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Creating Supplimental Visual and Manipulative Activities for Biology

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CREATING SUPPLEMENTAL VISUAL AND MANIPULATIVE ACTIVITIES FOR BIOLOGY

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Alternative visual and tactile teaching strategies and their educational effectiveness for students of diverse backgrounds in the life sciences were studied. Supplemental activities to traditional, commercial, science programs were found to provide many effective learning pathways to a wide spectrum of learning styles. To assist in providing additional learning approaches toward program goals, the educational theory in the literary review was applied to the formation of a set of classroom science materials. Suggestions for classroom use have been provided.

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Chapter 1

BACKGROUND OF THE PROJECT STUDY

Meeting the educational needs of a diverse population of secondary science students attending the Puyallup Public Schools requires a wide variety of supplemental teaching strategies. Student exposure to science, their academic levels, and their family and cultural backgrounds differ as much as the ways in which they each learn best. Students of all abilities have been mainstreamed, giving educators the opportunity to provide equitable, unsegregated experiences. As stated by Bybee and Trowbridge (1982), "the effective science classroom appears to be one in which students . . . . get opportunities to physically interact with instructional materials and engage in varied kinds of activities" (p. 285).

In attempting to satisfy heterogeneous needs, precautions need to be taken to provide realistic science challenges for all levels of student ability and proficiency. While current trends concentrate on incorporating inquiry, problem solving, and other higher level thinking skills, as well as computer competency, the lower levels of cognition cannot be dismissed, even at the secondary levels. A balance of providing experiences to reach as many levels of cognition as possible must be included. After a concentrated study on the effectiveness of various futuristic innovations, Moore (1978) discovered that they produced no significant difference. He states, "...that we shall never find the ideal teacher, method, or climate for learning," that there is a great diversity in students and in learning, and that no single method of teaching is necessarily superior to another (p. 436).

It is with these goals in mind that the author began a study of the effectiveness of visual and manipulative science activities. Research led to the identification and creation of classroom instructional materials which provided learning opportunities in the cognitive, affective, and psychomotor domains, and accomodated as many learning styles as possible.

To enhance the effectiveness of restrictive, commercially adopted programs, other affordable learning avenues needed to be discovered or created. In seeking the least expensive approach, teacher-created materials proved to be the most effective and productive. While applications of the ideas of other published teachers were usually successful, innovative creations were just as educationally fruitful and provided instructor motivation to continue production.

Purpose of the Project

The intent of this project was the production of economical, visual-spatial teaching materials, whose classroom value in providing educational benefits to life science students in grades 7 through 11 was supported by research and classroom success. Heinrich, Molenda, and Russell (1985) confirm that "without a good theoretical rationale, use of specific materials may become simply mechanical, with the fond hope that what is presented to learners will eventually become meaningful to them"(p.7). These researchers promote the requirement of a strong "conceptual and theoretical bases on which to choose specific materials by discussing the relationships between media, learning, and instruction" (Heinrich et al., 1985, p.7).

Need of the Project

Failing to understand teachers' needs in educating students with diverse interests and learning styles, publishers of science texts have placed little emphasis on providing affordable, supplemental, activity materials. Traditionally, commercial programs have not provided reading levels, lab activities, or instructional materials required by less capable science students particularly for those with weak science backgrounds, language barriers, or limited ability. The need for supplemental teaching materials at introductory levels has continued to be a necessity. Concrete formats continue to have a valuable function in the secondary science curriculum. According to Kinder (1965) the most common values of concrete instructional materials are that "they illustrate and clarify nonverbal symbols and images, quantitative relationships, complex and abstract relationships, time and space relationships, and specific details" (p. 15). The sole exceptions are commercial student worksheets, and hands-on class activities where the instructor provides inexpensive, locally obtained items. The cost of preassembled lab kits for specific experiments and demonstrations, as well as manipulative life science activities have been prohibitive. Commercial models and manipulative charts have rarely been financially feasible for most public schools. In the area of manipulative life science activities there is a deficiency of affordable options.

While affordable to many secondary science departments, many commercial games are lengthy, overly sophisticated attempts to deliver complex science concepts or processes. Other games frequently fail to provide science substance, topic relevance, or accurate presentations. Games involving enjoyable yet relevant learning experiences are rare.

Adequate, equitable funding of computer-assisted instruction in the sciences has produced a large gap within and among school systems. While computers offer tremendous potential in science education, they produce limited personal , tactile and spatial reality compared to some of the items generated by this project or reality.

The monotony of repetitive, traditional commercial learning activities does little to stimulate positive attitude, interest, or relevancy for many students. Teachers need to apply a creative hand in forming supplemental educational materials. As Schuller and Wittich (1973) state, "today's school environment should offer varied alternatives among instructional experiences" (p. xxi).

Scope of the Project

This project covered two phases related to supplemental teaching strategies for the life sciences. The first involved the identification of iconic and spatial materials in learning activities that had educational potential as determined by research or had been determined successful by published science educators. The second stage involved the production of a variety of each media form, each composed of a set of graphic or three-dimensional hands-on biology activities. The four media forms will be identified as the following: manipulative boards, manipulative activities, games/simulations, models.

From seemingly endless possibilities, the supplemental materials produced were limited to a few examples of each of the following: manipulative charts or boards, hands-on activities containing graphic manipulatives, games/ simulations, and models. Each of these has applications for most junior high and lower level high school students in the life sciences. .

Definition of Terms

Affective Domain: " The domain of human learning that involves changes in interests, attitudes, and values, and the development of appreciations and adequate adjustment" (Heinrich, Molenda, & Trowbridge, 1985, p. 395).

Charts: Two-dimensional surfaces with diagrams (labeled drawings, pictures, or movable graphic elements) used to illustrate examples, structures, relationships, skills, processes, concepts, etc.

Cognitive Domain: "The domain of human learning involving intellectual skills, such as assimilation for information or knowledge" (Heinrich et al., 1985, p. 396).

Cognitive Level: The four stages of intellectual development according to Jean Piaget- sensorimotor, preoperational, concrete, and formal operational (cited in Sayre & Ball, 1975, p. 165).

Computer-Assisted Instruction: Instruction delivered directly to learners by allowing them to interact with lessons programmed into the computer system.

Descriptors: Words used by the *ERIC* (Educational Resources Information Center) system to focus a computerized search for related literature.

Game: " An activity in which participants follow prescribed rules that differ from those of reality in some form as they strive to attain a challenging, simulated goal" (Heinrich et al., 1985, p. 398).

Hands-On Activities: Any classroom behavior involving tactile sensation, and more importantly in this context, student manipulation of visual or spatial materials during a learning experience.

Inquiry: In science education, a teaching strategy in which students are posed questions or problems, and encouraged to use the scientific method to produce, test, and alter a hypothesis. These activities lead to continuous cycles of questioning the effects of related experimental variables, and attempting to expand their inquisitiveness with further experimentation.

Learning styles: Means by which one is able to learn which is related to preference, ability, and/or developmental stage.

Mainstreaming: Placing all students in a curriculum which is not segregated by ability, behavior, language, or physical handicap.

Manipulative: An activity that requires a student(s) and/or teacher to move objects to complete the learning activity.

Manipulative Boards: Surfaces with graphic components that can be manually arranged with limited pattern of correctness. Velcro boards, felt boards, and magnetic boards are three examples of "manipulative boards."

Media Form: Visual and spatial teaching aids including but not limited to models, diagrams on charts, manipulative boards, games, specimens, bulletin boards, and mobiles.

Models: Three-dimensional objects used to represent selected characteristics of real things which themselves prove difficult to examine for a variety of reasons.

Psychomotor Domain: (also motor skills domain) "The category of human learning that involves athletic, manual, and other physical action skills" (Heinrich et al., 1985, p. 399).

Simulations: "An abstraction or simplification of some real life situation or process" (Heinrich et al., 1985, p. 401).

Supplemental Teaching Strategies: Teaching methods and materials other than those provided. Generally those in exception to a textbook.

Chapter 2

REVIEW OF THE LITERATURE

INTRODUCTION

In addition to learning theories which have emerged in the last three decades, a multitude of research has supported the benefits of visual and manipulative experiences in science education. The instructional value of the production and application of a variety of such materials can be identified and acknowledged in education and science literature. The popularity of the multimedia packages or learning kits, continuing to the present, has been a strong indication of the need for variety in our approaches to providing effective education. Kemp and Smellie (1989) outline three directives for those involved in planning and producing effective instructional media: a. examine the fields of psychology and communication regarding perception, communication, and learning, b. review reports on experimental studies measuring the effectiveness of the materials, c. develop objectives, planning, and preparing for production. In a recent study Biermann (1989) states, "It should be advisable for instructors to devise as many dynamic, concrete aids as possible to facilitate the encoding of biological information (even at the college level)" (p. 234). These two citations have formed the philosophical backbone and guide for this project.

Since the goal of educators is to affect the behaviors of students, teachers find it prudent to turn to the psychology of learning for help in locating guiding principles for the planning of effective instructional activities and related instructional media. Kemp and Smellie (1989) review seven significant learning theories and their associations with media production in the sixth edition of their text Planning, Producing, and Using Instructional Material. A familiarity with these theories provides a foundation of strong educational fundamentals to begin the exploration of teaching strategies. Their list includes the following theories: operant conditioning by Skinner, conditions of learning by Gagne, component display theory by Merril, elaboration theory by Reigeluth, the information-processing theory by Norman, the social learning theory by Bandura, and the attribution theory by Weiner. Areas of agreement and similar emphasis among these theories from which important factors to consider in the design and use of instructional media can be drawn.

In addition to acquiring a familiarity with learning theories, one who proposes change in science instruction would also attempt to gain insight as to what is presently considered "science education." The collective view of what it means to teach science effectively has evolved considerably from the pure lecture and cookbook lab approach. The synopsis revealed by this review could be characterized in a statement by Witkins and Moore (cited in Charlton, 1980): " We find that no one best way of teaching exists. Cognitive styles of both students and teachers must be considered" (p.244). No longer is the teacher the sole dispenser of knowledge and the center of activity in the classroom. Explosions of scientific information, massive leaps in technology, and new concepts of how different students learn have greatly increased the complexity of science education. The science classroom has awakened to a more encompassing, holistic learning atmosphere. For example, what were once considered useless frills are now encompassed in providing an effective atmosphere for education. "A meanly furnished school radiates the message that learning is not valued here....A room in which there is a mix of interesting permanent and temporary displays teaches much good science" (White, 1988, p. 11). As early as 1965 Kinder noted that "First impressions of the teacher and the course are received when students and visitors enter the room. The bulletin board and other decorations reflect the philosophy of learning which prevails in the room" (p.118).

In his book A History of Ideas in Science Education, DeBoer (1991) points out that, to date, concepts in science education have had their source in sense perceptions and are linked to form clusters of ideas. The more connections that are made among these ideas, the richer is the conception. Some of the implications derived from this idea that affect science instruction include the understanding that sense impression functions as a precursor to verbal manipulation, that related ideas have more meaning than disorganized ideas, and that personally relevant instruction supersedes the unfamiliar. His impression is that most science educators who adhere to directed discovery methods are providing a variety of ways to allow students to draw meaning from their experiences. Three major interpretations of what it means to teach science were drawn from DeBoer's (1991) extended research in science education:

1. Teaching the science disciplines as structured bodies of knowledge to be learned as logically organized subject matter
2. Teaching science as a set of investigative processes
3. Teaching science as a human activity closely interconnected with its technical applications and with the rest of society (p. 219)

He sees most of what is being taught and what is currently taught as blends of these three approaches. Rarely do they stand alone.

In a more general form Lundberg (1975) sets three tasks for teachers: a. Identify the styles/levels of students. b. Match the learning environment with style/levels. c. Create a learning environment to move each student to the next level. (p. 244)

No matter to which theory or current educational trend one adheres, " a fundamental reason for instructional design is to ensure that no one is educationally disadvantaged: that everyone has an equal opportunity to use his or her individual talents to the fullest degree" (Gagne & Briggs, 1974, p. 5).

THE NEED FOR CREATING VISUAL AND MANIPULATIVE INSTRUCTIONAL MATERIALS BASED ON RESEARCH AND LEARNING THEORY

The need for creating visual and manipulative instructional materials in secondary life science classrooms is well documented in science education journals and media texts. As Dwyer (1978) states, "The spoken and written word alone has been found to be an unreliable medium for optimum communication between and among individuals who have had limited opportunities for sharing identical concrete experiences" (p. 18).

Several learning theorists have expressed the significance of concrete materials during the learning process, and many science education researchers have addressed their positive effect in the classroom. Jerome Bruner (1966) proposes that instruction "should proceed from direct experience, through iconic representations of experience, through iconic representations"(p.49), encountered in a particular sequence. He amends this statement with the clarification that the learning sequence is critical and that development of instruction should parallel the "differentiation-integration learning process" (p. 8). In a similar fashion Edgar Dale presents his "Cone of Experience" theory which emphasizes the nature of the stimuli to the learner rather than the nature of the mental operation (cited in Heinrich et al.,198). Like Bruner and Dale, Levie and Fleming (1978) derive similar principles: concrete experiences facilitate learning and the acquisition, retention, and usability of abstract symbols.

Hemispheric preference, another element of learning which has gained favor in the last two decades, speaks to the concrete experiences required by many students. Zenhausen (cited in Dunn, Cavanaugh, Eberle, and Zenhausen, 1982) and Sperry (cited in Lord, 1985) refer to the left hemisphere as the processor of verbal, linear, and analytical phenomena while the right hemisphere relates more to nonlinguistic, spatial, and experimental phenomena. The maturation process in humans tends to move from the concrete right toward the abstract left side. Mcgee (1979) claims that this preference for cognitive style is frequently the basis for career decisions between the holistic-spatial mathematicians and scientists and the linguistic artists, historian, and writers.

While the case for matching learning and teaching styles grows every year, researchers have found evidence that both achievement and attitudes toward school improve significantly when instructional methods or resources complement the way individuals learn. A right hemispheric-preferenced person appears to be more efficient at tasks associated with deductive reasoning and thinking "in pictures". The differences in learning style characteristics would suggest that different settings and instructional approaches are necessary to provide complementary instruction. "Hemispheric preference is likely to gain increasing attention among those who are concerned about providing maximum instructional opportunities for all" (Dunn et al., 1982, p. 293).

Indications of the acceptance of hemispherical preference appear in many science education articles. Ward (1988) points out that initial attempts to communicate abstract concepts in biology should first stimulate the right brain since it has a greater capacity to comprehend intricate, detailed information. McCarthy's study (1988) indicated that concrete experiences with right-brain stimulation should be used to introduce new topics due to its greater capacity for initial orientation to complex information. A strong link between right cerebral hemisphere activity and the understanding of biological concepts has been shown by Lord (1985). According to Biermann (1989), "We often use right brain activities to encode more difficult concepts" (p.236). He feels that kinesthetic analogies are a dynamic illustration and an invaluable tool for learning in the biological sciences. Siemonkowski and MacKnight's (1985) research suggested that most all successful college science majors are effective holistic-spatial conceptualizers as in their superior ability for three-dimensional imagery.

Possibly the most cited learning theorist with the greatest impact on recent science education thought and literature has been Jean Piaget. "His theories of psychological development and intelligence fit best with recent discoveries about psychological consciousness"(Restak, 1979, p. 261). According to Piaget (cited in Sayre & Ball, 1975) intellectual development evolves through the following four stages in the growth of a child: " the Sensorimotor (0-2 years), the Preoperational stage (age 2-7 years), the Concrete stage ages 7-11 years), and the Formal Operational state (ages 11-16 years)"(p. 165).

With Piaget's developmental scale in mind it would appear that most secondary science students would not benefit from the visual, spatial, tactile or manipulative modes. However, according to Flavel the stages of invariable sequence may vary as to duration and chronological age (cited in Sayre & Ball,1975). Many other researchers have found formal thinking to develop much later in adolescence than Piaget's initial estimation. Lovell, Case and Calhoun, and Randall (cited in Sayre & Ball, 1975) indicate that many adolescents are somewhere in a transitional state between the concrete and formal operational stages. More recent findings by Purser and Renner, Schneider and Renner, and Inhelder and Piaget himself (cited in Cate & Grzybowski, 1987) as well as McKinnon and Renner, Tomlinson-Keasey, and Towler and Wheatley (cited in Cantu & Herron, 1978) and Chiapetta (1976) showed that at least half of all high school biology students function at the concrete operational level. Lawson and Renner (1975) found that 65% of the students in their sample were concrete thinkers, unable to understand abstract subject matter. They also found that a substantial amount of secondary science subject matter was at an inappropriate intellectual level. They cited ten other similar studies conducted throughout the United States with virtually identical intellectual ability test results.

Lawson and Renner (1975) stress that, "Perhaps more important than major shifts in content matter would be a careful evaluation of teaching procedures and sequencing of materials to help lead these learners from concrete to formal thinking patterns" (p. 356). As a result of finding that most of what was being taught in science required formal-operational thought, Cantu and Herron (1978) proposed that we must assist the development of reasoning or learn to teach so that ideas of science are understood by students who remain at the concrete level. While they found that formal-operational students learned more concrete concepts than the concrete-operational students, Cantu and Herron insisted that there are many concrete concepts capable of reception by concrete thinkers if the instruction is carefully designed to avoid formal reasoning. Saunders and Shepardson (1987) found a significantly higher level of performance in science achievement and cognitive development favoring concrete instructional groups over formal-operational methods. Similarly, Schneider and Renner (1980) found concrete instruction techniques were superior to formal instruction in promoting intellectual development for the concrete operational student. They felt "the implication for educators concerned with promoting the acquisition of science content and/or intellectual development is that the actual first-hand experience of concrete instruction should replace formal instruction techniques" (p. 516).

Goodstein and Howe (1978) attempted to apply Piaget's theories of cognitive development to test Sheehan's studies and improve secondary science instruction. According to Sheehan (cited in Goodstein & Howe, 1978) the use of concrete methods was more effective with not only concrete operational learners but also with the formal operational learners when compared to formal methods. By providing science students with concrete models and examples Goodstein and Howe found that formal operational students learned more than the concrete learners. They also boldly concluded that no matter how they were taught, lower level students tended not to be able to learn concepts requiring advanced thinking.

Conversely, Peebles and Leonard (1987) claimed success with their concrete students when they developed and used "manipulative activities using inexpensive but graphic materials" (p. 436) to develop higher level concepts in molecular genetics. McKinnon and Renner, Renner and Paske, and Smith and Von Egeren (cited in Gable and Sherwood, 1980) also found that by using more concrete methods in the classroom students learned to think more abstractly and therefore change from the concrete to the formal operational stage.

A major consequence of the aforementioned learning theories and research has been the call for increased active student involvement as cited in science education journals and instructional media texts. Wolfinger (1984) lists several advantages of the process approach over the content approach in teaching science:

1. it requires student involvement
2. it requires cognitive participation in the learning process
3. it reduces the chance of student failure
4. it requires conclusions be drawn from data
5. it develops skills applicable to many other areas of science (p. 35)

Wittich and Schuller (1973) have accumulated four basic generalizations and guiding principles in their fifth edition on instructional technology. Two of them support the use of concrete materials and relevant activities:

1. Effective learning begins with firsthand or concrete experiences. Thus, a student who has the advantage of reacting to well-selected and wisely used media and materials can learn more effectively than one who is provided with largely verbal information and materials.

2. A learner profits most from instruction when he/she becomes involved through his/her own interests and desires. Well-chosen educational media present concepts in such a way as to incite interest and stimulate involvement. (p. xiv)

Staver and Small (1990), driven by the alarm of the report *The Nation at Risk and Educating Americans for the 21st Century*, compared American and Japanese science programs. When comparing the few American activity-based programs with the widespread Japanese activity-based science programs they found striking similarities in four of the five testing scales. In their conclusion they state "Our problem is not that effective science programs do not exist in the U.S., but that too few schools provide them" (p. 88).

The Peagetian approach suggests that students who reason at the concrete level benefit from hands-on activities. Despite this fact, hands-on activity based science programs have fallen out of favor because they are expensive and difficult to secure and maintain. These types of experiences however, lead to increased science achievement and cognitive development (Koballa, 1986).

The need for more than just "high tech" educational strategies are noted by Taylor (1988):

> Even at the present time with the wide array of commercially available audio-visual aids including computer simulations, such instructional tools may not be feasible due to economics, space available, or the lack of time needed to use them as in computer access time. (p. 509)

The call for an approach that provides an exposure to important aspects of computer technology while preserving concrete experiences provided by hands-on activities has been expressed by Winders and Yates (1990). Berg, Malian, Marr, and Nagel (cited in Ward, 1988) affirm that science teachers should increase participatory learning by involving students kinesthetically since students physically involved in the learning gain more. Wollman and Lawson (1978) showed that students whose instruction included active student involvement with physical objects, performed with greater success than a control group in which the instruction was totally verbal.

Too often secondary science courses disregard provisions for "slower students". Allen (1975) suggests that materials designed for learners with low mental ability should employ design techniques including not only strong cuing devices but methods which elicit active participation and response. He also insists that instructional content may be more completely learned if it is presented to the learner two or more times, in identical or varied forms. Norris, Heikkinen, and Armstrong (1975) concluded in their study that students not only vary in speed of learning but in the styles in which they learn most efficiently. They feel that biology programs which provide a flexible system of styles and conceptual complexity are more likely to provide an appropriate learning environment for the many than for a few. In summation, the need for a wide variety of inexpensive concrete modes of instruction, involving high degrees of student participation which will reach a broad spectrum of student learning styles, ability levels, and interests, are suggested by the literature.

TOOLS FOR DETERMINING COGNITIVE LEVELS

Sayre and Ball (1975) remind us, "The ability to properly determine students' cognitive levels is necessary for effective planning and sequencing of science instruction" (p. 173). Science instructors, then, should have at their disposal a set of evaluation tools available for classroom application. Several examples of tools available for testing cognitive levels and hemispheric aptitudes are described in the literature. The Educational Testing Service has a "Kit of Factor Referenced Cognitive Tests" (Ekstrom, French, Harmon, & Derman, 1976) and the "Learning Style Inventory" (LSI) (Dunn, Dunn, & Price,

1978) for measuring right brain abilities. Cognitive level can be assessed with Piagetion-based tests by Onslow (1976), Gray (1973), and Longeot (1962, 1964). The "Meyers-Briggs Type Indicator" (MBTI)(1962) assesses cognitive style dimensions based on Jung's theory.

EDUCATIONAL VALUES AND PRESENT APPLICATIONS OF RELATED MEDIA IN THE LIFE SCIENCES

"There are numerous classroom strategies which the science teacher could use to make science more fun- to facilitate learning scientific concepts and principles, to interpret the real world and life situations" (Madrazo & Wood, 1980, p. 558). While science education journals and media texts illustrate many ideas for improving visual and manipulative forms of science activities, there remains a large gap for future creative possibilities. Science teachers have attempted to improve their instructional strategies in a variety of ways. The educational values, considerations, and applications of four media forms were surveyed in the literature: manipulative boards and charts, graphic manipulative activities, games and simulations, and models or kinesthetic analogies.

Manipulative Boards and Charts

In the context of this project manipulative boards and charts involve large flat surfaces, held horizontally or vertically, with movable, related elements. Components will only associate in a predetermined scheme to illustrate a scientific concept. In science these aids might be used to teach structure, processes, relationships, and many other concepts in an individual or large group situation. This media form has been identified under many names including feltboards, magnetic boards, and manipulative corkboards. The two most significant aspects of this teaching aid are the visual- kinesthetic qualities and the relationships of the elements in the predesigned pattern. The educational values and applications of this medium have been expressed in educational literature.

The qualities and uses of visuals play a significant, often complex role in determining the educational benefits of boards and charts. Boguslavsky (1967) stressed to science educators that a visual demonstration, to be an aid, "must minimize those aspects which are not immediately relevant to the accompanying text. The principle is that of contrast between the feature under discussion and its background. The making of instructional, visual demonstrations must move in the direction of greater simplicity, with attendant reduction in cost." (p. 1). Dwyer (1967), a prolific writer on visual research, provides the novice designer with a starting point and several helpful basics. "It seems necessary for educators concerned with the structure of visual illustrations to attempt to discover those characteristics that will facilitate particular kinds of learning" (p. 253). As we learn 83% by sight and only 11% by hearing, providing the learner with effective visuals can make a large difference in the final outcome. The greater the number of sensory modalities in a learning experience, however, the greater the memory or delayed recall (Dwyer, 1978). In his 1972 study Dwyer found that: a. not all visual illustrations are equally effective in complementing instruction, b. that excessive cues in realistic illustrations often distract from relevant learning, and contrary to his 1968 study, finds c. that color in specific illustrations is an important instructional variable in increasing student achievement of specific objectives. In addition, he finds that merely increasing the size of instructional illustrations by projecting them on larger viewing areas does not automatically improve their effectiveness in facilitating student achievement. Another visual authority recognized by many researchers, Holliday (1990), also contends that color is useful when employed to highlight or discriminate important pieces of visual information, but does not necessarily add to the scientific information or motivational value.

In regard to individual difference provisions with visual instruction, Dwyer

(1978) proposed that:

> there are sufficient commonalities among students so that instruction complemented by a specific type of visualization may be used effectively for students representing a rather wide band of a specific individual difference variable. The learning potential of an individual at any particular moment depends not only on individual difference variables but also on the type of learning the student is expected to achieve. (p. 229)

An awareness of these factors and others present in the literature would be prudent in the creation of educationally effective learning materials. Fleming and Levie (cited in Kemp and Smellie, 1989, p.14), provide a summary of over 200 principles from the behavioral sciences as they apply to the designing of instructional media.

The educational necessity and advantages of manipulative boards and charts have been presented by many media authors. According to Lord (1985) "It is the job of our schools to develop the cognitive potentials of its student population- potentials that include the ... formation and manipulations of images" (p. 404). "The carefully planned use of appropriately selected graphic materials- including charts, diagrams, graphs, flat pictures, and combinations of these- gives pupils increased conceptualization and understanding than with verbal methods alone" (Wittich & Schuller, 1973, p. 33). In addition, Wittich and Schuller emphasize that, "The instructional value of graphics lie in their capacity to focus attention and to convey certain types of information in condensed, summarized form" (p. 111). They also contend that manipulative displays are

> particularly convenient for use with sequential and additive concepts in many subjects and at many levels....These visual aids are also well suited to situations calling for step-by-step development of a topic, but it is valuable as well for discussion,

> drill, review periods, for visual change during the development of a topic, and for student involvement. (p. 205)

Brown, Lewis, and Harcleroad (1983) emphasize that they are among the least expensive and most productive instructional resources with instructional functions that include:

> to facilitate the study of single-copy materials, to stimulate interest, to save time, to encourage student participation, to provide a review, to make the classroom dynamic, relevant, and attractive, to make displays and exhibits of relevant subjects, and to inform or promote. (p. 94)

Holliday's research (1975) suggested that a single flow science diagram could teach more effectively than either text description or combination of text and diagram. In a later study with Brunner and Donais (1977) he found that students and teachers generally prefer picture-word diagrams and to work with displays containing colored simple line drawings, realistic illustrations, familiar elements, and perceptually complex stimuli. Holliday's studies support the use of picture-word diagrams in science classrooms, particularly for learners with verbal ability deficiencies. More recently (1990) he expanded these values:

> Visuals such as diagrams, tables, and charts, can be used to reinforce important information and to summarize. Summarizing visuals accent important relationships and reorganize information presented in the printed text. A good diagram can disentangle, segregate, group, and compare important information about ideas which are often difficult to learn. (p. 27)

Spangenberg (1971) supports the use of flow diagrams using pathways and cyclic schemes to concentrate descriptive material into intellectually manageable visual displays. Wheeler and Hill (1990) have also studied the purposes and applications of diagrams in science education.

However, they take an impressive instructional leap in supporting the need for students to become more critical consumers and creators of diagrams. In creating their own diagrams they feel students would be confronted with the factors and decisions necessary in producing effective educational materials.

Graphic Manipulative Activities

Supplemental instructional processes which require individual students to move analogous, iconic components of a concept (structure, function, process, etc.) to see scientific relationships constitute graphic manipulative activities. While charts are used more for medium or large groups, these exercises are intended for individuals or very small groups in concept building and review. Such manipulative procedures are frequently accomplished without a board, leaving only a set of instructional pieces to be articulated by the student. While relatively new to the secondary science classroom with little related specific research completed at this time, the general educational advantages of related hands-on media including the aforementioned benefits of visuals have been described in the literature.

The term analogies has been applied to models, maps, diagrams, etc., by Burns and Okey (1985) where the model is the "vehicle" and the concept is the "target" between two distinct domains of knowledge. In this case prior knowledge of the vehicle is crucial to the transfer to the target. " Analogies appear to be a viable means for facilitating comprehension of abstract concepts. Analogies provide a window or vehicle for viewing target information in terms of previously known information, and serve to highlight similarities or pattern repetitions between two different phenomena" (p. 1). In this respect two-dimensional kinesthetic analogies could be considered graphic manipulative activities.

Bean (1990) showed the significant improvement on student comprehension with the inclusion of a pictorial cell analogy comparing the cell to a factory. He stresses the individual functions of cell organelles as factory divisions, and the complementary functioning of the whole unit. The addition of a pictorial representation helped the students grasp and retain cell structure/function relationships.

Piaget (cited in Wittich and Schuller, 1973) points out that unfamiliar objects have little relevance or meaning for learners until they have the opportunity to touch or grasp it or relate to it through their other kinesthetic response mechanisms. Barnett (1974) found evidence that students with a preference for application learn more effectively than students who display a strong preference for memory, and suggests that a nondirective teaching style promotes achievement more than a directive teaching style. Hands-on activities also promote peer interaction where students are free to argue, make mistakes, and challenge each other. Students in such classes perform significantly better on a problem solving test than do students in the teacher demonstration class (Glasson, 1989). The results of an experiment by Vasu and Howe (1989) suggested that experience with physical objects has greater learning potential than verbal alone, but the combination of seeing and hearing was best. A quantitative study by Shymansky, et al. (1983) showed that students taught by hands-on methods outperformed students in traditional programs. Lord (1985) identifies the introduction of the conceptual approach with hands-on, student-directed, activities as the reason for increased success for those with right hemisphere cognitive aptitudes in the last few decades. According to research by Biermann and Sarinsky (1990) biology preparatory groups utilizing the hands-on approach were significantly better prepared for follow-up biology courses as measured by course grades when compared with the remediation-based group and the control. In the conclusion of their report they state: "With respect to science education in general, it would be advisable for instructors at all levels of education to consider reinstitution and refinement of hands-on approaches in the teaching of science classes" (p. 12). Many first-year biology students in high school and college have a great deal of difficulty gaining an understanding of the process of biological processes. The students' lack of knowledge in these areas makes understanding the related concepts equally difficult. Simply reading and looking at pictures in a textbook may not prove to be as successful as a hands-on approach (Taylor, 1988).

Games and Simulations

While games may be considered contests based on skill and/or chance that are played according to rules, simulations are concentrated learning exercises specifically designed to represent important, real-life activities by providing the learners with the essence or essential elements of the real situation without its hazards, costs, or time constraints (Wittich & Schuller, 1973). Many proponents refer to blends of these two with the term "simulation gaming." While the systematic research appears limited and inconclusive, the claims of instructional benefits by game theorists are well documented and show general agreement in the literature .

In the late 1960's the first commercially available science games related to pollution and environmental science appeared. As judged by the continuing number of commercial games produced and articles published on the subject in science education journals, there has been a considerable, continuing growth of interest. Barker (1982) listed over 40 commercial, noncomputerized biology games, and an additional reference to dozens of science education articles describing various other games and simulations. Hounshell and Trollinger (1977) in their text, Games for the Science Classroom, also list dozens of science games available from various commercial, governmental, and institutional sources. In their attempt to bring science into a more social context, the Association for Science Education went so far as to publish an approach to science education in the early 80's based on such gaming techniques.

Barker (1982) contends games and simulations are valuable supplements to cognitively oriented courses in achieving some of the traditional aims of science. These advantages include increased student motivation through more inter-student communication and competition. Initiative and powers of creative thought are important components of these activities which include role-playing. Simulations often foster a range of valuable noncognitive abilities including decision-making and communication skills. Cognitive areas such as analysis, synthesis, and judgment which are seldom reached through traditional teaching techniques may be reached. Blum (1979) complemented research by Abt (1968) indicating that learning games can aid a student's sense of structure of the subject simulated. Ellington, Addinal, and Percival (1981) have identified three ways in which science-based games can be useful in secondary and tertiary education: a. as aids to the teaching of the basic science courses (They advocate the use of games and simulations not as front-line teaching methods, but rather in a complementary and supportive role in reinforcing basic facts and principles and developing laboratory skills. Until quality, economical, computerized simulations become available on a widespread educational basis, other forms may be useful where activities may be extremely difficult, timely, complicated or expensive, or dangerous to perform.); b. for educating through science (using science-based exercises to cultivate useful skills and desirable attitudinal traits); c. for teaching about science and technology and their importance to modern society. Tentative conclusions from their research evaluations on games and simulations include: "a. They appear to have no advantage over other teaching methods in teaching basic facts and concepts. b. They frequently demonstrate attitude improvement. c. They are strong motivators of players" (p. 117).

A review of Hounshell and Trollinger's text (1977) reveals similar claims by game theorists. Simulation gaming can teach factual knowledge to include specific terms, concepts, facts, or relationships between items. Students are motivated to learn the information so that it can be utilized correctly during play to provide an advantage. Games provide students a chance to utilize knowledge in an active manner. Many theorists also maintain that in certain types of games students may increase their critical thinking and decision-making skills. Players may make real-life decisions without suffering severe consequences, and have more fun during active participation in an academically competitive setting. Many simulation activities are preferred by students to other teaching strategies for at least three important reasons: students are active participants not passive bystanders, the teacher's role turns to a less threatening "facilitator of knowledge", and they help make the learning more relevant. Games are effective in changing attitudes of students about a subject. Games are frequently interdisciplinary in nature and involve the learning of skills from other academic and social areas. Games are usually adaptable to several age levels. They are ideal for heterogeneous groups, and can be used as starting points for other activities. In addition, game designers strongly recommend that grades not be used to evaluate a student's participation in a game.

Simulations provide students with experience which helps them to understand and to function better in the situation or comparable situations at another time as in a lab activity, review, test, or real life situations. One of the marked advantages of simulation is increased motivation and participation. Another is the social interaction generated including group decisions, persuasion, peer tutoring and group discipline. Simulation games can accommodate a wide range of age and achievement levels. Well-designed games can approximate reality far more closely than classroom procedures of the past (Wittich & Schuller, 1973). In their text, <u>Becoming a Secondary School</u>

Science Teacher, Bybee and Trowbridge (1982) provide a set of purposes for simulations: "To increase students' abilities to apply concepts, analyze situations, solve problems, and understand different points of view." They reaffirm that "simulations are fun for students, and provide teachers with a means of presenting situations, concepts, and issues in a condensed, simplified form" (p. 285).

Learning from educational games can take a number of forms, of which cognitive learning is only one. The learning of processes and experience with the relative risks and potential rewards of alternative strategies and decisions are also important, and these values are more difficult to measure. The affective elements and social interactions are also important educational goals (Wittich & Schuller, 1973). According to Gordon (cited in Madrazo & Wood, 1980) simulations and games offer the greatest promise for changing the classroom into a laboratory of active participants in the learning process. Simulation games not only have the potential to arouse curiosity but also to create an atmosphere that allows and encourages nonconformity in the classroom. Teachers can use student conflict to resolve problems that call for a solution instead of creating discipline problems. "Games have reached the acceptance as potent learning tools. They challenge the students to learn as they compete, as they socialize, as they solve problems and make decisions, and as they have fun" (Carter & Lee, 1979, p. 34).

Studies of classroom applications include Spraggins and Rowsey's (1986) which supported the hypothesis that high school biology students could learn factual information equally well regardless of sex or ability using either simulation games or worksheet activities, but that games was the preferred mode. Calver, Porter, and Bradley (1990) consider game board or computerized simulations to be the next best thing to an actual field activity. Their board game activity has been successfully applied at both the high school and associate level. Similar results occurred in an investigation by Hazen (1975) which supported the hypothesis that simulation gaming could be a useful and successful alternative to the traditional teaching techniques in high school biology. McKean and Gibson (1989) have developed a hands-on "Meiosis/ Mitosis Game" that not only illustrates the physical processes of each, but also connects Mendel's laws. Wimpenny and Cooper (1979) have produced a game to use as an aid in teaching microbial systematics. They have found such activities valuable tools in helping students learn where vast amounts of factual data precede effective functioning in the study of a subject. The microscopic nature of fungi and their complex life cycles created considerable teaching challenges for Blum (1976). One of these problems was the misconception of a life cycle as a linear process rather than cyclic. Blum's solution appeared in the form of a circular fungus game.

In general, most gaming advocates in science education use fairly simplistic evaluation formats. For example, Hounshell & Trollinger (1977) found that games were frequently evaluated by two criteria: What are the learning objectives? Does the game reach those objectives? Similarly, two questions were used by Wimpenny and Cooper (1979) to evaluate their game: How important is it to learn the intrinsic knowledge of the activity? and Does the game succeed? Blum (1976) found evaluations to be simple, observable mistakes made during the game which were readily identified by the players and instructor. Evaluation considerations are fairly universal in regard to science education games.

Models

"Since much of science concept learning depends on the visualization of objects and models, active encouragement of image formation and representation should be an integral part of science education" (Vasu & Howe, 1989, p. 406).

The biological advances of the 1950's and 1960's were largely related to the successful explanation of the three-dimensional structure of a number of biologically important macromolecules, and the realization that the function of such molecules were inferred from a knowledge of their structure. The teaching of molecular biology is now commonplace in secondary schools as well as in the universities. This situation has presented teachers with instructional problems related to the complexity of the structure of macromolecules and the cost of commercial models (Ashworth & Fieldhouse, 1971). Similar instructional obstacles occur in other areas of life science.

> Among the most difficult concepts for beginning biology students is the relationship between longitudinal, serial or cross-sections and the entire organism or structure from which the sections were made. Although most textbooks offer diagrams, students may not fully grasp spatial orientation without referring to three-dimensional models. (Foote, 1981, p. 31)

Structures and processes involved with metabolism, cytology, genetics, reproduction, embryology, and microbial forms (viruses, bacteria, fungi, protists, etc.) all have similar instructional barriers. Models are three-dimensional analogies that can perform considerable educational functions in the life sciences providing both teachers and students relief from instructional frustration.

Wittich and Schuller (1973) advocate the use of three-dimensional materials that can provide opportunities for useful learning experiences when direct, firsthand conditions are either impractical or impossible. They have identified seven characteristics of models that make them formidable teaching tools:

1. The three dimensional aspect is often necessary in a more complete understanding of many structures and processes.

2. Models reduce or enlarge reality to an observable size.
3. Models can provide internal views of related structures
4. Models can be simplified compared to the complex objects they represent.
5. Models can accent important features with color and texture.
6. Models can be made inexpensively in or out of class.
7. Many models can be assembled and reassembled to show size, shape, and interrelationships.

Models can provide learning experiences real things cannot:

> Models have the advantage of size, smaller or larger than reality. Important details can be emphasized by color. Many models can be disassembled for views not normally available. Their three-dimensional nature makes them a more concrete referent than a photograph, or motion picture.(Heinrich et al., 1985, p. 99)

A study by Lord (1985) found that improvement in visuo-spatial cognition did occur for his experimental group which supports researchers who claim visuo-spatial aptitude can be enhanced through carefully planned interactions. Mathis (1979) makes minimal yet vital instructional claims for models:

> As teaching devices models have at least two advantages. First, they force the learner to actively participate in the learning process. Second, they offer concrete objects to assist the thinking of students who have not reached that stage of intellectual development allowing them to grasp abstractions.(p. 561).

Science instructors have performed considerable research related to the benefits and applications of models in the classroom. The results of a survey by Gilbert (1991) indicated that a broad understanding of science models is lacking among students. He asserted that "Science is a multifaceted activity which may be operationally defined in a number of ways. An understanding of the nature of models and model building is an integral component of science literacy" (p. 78). Similar research by Grosslight, Unger, Jay, and Smith (1991) found that students at both secondary levels have "naive realist conceptions" of models. Hence, students were more likely to think of models as physical copies of reality that embody different theoretical perspectives. Their findings also suggest that students need more experience using models as intellectual tools, more experience with models that provide contrasting conceptual views of phenomena, and more discussions of the roles of models in the service of scientific inquiry. Making models both quantitative and real, and focusing on the generality of a particular model in class briefly describes the position of Schamp (1990). He takes a step further by advocating student understanding by emphasizing the model's limitations. Science instructors should not mislead students with the false perception of a models realness, but require them to scrutinize the model's weaknesses in terms of what it does not answer. Schamp's admirable goal then, is to encourage students to make their own models based on the experimental evidence.

The better a model accords with structural or operational principles of what it is intended to simulate, the better it will serve as a teaching aid. The mode of analogy is a very important tool for cultivating the transition from concrete to formal operations as defined by Piaget. "The development of the ability to create, use and evaluate models to explain natural phenomena should be a major concern of the... school science program" (Royer & Haaseth, 1986, p. 483). Results of Gable and Sherwood's investigation (1980) indicated that science students who manipulated models were more successful than students who watched the instructor manipulate the models. Both concrete and formal operational students profited from model activities. Teaching strategies involving manipulative models of chemical entities along with combined, structured, peer interaction, were found to enhance concept learning for both formal and nonformal operational students in a study by Howe and Durr (1982). Rather than limit the scope and depth of the curriculum for concrete students, they suggested the creation of instructional techniques that would make high level concepts more readily attainable for the many students whose cognitive development has not yet reached the level of formal operations.

Kinder (1965) suggests several principles to be applied when using models in class:

1. Use them in an interesting manner
2. All students must be able to see/touch it
3. Models should be used in conjunction with other learning materials
4. Students should be encouraged to observe, analyze, generalize and question
5. Avoid the presence of other distracting materials
6. Use as exhibits and displays
7. Encourage students to produce their own models to illustrate objects, concepts, or principles

Science educators at many levels have created, applied, and recommended an impressive variety of model forms in the literature. Using commercially available beads Heath (1975) was able to illustrate biochemical and chromosomal processes easily and cheaply. Simplification in structure allowed the underlying shape and function of the molecule to be more clearly appreciated. His model was created to demonstrate the characteristics and behavior of chromosomes during meiosis, but has more recently been developed to model nucleic acids. Being designed for student as well as teacher use and for static display purposes, the model has proven to be a flexible instructional aid. In addition, Heath found that models showing dynamic processes hold the attention of the student better than other conventional representations. Even human hands have been adapted to modeling mitosis in science classrooms. "The handy model is what is what is known as a heuristic model: a teaching tool that sacrifices absolute technical correctness in favor of a concrete model that can be used to facilitate learning" (Ward, 1988, p. 171). Park's (1969) three-dimensional biology models are time consuming but relatively inexpensive. Cutting them from dense styrofoam, using water putty for smoothing, and then hand painting them has saved him hundreds of dollars. But he admits students could have made them just the same with increased educational benefits. O'Kennedy's (1991) antibody model system arose from a need to demonstrate the structure, fragments, chain arrangements, and the labeling of antibodies. The analog he describes is claimed to be very useful for demonstrating aspects of antibody structure and function, can be readily modified and dismantled, and is very cheap to construct. It has been successfully used to give inexperienced students from high school to the university level a clear insight into the nature and applications of antibodies. In a comparison study of the use of protein models Mensch and Rubba (1989) found that while the students using three-dimensional representations only matched the content achievement of the control group, their attitudes were significantly better. Sigismondi (1989) has found that students have trouble visualizing the structure and replication of DNA. She has found that even her economical, paper, hands-on application greatly facilitates learning and leads to better attainment of objectives. Spencer (1985) has created a very economical but relatively accurate heuristic model of supercoiled DNA using small styrofoam spheres, two twisted wires, and a few u-shaped nails. A parenchyma cell model formed by Lehman (1969) illustrates its third dimensional shape, demonstrates the relative size and position of the main parts, and serves as a model for other cells. Shmaefsky (1991) promotes the use of accurate, analogous student-teacher models to clarify the nature of biochemical activities in college courses. It is difficult to clearly relate complex chemical activities to both nonscience and science majors. Oversimplified and unintentionally inaccurate descriptions of chemical activities exist even at the college level. Shmaefsky claims student involvement creates extra interest while clarifying concepts involving complex chemical structures. Most importantly, the presentation accurately portrays the theoretical molecular activity.

In addition to crafts and science, models may integrate learning in other subject areas. A paper model which compares cell size to surface area integrates math skills and interdisciplinary thinking in a small group setting with a student-active format was produced by Deaver's (1978). Similarly, Dudley (1971) from the Centre for Science Education in London has produced models of land mammals to draw together mathematics and biology. His group has noted success with the model described in addition to a number of other potential examples.

In addition to the lack of tactile qualities, computers and their programmed, biological analogies are generally unavailable and unaffordable to many science students. Moreover, " the repetitious use of single stimuli may quickly produce disinterest and boredom. Teachers have learned by experience that variation in classroom procedures and in the selection and use of teaching materials ordinarily heightens the interest and enthusiasm with which pupils approach their work" (Wittich & Schuller, 1973, p. 32). Secondary science students with prolonged exposure to computer programming may eventually find instructional tasks tedious and boring not unlike the television science curricula of the 1960's. As long as this condition exists inexpensive, teacher or student-made models will perform key roles in supplementing science education.

<u>Design Considerations and Use</u>

The design and use of supplemental visual and tactile instructional media as it pertains to this review can be found in media production and science education literature. "The use of instructional media rests on the assumptions that people learn primarily from what they perceive and that carefully designed visual experiences can be common experiences and thus influence behavior in a positive way" (Kemp & Smellie, 1989, p. 14). When developing new instructional aids, Kemp and Smellie suggest four basic considerations be made:

1. For whom is the program being developed? (nature of the learners)
2. What do you want the individual to learn or be able to do? (objectives)
3. How is the subject or skill best learned? (teaching/learning methods and activities with resources)
4. How do you determine the extent to which the learning has been achieved? (evaluation) (p. 4)

For instructors designing their own new classroom teaching aids Heinrich et al. (1985) suggest seven related considerations:

1. What are the objectives?
2. Who is the audience?
3. Will your budget meet the cost?
4. Do you have the technical expertise to design and produce the materials?
5. Is the necessary equipment available to aid in production?
6. Are special facilities required and available?
7. Do you have adequate time for completion?

Witt (cited in Kemp & Smellie, 1989) , a media psychologist, suggests some practical guidelines for designing media to present factual information:

1. Design the production for your audience
2. Inform the audience of the goals or objectives of what is coming
3. Associate new facts and ideas with what they already know
4. Rely on visuals and mental imagery to help viewers remember
5. Don't overload your production with information
6. Allow time to sink in
7. Use repetition to hammer in critical facts
8. Present a closing review in an organized, pyramidal structure (p.21)

When considering the design and use of instructional media the following psychological conditions should also be considered and integrated:

1. Motivation- a need or desire to learn
2. Individual differences- abilities, present levels, learning styles
3. Learning objectives- directions, expectations
4. Organization of content- arrangement in meaningful sequence
5. Prelearning preparation- sufficient experience for success
6. Emotions- feelings generated
7. Participation- internalization of information by senses and actions
8. Feedback- knowledge of successfulness, evaluation
9. Reinforcement- success breads encouragement to continue
10. Practice and repetition- retention development by related experiences
11. Application- transferal of learning to new situations (Kemp & Smellie, 1989)

For a visualized presentation to achieve maximum instructional effectiveness, the instructor/presenter must initially attract and focus the student's attention on relevant cues and then sustain the attention over extended periods of time (Dwyer, 1978).

("Cuing is defined as the process of focusing student attention on individual

stimuli within a visual illustration to make them distinct from other stimuli" p.175.) Verbal and motor stimuli added by the instructor may facilitate the effectiveness of the visualized instruction. In using manipulative boards Brown et al. (1983) advise instructors to: a. reinforce with verbal responses, use them to promote interaction among students in drill work or games, b. keep the visuals legible, appropriately large enough for the group, and c. keep it simplistic. According to Heinich et al. (1985) teachers have to make appropriate choices even between effective illustrations and student-preferred illustrations. With no unanimous agreement on what are the skills of visual literacy, decoding and encoding abilities must be included. Other considerations in forming visual materials include: arrangement, balance and color, dynamism, emphasis, fidelity, and graphic harmony. When drawings are used in science education, Holliday (1975) suggests three reminders for greater effect: a. it should emphasize important characteristics of concrete things,
b. they should contain detail directly related to the teacher's objectives (avoid clutter), and c. that students react differently to science pictures depending on I.Q. and attainment on the Piagetian scale.

Several authors have identified their specific approach to the formulation of educational games; only three will be mentioned here. The first step in designing a game is to identify a concept or objective for the game which:
a. is important to be learned but is known to be difficult, b. is appropriate for the student's age level, c. relates to your science program, d. conveys a concept that is not easily observed, experienced, or manipulated in any other way (Carter & Lee, 1979). Ellington et al. (1981) have provided a more detailed approach to the development process they use in producing new games and simulations:

Phase I - Development of the Basic Idea

a. Curriculum weaknesses identified

b. Application effectiveness of a game/simulation

c. Failure to find an existing, pertinent exercise

d. Realization that no other strategy would do better

e. A tentative solution is formed from three decisions regarding content, format (kind of activity), and structure.

Phase II - Development of a Viable Educational Package

a. Conversion from concept to reality

b. Performing Field Trials for Refinement

Phase III - Exploitation of the Exercise

a. Production of a do-it-yourself kit

b. Designer produces multiple sets of the package

c. The activity is published commercially by another

Coble and Hounshell (1982) affirm that teacher-made games are generally more specific to the learning objectives established by teachers; and they are also effective with students. They provide a series of similar steps in the formulation and production of instructional games:

1. Define the objectives and consider the students' skills and abilities.
2. Decide the group size for which it will be designed.
3. Select a suitable format.
4. Create the game rules and materials or equipment.
5. Produce a trial edition of the game.
6. Perform several trials providing modifications.
7. Produce the final edition.

Three-dimensional materials, models, may be more effective during classroom presentations when the instructor/student employs the following basics (Wittich & Schuller, 1973): a. be sure all can see, b. use with other materials as part of a team of materials (wall charts, 35mm slides, the real thing), c. practice use before class, d. provide for a correct concept of size, e. arrange for firsthand examination.

SUMMARY

If "Today's school environment should offer varied alternatives among instructional experiences" (Schuller and Wittich, 1973, p.xxi), and if "an approach to learning involving many foci will benefit the student" (Biermann, 1989, p. 236), then it would appear instructionally advantageous to create many educationally sound teaching strategies for science students.

> While the value and usefulness of logical reasoning patterns and critical thinking strategies cannot be argued, many prominent scientists and inventors- including Einstein,da Vinci, Curie, and Edison- have acknowledged that some of their greatest ideas and inventions were not the result of systematic, scientific, critical thinking but less structured creative thought processes....According to psychologist Jean Piaget , the primary goal of education is 'to create men who are capable of doing new things, not simply of repeating what other generations have done- men who are creative, inventive, and discoverers. (Cronin, 1989, p. 35)

In this respect a vast array of future possibilities exist for teachers and students in developing effective, supplemental, instructional aids for the secondary science classroom. Norris, Heikkinen, and Armstrong (1975) concluded in their study that students not only vary in speed of learning but in the styles in which they learn most efficiently. They feel that biology programs which provide a flexible system of styles and conceptual complexity are able to provide an appropriate learning environment.

Chapter 3

PROCEDURES OF THE PROJECT STUDY

The project literary search and materials production centered around three sets of terms applied to the computerized reference system called *ERIC* (Educational Resources Information Center). The first set of terms or "descriptors" which were found in the associated thesaurus limited the study to "life science" and "biology" since the author wanted the products to be beneficial and applicable to both levels of secondary schools. Second, the terms "models," "games," "simulations," "charts," "posters," "hands-on," " tactile materials," "supplemental activities," and "manipulative materials" joined another set. These descriptors were used to identify the spectrum of known visual and spatial teaching aids available including their educational significance and application. A third set of descriptors was used to provide an added focus on the related learning styles, and to determine the educational value associated with these activities. This final set of descriptors included "multisensory learning," "sensory experience," "dimensional preference," "presentation methods," "learning theory," "visual learning," "learning modalities," and "learning strategies." The *E.R.I.C.* system was searched, using these three sets of descriptors from the years 1966 to 1992. The bibliographies within articles provided by this system, became another key source of primary references. Significant numbers of highly relevant articles were located which the *ERIC* system deleted as they were articles from unincorporated journals or books. Articles were synthesized into the literary review, and many ideas were incorporated into the creation and production of specific life science teaching materials. Two other major library sources of information were the books found in the science section under "science education" and the education section under "science methods." Basic education texts, books on learning styles and teaching techniques, and audio-visual and media texts was valuable secondary sources of information.

Based on literary indications of the kinds and benefits of various visual-spatial instructional techniques, a set of products were created by the following procedures to supplement life science classes at the secondary level. Four general categories of instructional aids were chosen according to their educational value, student and curriculum needs, and the author's funds and creative ability: manipulative boards, manipulative activities, games, and models. Several examples of each of these four categories were formed and applied to biology courses grades ten and eleven for subjective evaluation. Two sets of 35 mm. slides of the instructional materials were also produced to accompany this project report in place of the actual instructional materials which would remain in the classroom. (See Chapter 4, pp. 52-54.) All manipulative charts, activities, and games are original productions to the knowledge of the author. However, National Teaching Aids, Inc. does have two similar respiration and photosynthesis charts but with a different layout. The originality of the models, on the other hand, vary considerably and will be spoken to on an individual basis. A description follows for the process of forming each example.

<u>Manipulative Boards</u>

Manipulative boards were generally formed to supplement the instruction of complex life processes. For example, two of the most consistently difficult biological reactions for students to comprehend are photosynthesis and respiration. Using student texts, <u>Biology</u> (Miller & Levine, 1991) and <u>Biology</u> (Gottfried et al., 1983), the basic processes of each were extracted and placed in a flow chart format. The purpose being to be able to visually identify the steps, relationships, and sequence of events. A large sheet of posterboard with arrows and blanks provided the background and direction of general reaction progress. Cards of identical material but different color and size were cut out and labeled according to the flow chart components. Similar colors were often used to show relationships of various chemicals. Several adhesive materials were tested for different charts: double-sided tape, felt strips, velcro and felt, and velcro. Charts could be used either vertically on a tripod stand, bulletin board, or chalk tray, or horizontally on a desk or countertop. As most units were initiated by hands-on lab inquiries accompanied by chapter reading guides as homework, the charts were often used as part of a lecture-discussion mode, drill, or review. Generally they were applied to two group sizes, either small groups of one to four or the entire class. As this was not an initial exposure to the processes, student participation in completing the puzzlelike chart was reasonable and desirable. The instructor could pass the cards out at random or selectively, and tactfully guide the class through the process, frequently using directive questioning techniques. The students provided the answers and solutions to the visual puzzle by placing the cards in the correct location on the chart.

A "flipchart" dealing with the life characteristic of irritability was also made from posterboard. Five inch by eight inch cards were cut and taped over the large, compouterized names of stimuli to which many living things respond. A drawing was placed on the front of the card as a clue to the hidden word underneath. This chart was used either as an introduction to the characteristics of life or as part of a review. The standard practice was to have volunteers come to the chart, guess one of the cards, and flip it up to verify their guess.

The construction of another set of charts was related to basic life cycles of various life forms discussed in the program. In this case the objective was to identify the stages and sequence of the organism's development, and to observe the character of its continuous, cyclic flow. A comparison of developmental styles was also provided as the students' investigation of life forms progressed through various taxonomic groups. The criteria for example selection was determined by inclusion in the text and possession of sufficient developmental stages to fill the chart. Most of the following forms were found to readily adapt to the life cycle chart: virus lytic cycle, paramecium, mold, mushroom, moss, fern, conifer, angiosperm, sponge, jellyfish, insect, sea star, frog, and human.

A heavy, white posterboard with a cardboard backing had eight rectangular blanks outlined on its perimeter. At the center a triangle labeled "LIFE CYCLE" was provided to identify the organism in question. Eight cards representing significant stages were drawn, colored, labeled, and provided with adhesive backings. This set was used in similar fashion to the chemical charts, for class discussion, individual drill, or class review. As in the biochemical charts, student involvement by providing answers and active placement of components on the diagram was the paramount concern of this technique.

A third chart related to classification was formed to help students review the five kingdoms and identify common examples of each. A large sheet of thick, white paper was labeled with the kingdom names at the tops of five columns. Duct tape was placed on the chart in vertical rows for the attachment of example cards. Four inch by six inch cards were used to write the names of common examples of organisms. One method of application, similar to the aforementioned diagrams, involved passing the cards out randomly or selectively, and then asking the students to classify the examples under the appropriate kingdom headings by individually placing them on the chart. When mistakes were made, students were given directive questioning techniques, based on the characteristics of each kingdom, to focus their attention and discover the error themselves.

Manipulative Activities

Manipulative activities were designed for small group investigations or review exercises. Frequently they were used to supplement units with little or no significant lab activity provided by the text publisher or other traditional sources. Several different prototypes were designed, produced in sets of fifteen, and subjectively tested in classroom conditions. A set of written activity directions have been provided to accompany these descriptions and slides in Appendix A . (In this project the unqualified term "model" was restricted to three-dimensional replicas which were limited to one example or set per class, and were used in large group presentations with no formal lab writeup.)

One hands-on exercise produced was an investigation on the formation of proteins from amino acids. Although the idea of using pop-it beads was not new in the study of biochemical reactions, the author was unable to find any similar activity of this kind. (See Manipulative Activity Lab Forms-"Lab on the Formation of Proteins," APPENDIX A) In this inquiry four colors of beads with four beads each were placed in a plastic pouch; each color representing a different amino acid. During the exercise pairs of students were asked to arrange the beads in different patterns to see the quantitative possibilities of forming different, short protein sequences. As the activity progressed, students were asked to derive a simple hypothetical equation, based on their lab data, for determining the number of possible variations when given the number of kinds of amino acids used and the length of the chain. Small group chains were then combined to illustrate the secondary and tertiary structure of proteins as a culminating class event led by the instructor. The intent was a visuo-spatial impression of the vast numerical possibilities for forming different proteins from relatively few subunits, and the integration of math skills into biology.

To offset the negative impact of an urban setting with no funding for field trips, several additions were applied to the zoology class for improvement. One of the easiest animals used to exemplify how body structure relates to function is the bird. Their marvelous adaptations to a particular form of flight, where they live, and what they eat are familiar to biologists. But how we teach this could be improved. The goal of this exercise, "Bird Adaptations Lab," was to have students become familiar with the adaptations of three bird parts: wings, feet, and beak. Rectangular poster board cards of three colors were cut out for each of the three kinds of body parts. Drawings of variations for each structure were reproduced, cut out, and glued onto the cards. Beaks and feet were mounted on both sides of the cards to conserve materials. The procedures were of two parts. First, students were asked to form four birds based on the functions of the three body parts given. These were checked and initialed by the instructor for accuracy. Second, the students were to make three different birds of their own, real or fictitious, without using combinations of the same cards in part one. These "creations" were also checked by the instructor. Credit was based solely on completion of the lab requirements.

Another zoology exercise, "Identifying Mammal Groups," involved a card matching exercise to help students become familiar with the names, characteristics, and examples of the major mammal orders. Pictures of representative mammals along with other printed example names were copied and glued onto cards as in the previous activity. Likewise, a second matching set of cards were produced with the mammal order name and distinguishing features printed on them. The two lab requirements were to match the two sets of cards, have them checked, and then answer fifteen questions related to the mammal orders on the cards. If the cards were out of order the couple was given a second chance to correctly rearrange their cards using their text and available charts. Credit was based on correctly matching their cards and answering their questions.

Further applications of poster board came in the form of several two-dimensional model activities. While relatively inexpensive, they were tedious to make. Colors were selected, templates were made, and the components were excised.

One of the most challenging life science topics for finding or creating hands-on student exercises is viruses. A second manipulative activity was designed around the student's ability to identify the stages and sequence of the viral lytic cycle. (See activity writeup- "The Lytic Cycle.") The activity components were again cut from colored poster board to represent major structural features associated with the process. Students were asked to complete the activity in pairs using their text, notes, assignments, and classroom charts for assistance. Three expectations were to be met by the students for each stage: a. two questions were answered , b. the stage was neatly diagramed, c. a two-dimensional model was formed. The instructor initialed the stages as the three criteria were met for each stage. Credit was based on the completion of the three established expectations.

Cell structure was another area chosen for improvement. While extra credit, homemade cookie models with accompanying diagrams proved exciting and productive, there were few commercial manipulatives to be found. Microscopic cell investigations revealed only a few of the structures mentioned in the text, and verification of student observations was extremely difficult. To review the structure and function of the cell described in their text, a two-dimensional model lab, "Model Lab: A Typical Animal Cell," was produced. A cell body and all major organelles were cut from colored poster board with additional characteristic marks and colorations where appropriate. The components were packaged. In pairs students completed the labs by sequentially forming a "typical cell" and answering twenty related questions. Credit was dependent on completion of the review exercise and on a short, oral, individual, practical quiz when they were completed.

A "Protozoan Model Lab" was designed to fill the gaps present after microscopic observations and comparisons of protozoa, and as a review of the three typical forms discussed in the text. Continually, the majority of students were unable to see all the structures the text addresses for each standard example: amoeba, paramecium, and euglena. Many times either inadequate funding for such specimens or their condition after shipping were not conducive to successful labs. To assist in alleviating this situation a supplemental activity was produced to help students become familiar with three typical protozoan cells, their cell structures and functions. The three cell forms of each protozoa were cut out along with the organelles discussed in the text. Common cell parts could be interchanged among the protozoa as students passed from forming one protist to the next. Again credit was based on completion of the three protists, their related questions, and a short, oral, individual, practical quiz on the three cell replicas.

The literary review revealed only two mitosis/meiosis related teaching aids, Mathis (1979) and Taylor (1988). Mathis' device, although similar in purpose and content to the author's, used different materials and format. The purpose of this activity, "Mitosis/Meiosis Model Lab," was to be able to visually identify the major mitotic and meiotic cell structures, stages and their sequences. Patterns of the necessary components were used to form a class set of kits from poster board. Coloring was added for detail, and the sets were packaged. A fill-in format directed students through both processes as they formed and remodeled each sequential stage and identified the key terms for the blanks. As before, credit was established by activity completion and a short, oral, individual, practical quiz.

Analyzing and comparing photomicrographs of human karyotypes was the only economical lab activity of consequence related to the chromosomal aspects of human heredity. To help fill this instructional gap in the advanced classes an exercise titled the "Human Chromosome Activity" was designed. Its purpose was to increase student comprehension of the number and kinds of human chromosomes, to demonstrate how haploid conditions are created and the diploid recreated, to illustrate the great variety of sex cells possible, to show the great variety of possible offspring formed from two individuals, and to see how sex is determined. Four sets of different colored chromosomes, 23 each, were cut from construction paper and sequentially numbered. A two-tone blue set represented the male, and a two-tone red set indicated the female. A fill-in answer format accompanied the required manipulative tasks in three sections: parent chromosome analysis, gametogenesis, and fertilization. The Instructor's initials were required at three places on the lab where the visual components and answers were checked for credit.

While flower dissection has been effective in the past for practical identification of flower parts, it has failed to demonstrate the general processes of pollination and fertilization typically covered in a unit on angiosperm reproduction. To form an exercise that would review all these floral structures and processes in a manipulative format the "Flower Model Lab" was written. Poster board cutouts symbolizing flower parts were given additional detail with marker pens, and placed into packaged sets. Credit was again based on correctly completing the two-dimensional model, the questions, and demonstrating a basic comprehension of the structures, their functions, and the processes of pollination and fertilization.

<u>Games</u>

Several forms of biology games were produced to determine whether their presence affected the attitudes as well as the cognitive levels that were indicated by the literary review. Even when adapted to commercial game formats like bingo, jeopardy, match game and linear path board games, they proved to be considerable challenges. The closest product to a simulation and its inherent educational benefits were the board games. Procedures for game production follow.

The bingo format was used most frequently to produce games for the review of vocabulary and names of example organisms, hierarchy, or people. An effort was made to name each game after the associated unit: PLANTO, BOTGO, BUGGO, BIOGO, ECOGO, LIFEO, CELGO, BACTO, PROGO, CHEMO. An attempt was also made at grouping related terms under each letter when possible. Game cards were either six squares by six squares or five squares by five squares on a computerized format. Small clue cards for each term were written using matching definitions or descriptions. To ensure individual performance five or six different forms of each of the twelve games were produced and duplicated to form class sets of forty cards. The cards were spread out around the class individually or in pairs with scrap paper used for markers. The instructor, lab assistant, or student randomly picked clue cards from a pile, read the letter and clue only once, and then laid it down on a tabletop in rows. False calls or incorrect calls were eliminated from that particular round of the game. The first call with five or six correct answers in a row received a small amount of extra credit, candy, or small prize.

Another game format, jeopardy, required the fabrication of a game board with five categories and three difficulty levels below each category. Review again was chosen as the classroom application. Four or five major topics for a unit were written on cards as the question categories. Varying difficulty levels of sample test questions were printed on cards and placed under the categories in pouches. Individuals, small groups, or the entire class were able to use this game. Intraclass team competition provided adequate motivation. As long as question categories were not used up, students could freely choose both the category and difficulty level.

The match game format proved to be a versatile mode of review. A sheet of

3/4 inch plywood,36 inches square, was painted and measured for twenty-five relatively square cards. Heavy casing nails were cut to one inch lengths, located on the board as card hangers, and hammered into the plywood with half an inch exposed. Cover cards were cut from poster board, hole-punched at the top, and numbered one through twenty-five. Matching cards were cut slightly smaller from any heavy, light-colored paper, punched, and finally inscribed with a term, description, or drawing. Many significant aspects of each unit could be adapted to matching: terms and definitions, structures and functions, structures and names, classification groups and examples, examples and names, developmental stages and names.

A board game with a progressive path layout was used to introduce students to simplified simulations of what it might be like to be other organisms, facing many of the same life conditions or situations. A fish, paramecium, and flowering plant were selected to provide diverse examples of life forms. Each organism's life style was analyzed for various factors or circumstances that could possibly affect it. Such factors were placed on various points of their path of life, and determined to have positive or negative impacts on their life cycle (to survive, grow, differentiate, develop, reproduce, etc.) A computerized path, covering two standard pieces of typing paper, was formed which could be reapplied to similar games. Directions and comments were typed on the path with sketches added for visual reinforcement. Both sheets were copied and taped together to form the "board." Using a standard die and numbered plastic game pieces, students could play in groups from two to four players.

Models

Single, three-dimensional replicas of living things or their parts were created by a variety of techniques to fill a void of unavailable instructional materials. Models were produced for the need of visuo-spatial examples that were too expensive, too large or small, inconvenient or difficult to maintain alive, dangerous, and many of the other reasons mentioned in the literary review. After fabrication these replicas were stored in display cabinets in the room until needed. A discussion of the formation and use of the individual models follows.

The idea for one of the models was inspired by an annelid film from the district film library. The idea of annelid segmentation was difficult for many students to visualize even during dissection labs. The intent was to form a model that illustrated the structural repetition and compartmentalization of annelid bodies. A block of four inch by four inch wood was rounded into a semicylindrical form and sectioned into two inch lengths. The sharp edges between the segments were rounded, and the pieces were painted a rose color. A cross section drawing was reduced and duplicated to form several identical views that were colored and glued to the larger, flat surfaces. This model was used in the study of worms as part of a specimen survey activity where students could freely manipulate the components to see the desired relationships.

Styrofoam proved to be another feasible medium for creating many models. One set of figures used to illustrate symmetry were carved from styrofoam chunks with razor knives and sanded. Colored lines were drawn to show planes passing through the central axis, if present, of each specimen. Used in class discussion to distinguish the types of symmetry, students were able to handle, question, and evaluate the application of these visuo-spatial replicas, and challenged to make their own.

Another styrofoam application was the construction of a fish model taken from a zoology diagram showing the standard planes that divide an animal's body. In a similar manner this model would spatially demonstrate the relationship of the planes and label standard body terminology as well. Thin plexiglass was cut into two rectangular sheets, six inches by twenty inches, and a third sheet, six inches square. Deeply notched down the centers the two rectangular forms were joined and glued at perpendicular angles with the square piece glued at right angles (transverse) to them in the center. A fishlike form was carved and split according to its three perpendicular planes, and mounted on the plexiglass framework. Labels were added to the plexiglass to identify the planes and views observed.

A third model composed of styrofoam was in the form of a series of eight, four inch spheres representing the embryological stages through the gastrula. Their purpose was to provide a three-dimensional, inexpensive view of each stage showing increase in cell number with associated decrease in size, and the formation of the three germ layers during gastrulation. This set was copied after a commercial form available in most biology supply catalogs. With the commercial set costing no less than ten times the price of the component materials; it was easy for the author to decide to make his own. The eight spheres were carved by hand with razor knives, lightly sanded, painted, and mounted in sequence on two finished boards. This model series was used as an instructional aid in a brief cell reproduction/embryology unit.

A set of cardboard protozoan models was produced to provide visible, tactile, semispatial forms of the three examples most frequently studied, ameba, euglena, and paramecium. The intent was to provide something more realistic than the pictures in their text or a diagram on the wall that all could visualize and feel. Layers of cardboard were shaped and glued to produce an appearance of depth in the cells. After painting and drying the main cell form, organelles were attached with glue and painted.

Although not a true model by some standards, another teaching aid produced that fit in the three-dimensional realm was a chicken skeleton. The author, after noting the exorbitant price in a science catalog, decided the need was great enough to attempt making his own. In a large group observation lab, the displayed form allowed students to make inferences about the structure of birds and their adaptations to flight and life style. Such observations would not be practical from two-dimensional diagrams. Received in a plucked condition with head intact from a local farm, the chicken was skinned and boiled until the meat was easily removed from the skeleton. After a light bleaching the bones were dried, glued, and reassembled onto a coat hanger for support. In addition a hollowed egg was placed on the wooden base. (A lab format for this model has been provided in Appendix A under "Chicken Skeleton Observation.")

Plaster of Paris provided the medium for making a model of mitosis. Mixed and poured into culture plates, dried, and glued to a wooden box, this type of model was inexpensive and simple to make. Cell structures were made from household scraps of wire, beads, BB's, threads, and decorative cords. The box was constructed from 1/4 inch plywood for the top and bottom,and one inch by two inch strips for the sides. Two hinges and a latch were the only hardware purchased. Leftover polyurethane was used to seal the box. This model was used in small groups during a cell reproduction unit to review the sequential stages of meiosis, its purpose, and the cell structures involved. As students were asked to discuss the separate stages they were allowed to freely touch the models.

Another class activity which the author found difficult to categorize was a visual-manipulative demonstration created for a genetics unit. The purpose of this exercise was a simple illustration of Mendel's Laws, how simple hereditary units could be passed from parents to offspring. The following crosses were a few of the possible uses: homozygous or pure crosses, heterozygous or monohybrid crosses, test crosses or back crosses, dihybrid crosses, incomplete dominance crosses. Colored beads were used to represent hereditary traits which were placed inside large culture plates, the parent, or small plates, the gamete. This kit was found useful either as an inquiry introduction led by the instructor or as a review with students choosing the traits of the parents, determining the possible gametes, and the offspring.

Chapter 4

THE PROJECT

This project has produced a set of manipulative boards, manipulative activities, games, and models to be used as supplemental instructional aids in secondary life science classes. Two sets of colored slides showing the various examples produced in each of these four instructional material categories accompany this report. A list of these slides are provided on the following page. Appendix A, with separate pagination, contains the written instructions for the manipulative activities.

LIST OF 35MM SLIDES

Manipulative Boards

Photosynthesis and Respiration

1. General Reactions

Photosynthesis Chart

2. Basic Process

Respiration Chart

3. Basic Process

Irritability- Characteristic of Life

4. Stimuli Flip Chart

Life Cycle Charts

5. Life Cycle Board
6. Virus
7. Fungi- Mold
8. Fungi- Mushroom
9. Plant- Moss
10. Plant- Fern
11. Plant- Conifer
12. Plant- Flowering
13. Protist- Paramecium
14. Animal- Sponge
15. Animal- Jellyfish
16. Animal- Insect
17. Animal- Sea Star
18. Animal- Frog
19. Animal- Human

Classification Chart

20. Kingdoms and Examples

Manipulative Activities

21. The Formation of Proteins
22. Bird Adaptations Lab
23. Identifying Mammal Groups
24. The Lytic Cycle
25. Model Lab: A Typical Animal Cell- Kits
26. Model Lab: A Typical Animal Cell- Example
27. Protozoan Model Lab
28. Mitosis/Meiosis Model Lab- Kits
29. Mitosis/Meiosis Model Lab- Example
30. Human Chromosome Activity
31. Flower Model Lab

Games

Bingo Format

32. Six Examples
33. Six Examples

Jeopardy Format

34. Cell Chemistry Game

Match Game Format

35. Moss Structure Identification
36. Echinoderm Structures and Examples
37. Classification- Identification of Terms
38. Microscope Parts Identification
39. Fish Structure Identification
40. Body Terminology
41. Lab Equipment Identification
42. Insect Structures
43. Two Game Boards for Match Games

Board Games

44. Fish Survival
45. Paramecium
46. Plant Life Cycle

Models

47. Annelid Worm Segments
48. Symmetry Set
49. Body Terminology- Fish
50. Embryology Set
51. Protozoa Set
52. Mitosis Set
53. Genetics Demonstration Kit

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This project emerged from the need for many secondary students at the lower cognitive levels or with variable learning styles to be involved in successful experiences in their life science classes. To improve the attitudes and reach a wide range of student abilities, learning styles, backgrounds, and aptitudes, the author searched for solutions provided by professional educators and research psychologists. The educational materials suggested by media experts agreed with the psychological principles presented by the learning theorists. The literary review revealed several instructional aids that might help solve the dilemma. Four of these techniques were selected on the basis of student need, funding, time, and the author's creative ability: manipulative charts, manipulative activities, games, models. Several variations of each instructional device were produced and applied as supplemental activities to the present biology program, grades ten and eleven. Colored slides of these project materials were taken in duplicate to accompany this project report as illustrations of the products.

Conclusion

In the limited classroom application of the four categories of instructional aids produced, several features became apparent. While their common visual and tactile characteristic benefits were readily exposed, finer differential qualities were also noticed. The performance and suggested modifications of the mechanical features of each category have been mentioned.

Manipulative charts were effective in providing visual and oral feedback to the instructor, and other valuable services. General class and partial individual progression in the comprehension of the topic in question could be roughly evaluated. Manipulative boards, as opposed to transparency lectures or discussions of posted graphic charts, allowed increased personal involvement and kept the class more alert. Students became the center of attention not the instructor. This teaching strategy enabled students to learn from each other as they approached the solution of a large puzzle together. Students could readily notice mistakes by others, could voice their opinions, question each other, and attempt to reason with or sway decisions. This process frequently straddled the features associated with cooperative learning. The application of analogies in discussing hydrogen transport chemicals and the cytochrome systems was of particular assistance. For instance, when likened to a specialized taxi service, students picked up on the function of NADP, FAD, NAD, and RDP much more quickly.

In terms of the mechanics themselves, a few problems were noted. First, the respiration chart was not large enough. Students often had to move forward to see the words. Poster board charts were laminated with cardboard to add strength, or with plastic laminate for durability. The velcro adhesives were so strong they ripped off the posterboard, the felt backings were too weak, but velcro hooks opposite felt worked best. Tape was cheap and functional but did not have the advantage of permanency. Placement of the board on a tripod stand proved to be most flexible in providing convenient locations for use.

The production of manipulative activities produced the greatest creative task. Content areas that were weak in visual and manipulative activities needed to be identified, an innovative lab format created and typed, and the production of many sets of appropriate components were required. The experience of having written several variations of lab activities previously and the time spent within the program to analyze weaknesses were the greatest advantages to the author in meeting such project challenges. The visual, tactile presence of the lab components relieved a great deal of ambiguity and frustration formerly noticed by "slower" students under previous conditions. At the very least the activities lightened the atmosphere, provided an involved learning experience, and clarified biological terms, relationships, and concepts for an increased number of students.

Mechanically, these tactile exercises worked surprisingly smoothly when directions were written clearly, and students read them correctly. Difficulties were identified by some students in identifying certain organelle pieces in the " Model Lab: A Typical Animal Cell" due to varying artistic expressions of the organelles or their natural structural similarity. The cilia and trichocysts which covered only a short segment of the paramecium cell model proved to be the most provocative pieces for identification. Both proved to be excellent examples of some of the inherent limits of such models.

Games in general were both exciting and educational when used in a conducive atmosphere and not overused. Students were amazed at the many "fun" ways to learn biology. Each time a new form arrived the students were extremely curious. Games were more frequently available to classes that demonstrated greater self control and could play by a set of rules. Infrequently there were classes whose game activities were limited. Although students preferred games over most other teaching techniques, the difference in the interest and competition was surprising when no reward or prize was offered. By their nature most games were reserved for reviews at the end of a unit, but even then, only occasionally. The jeopardy game proved more exciting when the class was divided for competition than among individuals, and it could only be applied to large instructional units with many possible questions. Bingo was a favorite format that could be applied to most topics. Classes often requested several replays. With the exception of trying to write down numbers and share answers, the match game played well and was also favored. The applications of this game to reviewing many cognitive goals was amazing. The games requiring the most time to make and possibly the most unique were the board games on life styles. Students were mainly surprised by how difficult it was for other living things to stay alive through an entire life cycle. Rarely was a student able to make it through the life cycle without starting over. After watching many cartoons and reading many storybooks, the idea that other forms of life do not have it as "easy' as most humans, is a often a new concept to students. Motivation to play such games without providing extra credit or other rewards in an age of materialism continues to be a problem. It is usually not enough to have the pride of winning or succeeding alone.

A few mechanical changes were made in most of the games shortly after their introductory appearances in class. The board games, for example, had the starting roll of the die quickly changed to either a one or a six to more quickly initiate play. Three difficulty levels in the jeopardy game were excessive for most uses; two were sufficient. It was soon found that the match game board required a second backup board to allow everyone on the class role a chance to play without spending the time to reshuffle or change clue cards during class.

The models produced were very inexpensive and not as time consuming as first imagined. They were, in fact, fun to make, and if "success breeds success," there should be more in the future. They performed their limited functions favorably, and in many cases motivated students to make their own. Some of the most commendable sessions in the science classroom were constructive discussions on how the models could be improved to better show the nature or characteristics of the real thing. All the models have become functional parts of the biology program. A display cabinet is a definite necessity for models.

In the opinion of the author the least effective models were the three-layered, cardboard protozoa. Styrofoam was much more effective in providing the third dimension desired. Wooden models took longer to make but had the advantage of durability over styrofoam and cardboard. When left to the beetles, skulls and skeletons cleaned and mounted at school also show future promise and application.

Recommendations

Making recommendations on improving visuo-spatial aspects of learning in the science class is tenuous with the many gaps remaining in research, and disagreements on experimental interpretations of how we learn. Without adequate research data and general agreement of interpretation our direction in education becomes a deceiving blur. To improve the clarity, increased research is the author's primary recommendation. Specifically, there is a need for additional quantitative comparison studies of the cognitive improvements produced by various instructional methods, and greater accuracy in determining effective modes of learning in the sciences. That is, the effectiveness of each of the four instructional aids of this project, and the effectiveness of the many other techniques employed in science classrooms need to be studied for their relative effectiveness at many educational levels. The qualitative impressions derived from this project study are hardly pillars of theoretical support, but they are a start. Only continued research will reveal a more focused direction for the future of science education.

This project has shown that a little time, money, creativity, and concern for improvement can make a significant change in a science classroom. Although adequate funding plays a significant roll in providing quality science education, this project demonstrates that many improvements are possible even during hard times.

By providing a more diverse set of quality science activities, educators may be able to reach more students who have traditionally been continually lost in the formal operational atmosphere of many science classrooms. As a result of more controlled studies and improved media forms, instructors and researchers working together may in the future find more effective means of bringing science students to higher cognitive levels.

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Appendix A

MANIPULATIVE ACTIVITY LAB FORMS

Table of Contents

Prologue

The following sets of directions have been provided as an integral part of the manipulative activities. Hopefully, they will both clarify the use of the instructional materials discussed in the project report and illustrated in the 35mm slides, and provide supplemental instructional aids or inspiration to those in need.

THE FORMATION OF PROTEINS

<u>PURPOSE:</u> To demonstrate the substructure of proteins and how great varieties of proteins are possible with relatively few subunits.

<u>MATERIALS:</u> sixteen pop-it beads (four beads of four colors) per group (two to four students)

<u>PROCEDURE:</u> *<u>Record the number and colors of beads in your packet.</u>*

A. <u>Primary Structure</u>

Each color of bead represents a different protein subunit called an amino acid. 1. How many different amino acids are represented by your beads? 2. How many different kinds of amino acids are there in living things? 3. What kind of bonds do the snaps represent?

Pick out two colors of beads and choose two beads of each color. If a short chain is made with only two of these four beads, colors A and B, 4. how many different chain sequences are possible? 5. Record these sequences in circles on your own paper.

(A)(A) (A)(B) OO OO

6. With only two colors of beads (two different amino acids) used again, A and B, how many variations are possible if the chain can be Three beads long?

7. Record the possible sequences.

(A)(A)(B) (B)(A)(B) OOO OOOcontinue if necessary

8. With only two kinds of amino acids used again, A and B, how many variations are possible if the chain can be four amino acids long? 9. Record the possible sequences.(B)(B)(B)(B) (A)(A)(B)(A) (A)(B)(B)(A) OOOOcontinue if necessary

10. If the number of different amino acids (colors) involved is three, and the length of the chain is three subunits, how many different combinations are possible? <u>Before</u> working out all the possibilities on paper, look carefully at the last three sets of numbers and guess the answer first! (HINT: 20-30)

11. Prove yourself right or wrong by listing all the different possibilities.

(A)(A)(A) (C)(A)(B) (B)(B)(B) (A)(C)(C) OOO OOO OOO

OOO OOO OOO OOO OOO OOO OOO

OOO OOO OOO OOO OOO OOO OOO

OOO OOO OOO continue if necessary

12. Write a hypothetical formula for determining the number of possible variations (V), if you are know the number of different kinds of amino acids used (N), and the length of the molecular chain (L). Try some of these:

$V = N \div L$ $\quad V = L \times N$ $\quad V = (N + L)^2$ $\quad V = N^L$ $\quad V = L \div N$ $\quad V = N + L$

13. After choosing your formula, show that it does work for each of the above situations.

14. Predict the variations possible using your equation with four different amino acids (A, B, C, and D) in a segment of a protein molecule only two amino acids molecules long. 15. Verify your hypothesis by showing these sequences.

(A)(D) (C)(B) (D)(C) (B)(A) OO OO continue if necessary

If your hypothesis (formula) was correct, continue. If your hypothesis was incorrect, change it to fit the evidence you have acquired.

16. Calculate the possibilities of four different amino acids in a chain four molecules long. (Hint: N = 4 X 4 X 4 X 4 =)

Make any arrangement you desire with your group's beads. Combine your groups chain with the rest of the class's chains to form a polypeptide. 17. How many kinds (colors) of amino acids compose this protein chain? 18. How many total amino acid units? 19. If most protein molecules range from 100 to 300 amino acids each, is the class chain a relatively large or small protein? 20. If the average protein molecule is 200 amino acids, what is the possible number of different proteins using all the known kinds of amino acids? (Hint: plug the two numbers into the formula as your answer if your calculator can not handle it.) You have just calculated the possible variations with only 200 amino acids in length. Since proteins differ not only in the sequences within a particular chain length, but also in the length of the chain, 150, 160, 170, 182, 197, 204, 238, 279, etc., there must be many other possible arrangements to form all the kinds of cells, cell products, and species possible in nature.

B. Other Basic Structural Characteristics

Proteins show greater complexity than their amino acid sequence and length. Place the class molecule on a table top and fold it into serpentine loops. Use paper clips to represent bonds to hold the loops together. This is called its secondary structure. 21. Diagram this form

To see the tertiary structure fold the looped chain into a three-dimensional glob. 22. Diagram this form.

If several such protein subunits (polypeptide chains) were bonded to form a larger protein, as in myoglobin and hemoglobin, a quaternary structure would be formed.

Please disassemble all beads to their original condition as you recorded in the first step of the procedure, and place your original set back in its packet.

BIRD ADAPTATIONS LAB

Introduction: Living things are structurally suited to particular life styles. One of the most common animals around us which clearly illustrates the concept of adaptation is the bird. Their great variety is a result of many timely, minute changes called adaptations. As habitats, food supplies, and competition have naturally been altered, so have the necessary survival features of birds. Their ability to successfully adapt is displayed by their large numbers, many species, and wide range of habitats.

Types of Beaks	Types of Feet	Types of Wing
Straining food from water	Walking and Scratching	Soaring and carrying prey
Tearing meat	Walking on snow	Quick ground takeoffs for a big bird
Spearing water animals	Running	Gliding and skimming over water
Probing deep into wet sand or mud	Clinging to sides of trees	All-purpose flight
Eating seeds and fruit	Perching on branches	Quick aerobatic maneuvering
Scooping fish from water	Swimming in water	
Catching insects in air	Wading in water	
Sipping flower nectar	Grasping and killing prey	
Eating seeds		
Chiseling wood		
Insect probe		
Eating fruit		

Purpose: To become familiar with the modifications of three bird parts to various life styles.

Materials: One set of cards showing various bird wings, feet, and beaks.

Procedure: Do not write on this lab sheet. Place all answers on your own paper. This activity requires previous class discussion and observation on bird structures and adaptations.

Use the cards illustrating various beak, wing, and feet structures to assemble birds with the following characteristics. After making the first four birds ask your instructor to check your birds and initial your lab paper. After creating four birds of your own choice have your birds and paper checked again.

A. Predetermined characteristics

Locate three picture cards which illustrate a bird with:

1. a. Wings for gliding over water b. Beak for scooping fish c. Feet for swimming d. Name such a bird
2. a. Wings for soaring b. Beak for tearing meat c. Feet for grasping prey d. Name such a bird
3. a. Wings for aerobatic maneuvering b. Beak for sipping nectar c. Feet for perching d. Name such a bird
4. a. Wings for quick ground takeoffs b. Short beak for seeds c. Feet for walking and scratching d. Name such a bird

B. Create Your own

Make four different birds of your own choice using other combinations of cards. No two cards that appeared together in section A may be used together again. For each bird, #5 through #8, describe its habitat, food sources, and motility in relation to the structure of its wings, beak, and feet.

IDENTIFYING MAMMAL GROUPS

Introduction: Some of the most familiar and appreciated animals you know are mammals. They are often farm, zoo, and pet favorites. To show similar characteristics and relationships scientists classify them into groups called orders.

Purpose: To help you become familiar with the characteristics and example names of the major mammal orders.

Materials: fifteen pairs of mammal cards, textbook, and mammal charts

Procedure: Complete this lab in pairs. Use your textbook and room charts to help match your mammal cards and answer the following questions. Match the pictured example name cards with the mammal order name/characteristics cards on your desk. After you answer the following questions ask your instructor to check your cards and collect your answer sheet.

Questions:

1. What is the order name for humans?
2. Name three examples of the order artiodactyla.
3. Which order has members that can actually fly long distances rather than glide?
4. Which orders appear to be mainly aquatic? (Hint: flippers, fins)
5. Which order has large claws but few or no teeth?
6. Which order has the largest mammals?
7. The Etruscan shrew is often regarded as the smallest mammal. To what order does it belong?
8. Name two mammals that lay eggs. To what order do they belong?
9. Which mammal order has a pouch?
10. Which order has the most species, rapid reproduction, and gnawing teeth?

THE LYTIC CYCLE

Introduction: Viruses are tiny particles that border on the realm of living things. They constantly affect our lives with many common diseases. It is the nature of many viruses in their reproductive cycle to destroy cells and be labeled as pathogens. Viruses that attack bacteria are termed bacteriophages or phages.

As this is a review activity, It is imperative that you have read the related material in your text and discussed it in class.

Purpose: To demonstrate the stages of the lytic cycle.

Materials: one lab kit- 6 protein capsids, 6 virus nucleic acid cores, 1 bacterial cell, 1 bacterial nucleic acid, textbook, class charts.

Procedure: In this lab you will use paper models of virus structures to observe a virus life cycle. Have your instructor initial your paper for each of the five stages after you have: a. made the model, b. answered the two questions, and c. diagramed the stage.

I. Make a model showing "adsorption."

a. What is adsorption? b. What two structures need to match?

II. Make a model showing viral "penetration."

a. What "opens" the bacterial cell wall? b. What part enters the bacterium?

III. Make a model showing "eclipse."

a. Why is the term "eclipse" applied? b. What is the virus doing?

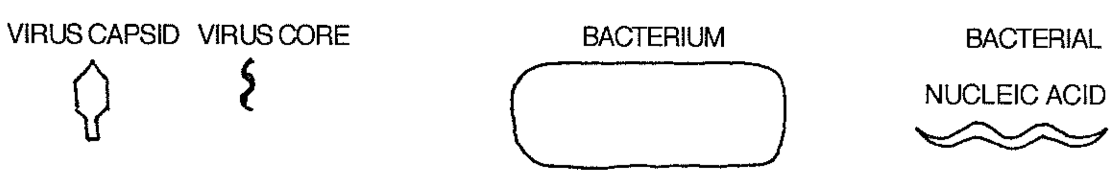
IV. Make a model of the "new phages" formed inside.

a. What parts join to make the new phages? b. How many phages are made?

V. Make a model of "lysis" of the bacterium.

a. What is "lysis?" b. What chemical destroys the bacterial cell wall?

Clean-up: Count all your model parts and return them to your instructor.



MODEL LAB: A TYPICAL ANIMAL CELL

Purpose: To help you be able to identify typical animal cell structures and their functions. To review the basic structural differences between plant and animal cells.

Materials: cell model kit, cell charts, textbook

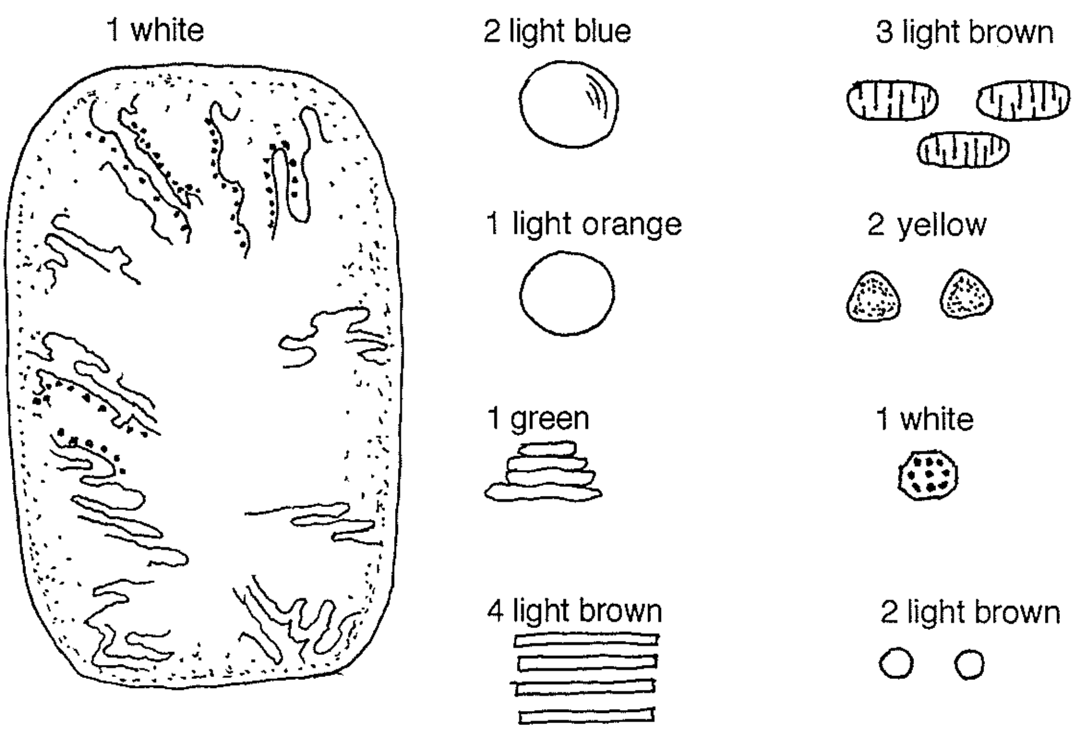
Procedure: As this is a review activity, make sure you have read the material in your text, have discussed this material in class, and completed all prerequisite assignments (diagrams, study guides,labs, etc.) before attempting it. Complete the following directions and answer the questions on your own paper. Caution: the colors used are not characteristic of most of these cell structures in nature. The only purpose of coloring is to help distinguish the cell parts

Place the large white oval in front of you.

1. What cell fluid or jelly fills this cell? 2. What does the thin flexible black line around it represent? 3. Why is this structure "permeable?" Observe the blue lines representing inner, partitioning membranes providing reactive surfaces and passageways through the cell. 4. Name these membranes. On the membranes are small red dots representing ribosomes. 5. What is their function? Locate the large, light orange circle which controls the cell's activities, and place it near the cell's center. 6. Name this significant structure. 7. What does the thin black line around it represent? 8. Why is this barrier porous? Inside this large, round,

orange structure place two, small, light brown circles. 9. What nuclear structures that may help form RNA would they represent? Add two blue spheres containing water with various dissolved chemicals. 10. Name these liquid bubbles. A green stack of parallel sacks are Golgi body icons. 11. Add this structure and give its function? Cell energy is produced by respiration inside the light brown, oval structures containing inner membranes. 12. Add three of these and name them. Add two, triangular, yellow, digestive organelles that release enzymes. 13. What are these organelles called? 14. Are they typical of plant cells? Add four, long thin microtubules together on your cell model. 15. What is their purpose in the cell? 16. According to most animal cell diagrams, next what important cell structure is the centriole frequently found? The centriole is represented by the small black and white octagon, and is actually a pack of short elastic rods similar to the microtubules. 17. During what important cell process are they activated? 18. Are centrioles typical of plant cells? 19. What thick, supportive structure of cellulose and lignin would be added if this were a plant cell? Wood, cotton, and paper are made of this. Two other typical plant structures are small, oval, green photosynthetic organelles that make sugar, and small, oval, white plastids that store sugar. 20. Name these two plant organelles.

*Have your instructor check your cell, check your understanding of this exercise, and initial your paper <u>before</u> you return the materials. Count all the model parts as listed below and place them back in their container.



PROTOZOAN MODEL LAB

Introduction: Protozoa are like microscopic, one-celled animals that are usually active in aquatic environments searching for food. Some of them also have plantlike characteristics. Through the microscope many of them are likened in form and life style to science fiction monsters at the theater. Protozoa play a significant step at the lower levels of marine and freshwater food chains helping support the many visible animals with which we are familiar.

Purpose: To become familiar with the structures of three common protozoa and compare their life styles.

Materials: Lab kit with three different cell bodies and assorted cell parts, charts, and textbook

Procedure: This is a review lab to be completed only if you have read the related material, discussed these organisms in class, observed them microscopically, and completed any other prerequisite assignments.

A. Amoeba (ameba)

Pick out the cell shape associated with the amoeba. 1. What cell structure does the outer black line represent? 2. What does the clear area between the membrane and the thicker, grainier fluid endoplasm represent? 3. What does this cytoplasmic difference in viscosity allow the amoeba to do? 4. Name the fingerlike extensions around the cell. 5. Besides movement for what other purpose does amoeba use these projections? 6. When this happens. Into what spherical structure is the nutrition placed? Add this digestive structure to the cell model. 7. Does this sphere remain in one location? 8. As there is more dissolved substances inside these cells than outside, which way does osmosis say the water will move? 9. Name the spherical structure associated with solving this problem. Add this structure for eliminating excess water. Cells have a controlling organelle to coordinate and give chemical directives.

10. Add this cell structure, N, and name it. Have your instructor check your cell, answers, and initial your paper at this point.

B. Paramecium

Pick out the cell shape associated with the paramecium. 1. The heavy, outer membrane has a special name called the p______. It gives the "slipper cell" its shape. Place a fuzzy orange section on the outer edge of the paramecium. 2. What locomotion structures does it represent? The direction of the oral groove on the side is a glue to the anterior-posterior attitude of the cell. 3. If the groove collects food as it moves forward, is the more pointed end or the rounded end the front? 4. What structures are formed at the end of the gullet? Add one of these to the gullet. They are like tiny stomachs in the cell. 5. As in the amoeba, do these nutritional spheres remain in one place? Place a second "f.v." near the cytopyge or anal pore. 6. Using scientific terminology what is the purpose of this cytopyge? Paramecium has tiny cytoplasmic spears on its inner membrane for protection. 7. Add this segment of defense structures marked "Tr" and name them. Like amoeba, paramecium also has water problems from osmosis. 8. How does it eliminate the water that continually seeps in? Add these spherical structures. Add a nucleus to the center of the cell with a red "E" beside of it. 9. What is the function of each of these two organelles? 10. What substance are the grainy dots most likely trying to represent? Have your instructor check your cell model, answers, and initial your paper at this point.

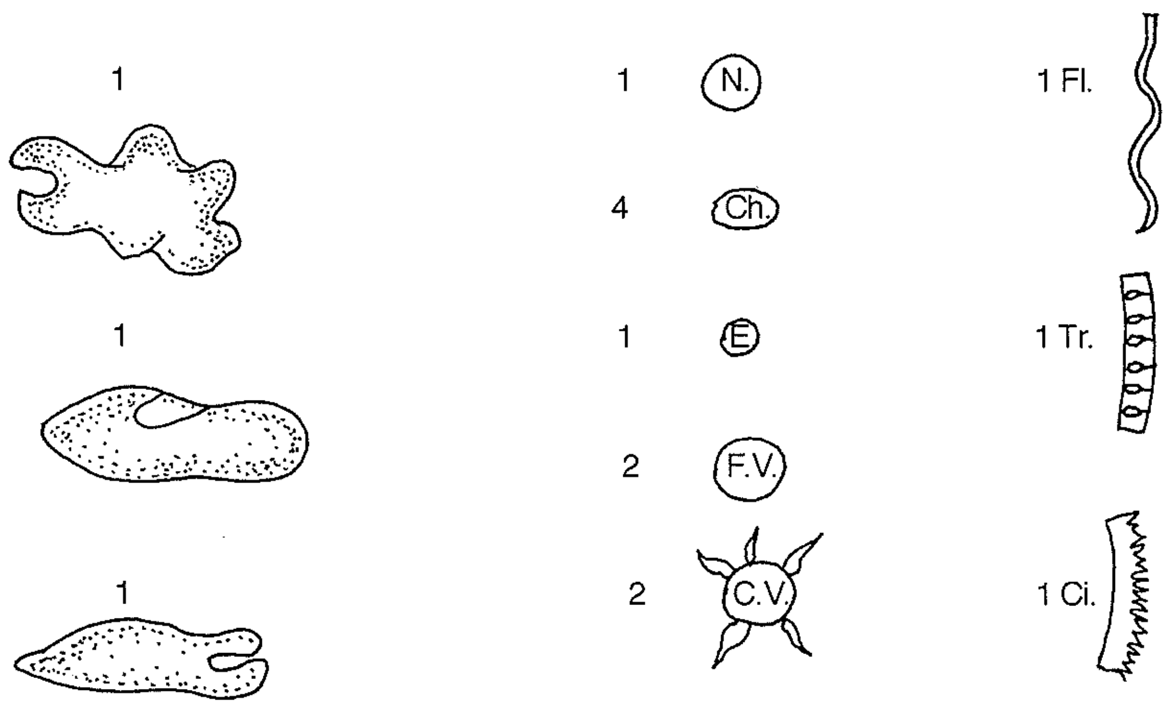
C. Euglena

Pick out the cell shape associated with euglena. 1. What long, hairlike locomotion structure should be added? It pulls the euglena through the water. 2. Which end is the anterior? Add a controlling structure "N." 3. Where in this cell is it typically located? 4. Propose a reason for this location. in most cells. 5. What structure is missing in this important cell structure which is found on most diagrams? 6. What green structures should be added to euglena?

7. Where should the small, red circle, "E," be placed in euglena? 8. What is this structure called? 9. What is the functional relationship between the green "Ch" and the red "E"? 10. Add the blue "c.v." to the cell, and name it.

Have your instructor check your cell model, answers, and initial your paper this last time.

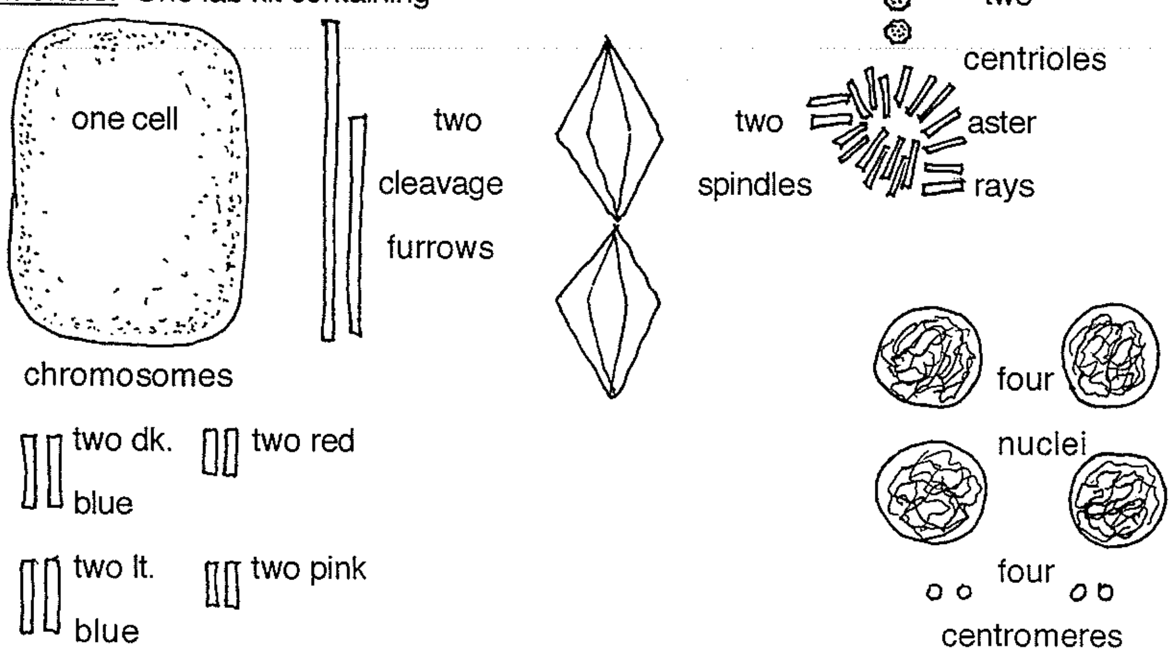
Count and return all components of the lab to their container. Here is an illustrated list of this labs components.



MITOSIS / MEIOSIS MODEL LAB

Purpose: To help you identify the stages of mitosis and meiosis and the associated cell structures. To be able to compare the outcomes of these two processes.

Materials: One lab kit containing-



Procedure: As you follow this activity- a. answer all questions on your own paper, and b. have your instructor check your models if you have any doubts. Before you start check your kit to make sure you have all the necessary pieces. This is not an introductory exercise. Make sure you have completed all prerequisite assignments before you begin.

Mitosis

1. Define the term "mitosis" from your text's glossary.

Interphase Locate the large, oval animal cell and place it in front of you. 2. Name the thin, flexible outer part of this cell. 3. Name the grainy substance inside. Locate one of the nuclei and place it in the center of the cell. 4. What do the long colored strands in the nucleus represent? 5. Why is this material important to the cell? 6. What does the black line around the nucleus represent? During interphase normal cell metabolism and growth occur. DNA replication occurs in late interphase. 7. What is the significance of doubling the chromatin or DNA? Place one centriole to the side of the nucleus.

Prophase In prophase the nuclear membrane disappears, so remove the nucleus. 8. How many centrioles should your cell now have? They are surrounded by thin , orange fibers that resemble a star called ____9.____rays. The replicated chromatin turns in to short, thick rods called ____10.____. You need to place two of each of the four colored rods in the center of your cell. As they are doubled chromosomes, the colors should be doubled, side-by-side. Holding the doubled chromosomes together is a small , round yellow structure called a ____11.____.

Metaphase The centrioles have now migrated to opposite ends of the cell to form the ____12.____ like the earth has. The aster rays extend to form the spindle which should be added. 13. What is found at the center of the spindle at this stage? As the center of the earth has an equator so does a dividing cell. You should now have two pink, two red, two dark blue, and two light blue chromosomes on this equator. The red and pink chromosomes carry the same general kinds of traits or genes. They are homologous chromosomes. One color came from the cells father, say the red, and the other came from the mother, the pink. Likewise, the light and dark blue are also ____14.____ chromosomes to each other. The number of body (somatic) chromosomes of this animal is four or two homologous pairs. Four is the diploid (2n) number.

Anaphase The doubled chromosomes are separating and moving to the opposite poles. 15. To what round, yellow structures are the spindle fibers attached?

Telophase The chromosomes have reached the poles. 16. How many single chromosomes are at each pole? 17. Name their colors. 18. Compare the chromosome number in each of the new cells with the original cell before replication in interphase. As the spindle disappears at this time remove it.

Replace each of the two chromosome sets with a nucleus. Mitosis has ended! Cytokinesis The important hereditary information has now been copied and given to each new nucleus. Add a short, black cleavage furrow down the center to divide the cell. The "mother cell" has now produced two, identical " __19.__ cells." (TAKE A REST)

MEIOSIS

Meiosis has a different function than mitosis. In mitosis (and cell division) you saw a diploid (2n) mother cell divide into two identical diploid (2n) daughter cells. The number of chromosomes remained constant from one cell generation to the next. This process allows for growth and replacement of lost cells, or the production of single-celled organisms like amoebas.

However, in meiosis the number of chromosomes is reduced to half (one set) for the purposes of sexual reproduction. The cells produced are haploid (n, sometimes called monoploid) gametes or sex cells. When haploid sex cells join at fertilization the new organism returns to two sets (2n) or the diploid condition again.

Meiosis has two divisions unlike the single division of mitosis. Each of the two consecutive divisions of meiosis have similar stages named like mitosis. Interphase Locate the large cell model and a nucleus. In late interphase the DNA is doubled or ____1.____. Something in the multicellular organism has triggered this particular kind of cell in a male or female r__2.____ organ to divide in a different way. When the normal diploid (2n) or in this cell's case four chromosomes is doubled at this stage, the term tetraploid (4n) is applied. (Tetraploid was not used in the mitosis section only to avoid early confusion.) There are two of each of the four different kinds or eight.

1st Meiotic Division

Prophase I Remove the nucleus. The nuclear membrane disappears, and the chromatin shortens and thickens into doubled red, pink, dark blue, and light blue chromosomes. 3. Based on the mitosis section, which pairs are homologous? These doubled homologous chromosomes will now pair up. They may twist around each other at this time, exchange genes, and create unexpected heredity changes or combinations in the offspring later. Don't forget the centromeres. 4. What term identifies this pairing process? (c_ i _- s_ a _ a) This does not occur in mitosis! These two sets of four homologous chromosomes called tetrads, two pinks joined beside two reds. The four blue chromosomes combined are also tetrads.

The centrioles have doubled and are now starting to move apart to the poles. Aster rays appear around them. 5. Do plant cells have these?

Metaphase I Place the spindle in the center of the cell, and the centrioles with aster rays at the poles as before. The paired, homologous chromosomes (tetrad) line up on the __6.__ plane of the spindle.

Anaphase I Paired, homologous chromosomes will now travel to opposite poles, but the doubled chromosomes stay together (ie., two pinks). Will the two reds separate with the two light blues or will they separate with the two dark blues? This helps produce new genetic combinations and is the reason why you are not like your brothers and sisters (unless you are an identical twin with the same chromosomes). You can not predict which chromosomes (colors) will go to which ends together because it is all a matter of ___7.___. This process helps shuffle genetic traits in populations.

Telophase I The doubled chromosomes are at the poles, and the spindle disappears. The chromosomes may become obscured again for a short time. 8. Try find the the term used to describe this first division stage (inter_____). No replication occurs during this time.

2nd Meiotic Division

Prophase II The two sets of doubled chromosomes, two large and two small, are in each cell. The centrioles and asters are doubled and move apart.

Metaphase II The doubled chromosomes line up on the spindle at the equatorial plane. 9. Where are the centrioles? 10. Are the cells diploid or haploid at this time?

Anaphase II The doubled chromosomes separate and move to opposite ends of the cell.

Telophase II The chromosomes are at the poles and the spindle disappears.

11. How many chromosomes are in each cell nucleus? 12. Are these cells diploid or haploid?

Cytokinesis Place the long cleavage furrow down the center lengthwise to divide the two sets of cells again. Replace the chromosomes with nuclei.

13. How many cells are there total? These are called gametes.

14. What happens to the chromosome number when two gametes (sex cells) join to form the new offspring?

Clean-up: Recount and replace your cell lab components in their original container, and hand in your paper.

HUMAN CHROMOSOME ACTIVITY

Purpose: To become familiar with the human chromosome complement. To show how haploid gametes are formed from diploid parents. To show the great variety of sex cells and offspring possible from two humans. To illustrate how fertilization restores the diploid number. To show how sex is determined.

Reference: Read the required sections on meiosis (gametogenesis), human karyotype, and sex determination before attempting this lab.

Materials: Four different colored sets of 23 numbered, paper chromosomes

Procedures: As you read through this lab, use the four colored sets of human chromosomes to help visualize the process discussed. Answer all questions on your own paper. If your instructor requires a signature at any location in the lab, do not go on until he has checked your work.

A. Parent Chromosomes

Father The dark blue and light blue sets of paper strips will represent the father's chromosomes. 1. How many chromosomes are there in each of his (somatic) body cells? The light blue set came from his mother and the dark blue set came from his father. 2. How many chromosomes came from each parent? Notice the smallest chromosomes have no numbers. 3. How are these two marked? They carry traits other than the one that triggers male sexuality. Pair up the two sets by size on the left side of your desk. These represent all the father's chromosomes in a diploid (2n) cell.

Mother The red and ___4.___ colored sets of paper strips will represent the mother's chromosomes in each of her body cells. 5. How many are there in each of her somatic cells? The red set came from her father and the pink set from her mother. Notice the two smallest chromosomes. 6. How are these two sex chromosomes marked? Pair up the two sets of mother's chromosomes by size on the right side of your desk to represent one of her diploid cells. Have your instructor initial your paper at this time.

B. Gametogenesis- the formation of gametes

Spermatogenesis When the father's diploid (2n) cells in the testes undergo meiosis they form four sex cells or gametes called ___7.___. Human sex cells are haploid (n, sometimes called monoploid) and contain only ___8.___ chromosomes. During their formation they receive a random selection of chromosomes from the parent, but there must be only one of each numbered chromosome. (ie., the sperm will get some of each blue color totaling 23) To show how this chance selection operates have one lab partner flip a coin. If heads appears take the dark color, and if tails appears take the light color from a given numbered pair. No two of the same chromosome number should appear in a sex cell. This normally results in a serious disorder or death of the cell. Place all the chosen 23 chromosomes below the original two sets. This represents one sperm's chromosomes. 9. Record your results by color and number of each. 10. Is it likely that you could receive this same set if you repeated the same coin toss procedure? 11. Is it likely that a father, then, would frequently produce two identical sperm? Have your paper initialed. Save this set for part C.

Oogenesis When the mother's diploid (2n) cells in the ovary undergo meiosis four cells are produced but only ___12.___ survives. (Most human egg cells are already partially formed at birth.) This sex cell is called an egg or ___13.___ . Like sperm they are also haploid (n) and contain only ___14.___ chromosomes each. Their chromosomes are also a result of random assortment during meiosis, and produce a wide genetic variety of eggs. To illustrate this process in females have the other lab partner flip a coin to select

23 re/pink chromosome combinations for one ovum. 15. Is it likely that, in her lifetime, she would produce two identical ova? Have your instructor check your work at this point. Save this chromosome set for part C.

C. Fertilization

The father's sperm chromosomes are on the left side of your desk, and the mother's ovum chromosomes are on the right side of your desk. The joining of the sex cells is conception or ___16.___ , and results in a single diploid cell (2n) with ___17.___ total chromosomes. This first cell of a new human is called a ___18.___ . To illustrate this new individual place the numbered pairs of chromosomes together. Those chromosomes that have the same size, shape, and genes (number) are said to be homologous. 19. What sex is this offspring? 20. How can you tell by the chromosomes?

21. By what process will this cell become a multicellular organism? 22. How many chromosomes will each of these new cells have? 23. Will the chromosomes in each cell be alike?

24. What are the chances that in two separate conceptions that two identical sperm and two identical eggs will ever join? The chances of one person forming two identical gametes is one in 8.4 million. When both gametes, sperm and egg, are considered, the chances of two children of the same parents being exactly alike is about one in 70.5 million, identical twins excepted. A high degree of variety is therefore possible with s___25.___ reproduction.

Have your instructor check your work and initial your paper.

Place all chromosomes of the same color together in number order in each of the four sets. Make sure all chromosomes are present in the container.

FLOWER MODEL LAB

Purpose: To help you identify the structure of a typical flower and the process of pollination and fertilization.

Materials: flower model kit- sepals/receptacle/pedicel, petals, pistil/filaments, anthers (2), pollen grains, egg and ovule, seed

Procedure: Form the following flower model and answer the following questions on your own paper. This is a review exercise. Make sure you have completed all prerequisite activities before attempting it.

1. Locate the green sepals/receptacle/pedicel section of the model. The pedicel connects the flower to the stem and contains vascular tissue.

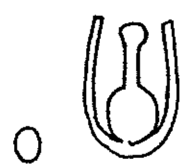
   a. Why would vascular tissue be connected with the flower? The broad, flat area above the pedicel is the receptacle or base of the flower which supports all the flower parts.

   b. What is the function of the leafy sepals? Place this piece down on a sheet of blank paper.

2. The large, three-lobed, white and purple structure represents the ___a.___. They are used to attract pollinators and protect the delicate flower parts.

   b. To what part are the above structures connected? Add them.

3. Locate the green pistil/filaments section, and place it on top of the receptacle. The pistil is the female flower part.



   a. What gamete does it produce?

   The pistil has three parts: the stigma, style, and _______.

   b. In which part of the pistil is the female part found? Add the red female cell.

4. Locate the dark blue anthers.

   a. On what structure of the stamen do these two anthers belong? Place the two anthers in position. The light blue dots are the pollen grains containing male sex cells (gametes). Place three or four pollen grains traveling from the anthers to the stigma.

b. What are the two black dots (gametes) carried inside the pollen grains?

5. Pollination- pollen is transferred from the anther to the sticky stigma 

a. List two ways this process is helped in nature. Place a separate pollen grain on the stigma. Add the light blue, j-shaped pollen tube on the pistil. This is formed by the tube nucleus which is part of the pollen grain. The two black dots in the tube are the two gametes from the pollen grain. 

b. Where does the pollen tube lead?

6. Fertilization- when the two sperm nuclei join with the egg and polar nuclei

a. What two parts of the seed do they become? (e______, f______)

b. What part of the seed does the outer ovule layer become?

7. Replace the egg with the mature seed. 

a. Is there a connection between the ovule, now the mature seed, and the ovary? Why?

b. What is the swollen ovary containing the mature seed(s) usually called?

CHICKEN SKELETON OBSERVATION

Purpose: To become familiar with the skeletal structure of a higher vertebrate, the bird, and how it is adapted to flight.

Materials: One chicken (or any complete bird) skeleton

Procedure: As your group observes the chicken skeleton, answer the following questions on your own paper. Be careful the skeleton is fragile.

1. Observe the mouth. a. Are there any teeth? b. Are teeth usually dense or light? c. What is the value of having no teeth if you fly? d.In what horny structure are the nostrils located? e. To what form of food is it adapted?

2. a.What is the birds keenest sense? b. What is the small opening behind its jaw? c. Why are the bird's orbitals so large? d. In what direction are they set in the skull?

3. a. Count and record the number of neck vertebrae. b. What is the function of so many long, swiveling vertebrae? (Remember: No hands!) c. For what function are the flexible,individual tail vertebrae suited?

4. a. What is the common name of the chicken's clavicle? b. What attaches to the large, flat surface of the keel and the wings? c. Observe the vertebrae of the back and pelvis. d. Besides number and size, how as a group, do they differ from yours? e. In terms of retaining a constant, streamlined shape in flight, how is this skeletal condition an advantage? f. How are the internal organs protected?

5. a. If available compare the weights of comparable size bird and mammal bones. b. How many digits do the wings have? c. How is this condition advantageous to flight? d.

6. a. Which is the longest bone of the chicken, and is sometimes called the drumstick? b. How many digits are on each foot? c. What are found on the ends of the phalanges? d. For what use are the feet adapted in a chicken?