply that more research is required with respect to the utilization of cognitive organizers and the optimum level of abstraction useful for their presentation to pupils in other communities and in various cultural situations.

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