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A science curriculum for preschool children based on a model designed to release human potential.

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A SCIENCE CURRICULUM FOR PRESCHOOL CHILDREN BASED ON A MODEL DESIGNED TO RELEASE HUMAN POTENTIAL

A Dissertation Presented

By

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August, 1973

DEDICATION

To my wife, Sylvia, and daughter, Lucita, for their patience, encouragement, and good disposition.

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A Science Curriculum For Preschool Children
Based On A Model Designed To Release Human Potential

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When new educational programs are devised, the focus of the curriculum is confined to the children for whom the program is designed and to specific subjects. Because of this approach educational ventures have failed to construct a conceptual model that includes all of human growth, and which could provide the basis for coordinating efforts between subject areas. Furthermore, it is only recently and at the preschool level that curriculum specialists have traced developmental growth within a subject level. For instance, no fewer than seven different curriculum models for preschool education have been designed within the past five years. Yet none of these programs addresses the need to construct an overall model which can identify the strategic areas of human growth. Furthermore, while some of these models are developmentally oriented due to the use of Piaget's research, they are limited only to the preschool and early elementary school period and only to the development of logical reasoning.

This dissertation addresses itself to these shortcomings. The primary purpose of this research is to describe in detail the processes of seriation, conservation, cognitive space, and cognitive time, to elaborate on the developmental stages from infancy to adolescence and adulthood, and to integrate these four processes into a cohesive unit.

The secondary purpose is to develop a set of prototypical learning experiences that demonstrate how these processes can release children's cognitive potentialities not only within the area of cognitive growth but also concerning such areas of human growth as increasing children's ability to focus their attention, promoting their understanding of people in other cultures, and facilitating children's setting of and completing goals.

The methodology for undertaking this study emphasizes the research of Jean Piaget with respect to the four areas mentioned earlier. Furthermore, the ANISA program, a comprehensive educational model designed to foster learning competence, is used as the basis for integrating cognitive development within the framework of human growth, and as a tool for predicting how cognitive processes might foster the development of growth in areas of human competence other than cognition.

The detailed elaboration of each of the four processes generates educational objectives from which prototypical experiences are designed. Moreover, three elementary science curricula, AAAS, ESS, and SCIS, are used as sources for generating learning experiences that promote cognitve competence.

Although this curriculum has not been field tested, evaluation procedures are discussed and used in the learning experiences. These procedures require that alternative approaches to evaluation be designed since a developmentally based model of learning assumes that learning is acquired over a period of time and is dynamic.

It is hoped that such an approach to curriculum development will provide the teacher with a diagnostic tool for determining the developmental levels of each individual student and then to suggest methods that might be taken to accelerate this growth if he is retarded of deficient. It also provides the teacher with a framework for developing the entire range of human potentialities of children so that they can release these potentialities for the good of mankind.

CHAPTER I

INTRODUCTION

Numerous changes have occurred in curriculum content and philosophy over the past ten years. In determining whether these changes include the necessary components needed for sound curriculum design, a curriculum rationale can be utilized (Baruch, 1971b). The most widely used rationale was designed by Ralph W. Tyler at the University of Chicago. His design organizes curriculum around five data sources: (1) the learner and his needs, (2) the demands of his society, (3) knowledge of a particular subject area as organized by subject specialists, (4) the school's philosophy of education, and (5) the stage of development of the learner as determined by educational psychology. Objectives are generated from the first three sources, while the last two serve as a screen and allow only the most consistent objectives to be used in molding the educational curriculum (Tyler, 1949, p.p. 7-10).

Throughout the history of American education one or two of these data sources have been emphasized at different periods of time. For instance, in the 1900's educational psychology and the subject specialist were primarily emphasized, whereas in 1918 the emphasis shifted to the society and its needs. This trend continued until 1935, when the learner and the school's philosophy became the main focus (Tyler, 1967). In contemporary society the launching of the Sputnik satellite (1956) generated a shift in attention to the subject specialist, initiated by the introduction of PSSC physics. Current trends of ecology and environmental issues (1969) demand a focus on society and its needs.

With regard to research concerning the learner and educational psychology, curriculum design is in an early stage of growth as demonstrated by the time lag in implementing findings of psychology in the classroom. The most important deficiency of curriculum development is that few planning efforts rely on a theoretical base or model of learning, which identifies processes or competencies, essential to the release of child's full potential. This was demonstrated by the MACE (Massachusetts Advisory Commission on Education) study on compensatory education com--piled within the state of Massachusetts. It indicated that three "characteristics" of compensatory education in the state which keep it from being effective are: 1) "lack of explicit objectives. . .which deal with the basic problems of the disadvantaged child; 1) lack of sound designs for evaluating programs. . .; and 3) lack of model compensatory educational programs which demonstrate appropriate curricula . . ." (Jordan and Hecht, 1970, p. 5). The deleterious effects of these factors would be vastly reduced with the establishment of such a theoretical base. Furthermore, such a model would have diagnostic implications for all children, since criteria based on sound, scientific research designed to stimulate full human development would be utilized.

The ANISA model is being designed to establish such a base. Its emphasis is on: 1) providing a theoretical framework which integrates the research on human development, 2) explicating the developmental sequences involved in this organization, and 3) designing curricula to help the individual become a competent learner so that he might recognize and utilize his potentialities for the good of society at an optimum rate. The method for building the theoretical framework consists of: 1) researching the various areas of human potential to identify those processes which underlie basic competence in the areas, 2) investigating the developmental sequence of these processes, and 3) providing formats for experiences to insure that a child will accommodate these processes into his own cognitive structure.

The ANISA <u>theory of development</u> provides a rationale for the research. Basically, ANISA views development as a process of becoming, which is further defined as the process of translating potentialities into actuality. This is coupled with the philosophical belief that existence presupposes the notion of process so that a process is defined as "the ordered expression of a potentiality initiated and maintained through the interaction with the environment."

The ANISA theory of development has established two categories of potentialities -- biological and psychological. Nutrition is the primary factor for actualizing biological potentialities while psychological potentialities are organized into five sub-categories: psychomotor, perceptual, cognitive, affective, and volitional. These are listed below with a brief description of their contents.

Psychomotor Potentialities. Psychomotor potentialities refer to "the capacity of a human being to coordinate, control, and direct the movement of voluntary muscles." Specific processes include balance and posture, locomotion, and manipulation.

Perceptual Potentialities. Perceptual potentialities involve differentiations of sensory information and the integration of that information into patterns which are interpretations of reality. Processes evolve around the development of each of the sense organs of the human body.

Cognitive Potentialities. Cognitive potentialities represent the ability of human beings for organized or logical thinking. This refers to the differentiation of attributes of objects and events in the environment and their integration to form internal structures or patterns of thought for the organization of that environment. Some of the processes are: analysis, synthesis, seriation, classification, and conservation.

Affective Potentialities. Affective potentialities concern the ability of humans "to organize their emotions and feelings in a way that supports and facilitates the release of further potentiality" both within individuals and among their fellow human beings. Processes include: the management of anxiety, the inhibition of destructive impulses, and coping with disappointing experiences.

Volitional Potentialities. Volitional potentialities refer to the ability of the human organism to structure his future through an organized set of intentions, which are guided by an internal purpose or subjective aim. Some processes in this area are: attention, goal setting, and perseverance (Streets and Jordan, 1973, p.p. 5-9).

These processes do not develop in a vacuum. To some extent they are determined by genetic potential while interaction with the environment is responsible for the remaining influences. Since the environment is such a significant factor in development, ANISA has differentiated the total environment into four categories for conceptual clarity:

1. The physical environment which includes the sub-classes: animal, botanical, and mineral.
2. The human environment which includes all human beings.
3. The unknown environment which includes that part of existence which is unknown. All lower

environments, the self, human, and physical environments, have unknown components to them.

4. The <u>self environment</u> is a special case of the human environment involving individual self-contemplation. It represents the most constant aspect of the total environment for the particular individual (Kalinowski and Jordan, 1973, p. 9).

The integration of the potentialities and environments is specified in ANISA's theory of curriculum. According to this theory, as potentialities are actualized, they are structured in relation to the various environments with which the human being is interacting, and this results in specific value systems.[1] For example, when children interact with the physical environment, all the potentialities previously outlined are integrated with the factual information (content) of that environment to form <u>material</u> attitudes and values which generate <u>technological</u> competence. Likewise, in the human environment the same basic potentialities form <u>social</u> attitudes and values leading to <u>moral</u> competence, while in the unknown environment the same integration results in religious attitudes and values underlying spiritual competence[2] (Streets and Jordan, 1973, p.p. 13-14).

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[1]The value systems represent an integration of both specific processes with the factual information about the environments.

[2]Spiritual competence is the ability to structure the unknown environment.

Context of the Problem

This dissertation pertains to the area of science education and uses the ANISA model as an integrating factor to present a unified set of learning processes designed for the preschool years that will enhance an individual's capability for structuring their environment. Understanding science and the scientific method requires that certain indispensable processes be acquired. These important processes make up the cognitive area, processes such as inference, hypothesis testing, and deduction. They operate within the conceptual structures of seriation, classification, and number relations. Therefore, the cognitive domain and the development of cognitive competence will be the focus of this thesis. Other areas of competence will be involved only as a demonstration of how they relate in an integrated way as the human organism functions as a whole.

The first step in developing the cognitive domain consisted of the review of possible theoretical frameworks upon which the area of human development can be expanded. After a review of different theories of cognitive growth, the research of Jean Piaget was selected as the initial foundation for identifying cognitive competencies. Piaget has been chosen because, through his interest in genetic epistemology, he has done more extensive research in identifying processes (operations) basic to the growth of logical thought in the child. Because this specific approach, followed by relatively few psychologists in the past, e.g., James Mark Baldwin has proved to be rich source of ideas for developing the cognitive area of the ANISA curriculum, other theoretical positions have been given a secondary position. However, Piaget's theory will be refined by: (1) integrating outside research specific to the operations selected within this context of Piaget's work, and (2) introducing new models for integrating and describing processes.

In terms of specific processes, Constance Kamii has isolated six processes, using Piaget's research, which have components that are on the level of the preschool child (Kamii, 1971). These include: seriation, classification, number relations, symbolization, and space and time relations. Because there is a team working on the cognitive area, this thesis will include only those processes developed by the author, namely, seriation, conservation (not included by Kamii). space cognition, and time relations. The thesis will attempt to investigate several problems originating from Kamii's research; (1) she has not incorporated research outside of Piaget, and (2) she constructed her curriculum without a full understanding of how formal operations broaden and give a fuller comprehension and significance to earlier stages of development.[3] The method

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[3]Lecture given by Constance Kamii, University of Massachusetts, March, 1972.

for investigating the first problem has been outlined in the previous paragraph. The method of solution for the second problem is presented in a section of this proposal entitled "Organization of the Study," in which one chapter will be devoted to the description of the formal operational stage and its implications for teachers of preschool children.

Statement of Purpose

The purpose of this dissertation is to develop a preschool science curriculum which will:

(1) Identify the various stages at the preschool level where the processes of seriation, conservation, space cognition, and time relations emerge and develop, showing justification for these operations with regard to the subsequent development of adolescent and adult logical thought from primarily a Piagetian perspective;

(2) Develop and document specifications for the above processes, the content of which is described in the organization section of the thesis proposal, from the sensorimotor through the concrete operational stages of development;

(3) Design learning experiences which will strengthen the cognitive capacity of the child within the areas of seriation, conservation, space cognition, and time relations at the preschool level;

(4) Design learning experiences which demonstrate how those cognitive processes can be generalized to strengthen learning competence in other areas of the ANISA model, and how they can be used with existing elementary science programs; and

(5) Specify methods of evaluation and discuss problems which occur in determining whether children are meeting the objectives of each process at their appropriate level.

Limitations of Study

1. This dissertation will not attempt to field test the learning experiences developed in the study. Since there is no school presently implementing the ANISA model, testing at this time is not feasible.
2. The main theoretical base for the cognitive domain will come from Piaget's research. No attempt will be made to review and integrate all theoretical models currently available.
3. The development of the model of cognitive competence described in this thesis represents the initial step of ANISA in integrating research in this area. As the model is field tested, constant revisions will occur so that a balance is maintained between the theoretical and the practical.

Educational Significance of the Study

The problems presented in this dissertation have significance to the entire educational community, i.e., students, teachers, curriculum specialists, and administrators. With regard to students, the development of competence is crucial. Cognitive competence refers to the ability of the individual (1) to organize an internal structure (accommodation) for assimilating or incorporating stimuli in the form of objects, events and people, and (2) to make refinements in this internal structure by the differentiation, integration, and generalization of new information with the previous structure to form a new one, more capable of assimilating new stimuli. This competence includes the ability to: (1) organize stimuli on the basis of similarities (classification), (2) order stimuli on some continuum, i.e., shape, size, degree of color, etc. (seriation), (3) recognize the constancy of objects and events across transformations (conservation), (4) measure quantitative properties, i.e., mass, weight, volume, length, velocity, etc., of environmental phenomena (number relations), and (5) comprehend spatial and temporal relationships. These abilities determine the extent to which a child can interact with his environment and the degree to which he will function with competence. Without these structures, individuals become overwhelmed by the complexity of life. In conclusion, science in the form of logical thought can provide an indispensable base for comprehending our surroundings. It also provides us with a structure for organizing emotions, moral values, and intentions. It is a basic structure on which other kinds of development depend.

From a teacher's point of view, the developmental scheme of competencies along with the prototypical experiences would be of immense value in diagnosing a student's educational needs and then providing meaningful learning experiences for him in the classroom. A teacher could discover in each individual student the competencies that are missing or operating at a low level. The curriculum could then be meaningfully individualized according to a student's deficiencies, offering him optimum growth. Such a model would also provide structure to allow innovative ideas, such as the open classroom, to be meaningful experiences for all children.

A systematic list of processes would be of indispensable use to a curriculum specialist, especially one concerned with science education. There have been almost 20 new curricula in this subject within the last 10 years extending from the elementary level through college, each with its own particular philosophy, structure, and teaching pedagogy (Baruch, 1971a). ANISA would provide a means of coordinating these programs so that a child would be exposed to a smooth development, regardless of the program he followed.

Finally, the list of basic competencies would also serve the educational administrator. Because of the comprehensive nature of ANISA (it integrates the total human personality, i.e., moral, cognitive, affective), the administrator will have criteria in the form of processes which specify the make-up of a well rounded individual. This will allow the administrator to integrate the desires of the parents and community, as to what specific content areas they want the school system to be concerned with, into a comprehensive curriculum that will allow for the release of human potential.

Organization of the Study

The following is an organization of chapter headings and their contents.

Chapter I. Introduction

The content of this chapter includes: (1) a general introduction to the problem of curriculum design, (2) a description of the ANISA model, (3) the context and purpose of the study, and (4) the educational significance of the study.

Chapter II. Review of the Research

This section will include a review of research necessary to justify and set the tone for the main treatment of the problem.

2:1 This section will review the literature of the disadvantaged learner with respect to cognitive deficiency to uncover the educational needs of these children.

2:2 This section will contain a review of preschool programs currently in existence, and a discussion of where they are deficient in terms of developing learning competence.

2:3 The third area will include a brief introduction to Jean Piaget and his research. Particular emphasis will be placed on describing the composition of his developmental sequence of stages to demonstrate the total context of cognitive development.

Chapter III. Seriation, Conservation, Cognitive Space, and Cognitive Time: Selected Processes Underlying Cognitive Competence

3:1 This section will provide a framework for understanding the included processes (competencies).

3:2 The specifications of seriation, conservation, space, cognition, and time relations will be presented. The specifications will include: 1) a concise definition of each process, 2) an elaborate description of the process with emphasis on the component parts of which it is composed, 3) a justification of why the process is necessary for learning competence, 4) a section on developmental sequences within each process.

Drawings and charts will be included to clarify ideas.

Chapter IV. The Growth of Seriation, Conservation, Space, and Time in Adolescents and the Relationship to Early Childhood

This chapter will discuss the contents and implications of formal operations for earlier stages of growth.

4:1 A basic introduction to formal operations will be presented with specific emphasis on the INRC group and 16 binary operations.

4:2 This section will describe adolescent thought with respect to the operations of seriation, conservation, space cognition, and time relations.

4:3 Implications of this stage of growth for earlier stages will be discussed with particular emphasis on the utility of understanding the content of adolescent thought for teachers.

Chapter V. The Curriculum

This chapter will introduce possible learning experiences for preschool children designed to strengthen competence in the four areas of seriation, conservation, space cognition, and time relations.

5:1 Specific objectives to promote competence in these areas will be developed.

5:2 Guidelines and prerequisites in each of the areas mentioned above will be cited.

5:3 Prototypical experiences for each process specifically designed to demonstrate abstract situations will be given.

5:4 Learning experiences will be designed which demonstrate how the cognitive processes developed earlier in the dissertation can be utilized to promote affective competence in the moral environment.

5:5 Three elementary science programs (AAAS, ESS, SCIS) will be reviewed to demonstrate how curricula can be used to support cognitive competence on the preschool level.

Chapter VI. Evaluation and Conclusion

6:1 In this section, general comments regarding the problems of evaluating children's answers in a Piagetian format will be explored.

6:2 This section will discuss in general the use of formative evaluation techniques and the design of extinction experiments.

6:3 Closing comments will include: (1) suggestions for further research, and (2) limitations in using the curriculum.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this chapter is to review the many programs designed to improve education at the preschool and elementary level. This will provide the background for pointing out the unique qualities of the ANISA model and to hypothesize how it can overcome difficulties in the field where previous programs have failed. This review will emphasize the cognitive portion of each curriculum, since that is the scope of this dissertation.

Preceding the review of curricula will be a review of some of the studies done with disadvantaged children. Although ANISA is intended for all children, most of the studies which have isolated cognitive deficiencies have taken place with disadvantaged students. The cognitive deficiencies that will be outlined provide background information concerning the reasons why the many new preschool curricula were initiated. Furthermore, these deficiencies provide clues as to why certain programs fail, and new models like ANISA can be evaluated on a conceptual basis as to whether they provide feasible remedies for these shortcomings.

In the final section, a brief review of Piaget's theory is presented, since the conceptualization of this dissertation is strongly influenced by his work. A basic comprehension of this theory is necessary for a thorough understanding of the projected curriculum.

The Disadvantaged Learner and Cognitive Competence

Most studies of disadvantaged students describe social and environmental factors that are characteristic of lower-class life. These factors, such as poor self-image, lack of a father figure in the home, the lack of a structured home environment, etc., need to be considered, especially in the affective and volitional components of the ANISA model. However, caution must be exercised less hasty generalizations are made. It was a well documented characteristic of disadvantaged children that they had insufficient stimulation from their environment early in life because of poverty and broken homes (Hebb, 1949). However, this hypothesis was made from a cultural bias and lack of awareness of the environment of such youngsters. In fact, Hunt infers that lower class children are exposed to more stimulation than middle class children (Hunt, 1966). Due to crowded conditions,they are constantly exposed to different people, customs, cultural variations -- a constant bombardment of stimuli. Another generalization is that lower class children are less verbal than their middle class partners.[1] However, lower class children may be just

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[1]The statement comes from the author's experience in the inner city and the fact that this was an often cited reason why children in the inner city did poorly in school.

as verbal once in a familiar environment. Observing these children at home or among friends may reveal an extremely verbal child. Such generalizations would mislead an educator; more precise and accurate descriptions are needed.

Some of the most far-reaching research concerning disadvantaged children concerns cognitive studies. These studies include both formal reasoning and language. With regard to formal reasoning, the following deficiencies have been noted in disadvantaged students:

1. they are poor performers on abstract concepts and tend not to use numbers in relating their experiences (Deutsch, 1967, p. 223);
2. they are less capable of making perceptual discriminations among physical objects in the environment;
3. they are deficient in pictorial representations of objects and actions (Berlin, 1964);
4. they are deficient in their ability to represent their experiences symbolically (Krutetski, 1963);
5. they attain the concepts of conservation of number, area and volume at a later age (Almy and Chittenden, 1963).

In addition, Riessman has noted differences in their cognitive style that may cause stress for them in a middle-class school setting where more rapid cognitive responses are required. Specifically, the style of a deprived child is:

1. physical and visual as opposed to aural
2. content-centered as contrasted with form-oriented
3. externally-oriented rather than introspective
4. problem-centered rather than abstract-centered
5. inductive rather than deductive
6. spatial rather than temporal
7. slow, careful, and perservering rather than quick, clever, and flexible (Riessman, 1962, p.p. 54-56)

Studies now show that disadvantaged youngsters are not retarded in areas of immediate memory span of the ability to master specific rote-learning tasks.

With respect to language ability, Riessman suggests that the major reason a disadvantaged student does not realize his full potential is because of his verbal difficulties (Riessman, 1962). In reference to specific cognitive deficiencies, Bernstein concludes that lower class speech is inadequate for:

1. expressing personal or original opinions
2. analysis and careful reasoning
3. comprehending anything hypothetical or beyond the present
4. explaining anything very complex (Bernstein, 1961).

Bereiter (1966a) concludes that disadvantaged children cannot integrate two statements to form a third (inference) because of their language deficiency. Luria (1961) and

Vygotsky (1962) have found that disadvantaged children show an inability to relate action through language, which is a prerequisite for dialectical reasoning. In summary, Bernstein concludes that language conditions what a child learns, how he learns, and how he sets the limits for future learning (Bernstein, 1961, p.p. 239-43).

What is the cause of this language deficiency? Hess maintains that the source of language deficiency is ". . .a lack of cognitive meaning in the mother-child communication system". In an experiment Hess showed that lower class mothers give less specific information and directions when trying to impart a concept or getting a child to accomplish a task. They do not give clear directions, do not know how to motivate the child, and they use commands "devoid of instructional content" (Hess and Shipman, 1965). Baldwin confirmed the above study when he demonstrated that the I.Q.'s of 4-7 year old children increase if parental discipline consists of realistic questions rich in content. However, there is no change in I.Q. if the discipline consists of ". . .nonchalant unresponsiveness or of demands for obedience for its own sake with painful stimulation as the alternative" (Hunt, 1964).

Specifically, what is the language deficit seen in lower class children? The deficit can best be described by comparing the lower class language structure with that of the middle class.

	Lower Class	Middle Class
Speech	- consists of giant phrases and sentences that function like giant words, incapable of being subdivided.	consists of distinct words.
Grammar Structure -	blends words with noises that take the place of words; there are no distinct units.	is a reduced grammar structure, leaving out words he doesn't know.

Lower class children will revert to a giant word complex even after they learn to discriminate smaller units of words. The solution is to transmit to the children the ability to speak in words rather than noises (Bereiter, 1966a, p.p. 35-40).

Among these studies which attempt to find a strong correlation between cognitive skills and specific language patterns are several that disclaim this evidence. Baratz (1969) counters Bereiter's (1966a) claim that if a child "does not know the word not. . .he is deprived of one of the most logical tools of our language". Baratz contends that each language may have its own form of "not" which is not recognizable by people outside of that social group. Furthermore, the cognitive strategy of the language may be entirely different so that there is no need to express such statements (Baratz, 1969, p. 891).

Houston (1970) argues that it is not possible to determine cognitive abilities from language patterns. If a certain structure is missing from a language, it cannot be inferred that people of that social class are not aware of that concept. However, Houston only cites one study supporting her position.

In conclusion, the section on the disadvantaged child generates some cognitive deficiencies which can be a starting point for constructing curriculum materials. However, because of the inability to control the many variables that are due to cultural differences, this area is still in an early stage of development. Even so, these hypothesized cognitive deficiencies can be used as a focal point in understanding the preschool programs presented in the next section.

Preschool Programs

This section of the literature review will summarize some of the preschool and elementary school models which are presently used and which contain unique and specific concpetual approaches. These programs will be compared as to: (1) their philosophy of learning, (2) their psychological orientation, (3) the type of motivation emphasized (extrinsic or intrinsic), and (4) their curriculum content. The programs that will be reviewed can be classified into the following three categories:

A. Programs which incorporate a Dewey philosophy and which stress interrelationships between intellectual and socio-emotional growth.

   1. Montessori's preschool program
   2. Armington's EDC action-oriented approach
   3. The Bank Street model of education
   4. Glen Nimnicht's responsive model of education for preschool

B. Programs which stress a cognitive developmental theory.

   1. Weikart's cognitively oriented preschool
   2. Ira Gordon's parent educator model

C. Programs which emphasize a motivational approach, specifically a Skinnerian emphasis on positive reinforcement.

1. Bushell's behavior analysis model
2. Bereiter-Engelmann's academically oriented preschool (Maccoby and Zellner, 1970, p.p. 59-75).

Maria Montessori.

Philosophy. The philosophy of a Montessori school reflects an emphasis on the objectives of : (1) developing the whole personality of the child and (2) developing each individual in the school. Montessori believed that "the vital thing in a true educational method is the activity of the child . . ." She has described the very young child as being like soft wax, capable of being molded in many different ways. Montessori believes that the intellectual and social powers of the child will be released in his spontaneous interaction with his environment and that teachers should be careful not to mold the child to their particular viewpoint, but allow the child to develop freely (Standing, 1957). Teachers should allow the environment to "reveal the child not mold him" by allowing freedom within a prepared environment so that a child can develop his physical, mental, and spiritual capabilities (Hamstock, 1968).

Psychological Approach. Montessori's beliefs exemplify the principles of Gestalt psychology, that is the organization of one's experience depends on the recognition of patterns between stimuli in the environment. Furthermore, there are certain sensitive periods in the development of the child during which increased stimulation facilitates a child's ability to master and transcend his environment (Hamstock, 1968). It was Montessori's central belief that ". . .education of the senses makes men observers. . .and prepares them for practical life" (Montessori, 1965, p. 218).

Motivation. Montessori's ideas of motivation stress the spontaneous interest of children in learning (intrinsic) motivation) (Hunt, 1966, p.p. 58-61). Her recommendations to teachers would include making careful observations to discover factors, which might foster these individual interests and promote growth. This intrinsic motivation is coupled with a type of self-discipline. "Discipline comes through liberty," although the liberty of the child should have as its limit the collective interest of the people that he influences (Montessori, 1965).

Curriculum. The basic learning principle of a Montessori curriculum is "learning how to learn" as opposed to the collecting of experiences and facts. A Montessori curriculum stresses: (1) motor education, (2) sensory education, and (3) language. Her emphasis in developing the senses is acute and there are many exercises developed for aural, tactile, and olfactory discrimination. Montessori believes that motivation for language is based on facility with the senses (Hamstock, 1968). She uses this facility to teach language with the introduction of techniques such as alphabet letters cut from sandpaper (tactile coordination), pictures of objects with their associated names (visual coordination), the use of phonetics (aural coordination), and movable letters (hand-eye coordination).

Montessori advocates that lessons used for children meet three criteria:

- simplicity - words used in lessons should be presented in the least complex manner; ideas presented should refer to the truth;
- conciseness - lessons should not contain useless words; the value of each word should be precise; and
- objectivity - lessons should be presented in a manner which removes the personality of the teacher; only the object that the lesson will call attention to should be visible (Montessori, 1968).

In summary, a Montessori philosophy believes in: (1) the basic goodness of children if left alone from adult influence, (2) the need for children to develop around their spontaneous interests, and (3) the necessity of early sensory training.

The Bank Street Model.

Philosophy. The philosophy of the Bank Street schools is congruent with the humanist school of thought. This philosophy is reflected in the school's concepts of competence, interpersonal relatedness, individuality, and creativity, which reflects the values, goals, and strategies of the program:

> Competence - Functionally, competence is divided into two functions, ego strength and the interaction with the environment. Regarding ego strength, this competence includes self-image, or how a person views his own worth and the make-up of his motivational system. The second factor includes one's interaction with other people, outside challenges, and other factors in the environment. Thus, competence is viewed as more than excellence of intellectual performance.
> Interpersonal interrelatedness - This concept includes a growing sensitivity and awareness of each individual's uniqueness and point of view. It focuses on cherishing rather than tolerating individual differences. Human communication becomes a means of ". . .extending knowledge and finding emotional refreshment;" it can help people ". . .understand the commoness of human feelings and conflicts. . .".

Individuality - The central belief is that a person is capable of making choices and preferences, of taking initiative for setting his own goals, and evolving his code of ethics, which represent the formation of his value system.[2]

Creativity - Creativity is viewed as a process rather than a product. It can be described as a system of expanding sensitivity that allows a person expanded modes of expression in order to synthesize diverse elements of one's experience, i.e., logical and alogical, reasoned and intuitive forms of thinking (Biber, Shapiro, and Wickens, 1971).

Psychological Approach. The psychological tenets of the Bank Street program are:

(1) that children learn best when they are along side other people who are learning;

(2) learning does not take place independent of healthy emotional development;

(3) learning and development are intertwined; and

(4) the process of learning is more important than the final product.

Bank Street emphasizes a "whole child approach" drawing on various schools of psychological thought for the organization

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[2]This represents a philosophy Bank Street is trying to implement.

of the curriculum. The humanist philosophy is the most influencing factor in the make-up of the curriculum.

Motivation. The emphasis of the Bank Street program is to stimulate a child's intrinsic motivation. Children's classroom experiences should be deeply gratifying and provide a stimulus so that learning becomes a way of life. School programs can achieve this when they are dedicated towards releasing the child's learning capacities, which in turn enable the child to interact with his school and community with purpose and joy. Intrinsic motivation affects the quality of a child's learning since learning experiences are most meaningful when interest is high and purpose is personal (Klopf and Hohman, 1967, p.p. 107-14).

Curriculum. The Bank Street curriculum can be described by the types of experiences necessary for the development of cognition and the categories used in the make-up of cognitive competence in preschool. Five kinds of experiences are necessary for cognitive functioning:

(1) direct experience with the physical world in terms of sensory and motor action

(2) nonsymbolic manipulative activities with objects

(3) experience with nonverbal representation

(4) proficiency in written and spoken language

(5) the integration of past experience conceptually.

According to the Bank Street model the seven categories which make up cognitive competence include:

(1) the identification of objects and persons through spoken and written signs

(2) the classification and differentiation of physical attributes, functions, roles, feelings, etc.

(3) the quantification of objects by different criteria such as size, amount, and degree

(4) the orientation of objects in space and time

(5) the awareness of transformation processes such as combinations, growth, decay, etc.

(6) the understanding of causality based on sequence, prediction, and effect, both in the physical and social aspects of life

(7) the formulation of undertainty and confusion by the use of questioning and expression (Biber, et.al., 1971, p. 25).

The EDC Approach.

Philosophy. The philosophy of the EDC program is the belief that a student's own self-interests are the best determinant for offering experiences for growth (Armington, 1969). The program stresses self-development for both teachers and students, emphasizing that students take responsibility for their own learning (Sacco, 1972). Furthermore, the EDC program attempts to strengthen the growth of the child in terms of his ability to relate to other human beings in society in productive ways. In this way this approach is similar to the philosophy of John Dewey.

Psychological Approach. One basic psychological tenet of the EDC approach is that the child is a whole human being and that he cannot be subdivided into various components for the sake of learning. A second tenet is that learning should be embedded in spontaneously developing life experiences. Third, there is a strong belief in the interrelatedness of feeling and thought, and that emotional feelings cannot be separated from intellectual growth (Maccoby and Zellner, 1970, p.p. 30-70).

Motivation. The type of motivation emphasized in the EDC program is totally intrinsic. In fact, Armington, the program director, believes that the use of reinforcements and incentives are a form of coercion. Since the program centers on children's needs, there is a strong emphasis on students setting their own goals, on self-expression and on active experimentation (Sacco, 1972).

Curriculum. The EDC curriculum is based on the assumption that children have a natural source of vitality, and it is the teacher's duty to channel this energy into positive,productive activities. Therefore, materials that stimulate these self-interests provide the basis for the curriculum. In contrast to structured programs, EDC does not believe that isolated, structured activities such as classification or seriation are of value, since children do these things naturally. Therefore, the main objective of an EDC curriculum is to create a classroom that is sensitive to the individual needs of children. Activities should be interdisciplinary and the schedule flexible. The specific content will be influenced by local needs and objectives; even areas of the curriculum like reading will better develop when taught in a natural environment.

Glen Nimnicht's Responsive Model.

Philosophy. The basic feature of the responsive model is that the environment of the child should be so arranged to encourage the child to make discoveries about his physical and social world.(Maccoby and Zellner, 1970). The characteristics of such an environment should:

1. permit the learner to explore freely
2. inform the learner of the consequences of his actions by providing immediate feedback
3. be self-pacing, i.e., pace is determined by the learner

The overall goal of this program is to help each individual to become inner directed (Nimnicht, 1967) and to meet his own needs regardless of his cultural background.

Nimnicht believes that parents provide a necessary role in the expected implementation of this model. The parents have several distinct roles:

1. They are trained to teach their child at home through toys and games.
2. They have the authority to approve any program before it is introduced.
3. They can participate as paid assistants or volunteers in the school.

Psychological Approach. The responsive model focuses on three basic psychological tenets. First, learning is most effective if the activities in a classroom concentrate on teaching children how to learn rather than concentrating on specific subject matter content. Secondly, a child better remembers what he has learned if he discovers knowledge for himself. Finally, problem-solving is the essence of learning.

Motivation. The goal of the school is to develop self-autonomous learners; therefore, the emphasis is on intrinsic motivation. Extrinsic reinforcement is never used because a reward system implies that the child who does not receive the reward is not up to standards; a practice deleterious to the improvement of each child's self-image. In addition, Nimnicht believes that reinforcement should come from the satisfaction inherent within a specific activity (Maccoby and Zellner, 1970, p.p. 17-18; 38, 78).

<u>Curriculum.</u> The curriculum of the New Nursery School is based on three objectives previously mentioned:

1. to help children achieve a healthy self-concept
2. to develop children's intellectual abilities by
    a. increasing their sensory and perceptual acuity
    b. improving their language skills
    c. improving problem-solving and concept formation abilities
3. to instill in children an understanding of their cultural background (Nimnicht, 1970)

This curriculum uses materials and equipment normally found in a nursery classroom, although some special materials have been developed to meet the needs of children from certain cultural backgrounds, specifically black and Mexican cultures. The structure of the school is that of an <u>open classroom</u>, although 15-20 minutes a day is spent in large group activities. Some specific contents of the school curriculum involve: (1) classification -- grouping on the basis of size, shape, thinkness, color; (2) finding the relative location of objects; and (3) labeling and counting. Specific problem-solving objectives which a child should have mastered after being in the program for two to three years are:

1. to recognize, complete, extend, and discover patterns in one and two dimensions;
2. to think inductively, i.e., to discover rules from examples;
3. to eliminate what is known and determine what is unknown;
4. to use feedback to modify actions; and
5. to recognize a problem which cannot be solved with the information present (Kelly and McAfee, 1969).

The Cognitively-Oriented Curriculum.

Philosophy. The basic philosophy of Weikart's program is that a child needs a basic understanding of himself and the world. He cannot grasp this without the abilities of (1) placing himself in time and space, and (2) classifying and ordering objects and events. The key for the child is to produce meaningful representations and derive relationships between objects and events. Self-concept is stressed, and the child is treated as if he is a "self-propelling" individual who can make individual decisions. Within the Weikart strategy, teachers have the right to design their own classroom. In addition, home visits are designed to provide parents with the motivation to use their own skills in language and reading to observe and enhance their child's cognitive abilities.

Psychological Approach. Weikart's preschool emphasizes cognitive growth, and the curriculum is built entirely on Piagetian concepts, stressing the child's ability to represent objects and events in his environment and the modification of those schemes to fit new information or more consistent explanations.

Basically, Weikart uses two levels of operation, motor and verbal. He also uses three levels of representation. The first level is the index level, where parts of objects are seen as representative of the whole, and objects can be represented by certain marks or sounds, i.e., footprints of a bear or the ringing of a doorbell. The second level is the symbolic level which consists of representations that are apart from the objects themselves and require a link to connect the representation and the real object, i.e., a clay model of a duck, pictures of bears, motor imitation which symbolizes a rabbit hopping. Finally, at the concrete and formal operational level representation takes place at the sign level, that is, representation through words, both written and spoken (Weikart, Rogers, and Adcock, 1971, p.p. 4-8).

Motivation. Motivation in a Piagetian curriculum is intrinsic with the assumption that the mastery of new tasks is intrinsically gratifying to a child.

Curriculum. The curriculum consists of four Piagetian concepts: (1) classification, (2) seriation, (3) time relations, and (4) space relations. Basically, these processes or operations require the child to: (1) order objects and events on the basis of recognized differences, (2) to group objects and events on the basis of similarities, and (3) to place objects and events in space and time within the environment.

Incorporated into this Piagetian framework are Smilansky's concepts of play which fit well into Piaget's concepts of imitation. Also included in the curriculum are specific activities designed to teach impulse control, which includes the ability to lengthen one's attention span and to carry out self-selected activities using objects from one's environment.

Ira Gordon's Parent Educator Model.

Philosophy. The philosophy of the parent educator's model is that any type of intervention must begin early in life and must include the home environment, particularly the mother. The attempt of this program is to effect change in the affective and cognitive competence of the mother (Maccoby and Zellner, 1970, p.p. 7-13, 65-67, 96). A key belief of this program is that non-professionals can be trained as parent educators and para-professional teaching aides to participate effectively in the teaching process in the classroom. Gordon believes that appropriate observational and instructional techniques can be developed to train parents to establish an effective home learning environment (Gordon, 1969, p.p. 69-71).

Psychological Approach. The psychological approach adopted by this model draws heavily from Piaget's developmental theory, although some of Gesell's infant stimulation tests and Hunt's vocal imitation exercises are used in the early part of the program (Gesell, 1943; Hunt, 1966). There are two basic tenets which are central to this program and which are derived from Piagetian theory. Gordon sums these up by saying: "Our belief is that the provision of experiences which require adaptation through accommodation will lead to modification of development and greater cognitive organization than what might be expected from purely 'natural' or 'spontaneous' growing-up in a culturally deprived environment" (Gordon, 1967). Another belief is that a "child learns concepts by a variety of experiences, manipulating a whole set of things around that concept rather than just being taught. . . " (Maccoby, 1970).

Motivation. The parent educator model emphasizes intrinsic motivation, where a personal search for meaning is stressed rather than a program designed around external reinforcement. This principle must be emphasized in parent training, since there might be coercion in attempting to guide children too quickly into task-oriented behaviors.

Curriculum. The curriculum of this approach is process oriented and the content is based on Piagetian type learning experiences. Learning tasks are being developed that meet the guidelines of a Piagetian task. Learning tasks should meet the following criteria:

1. the task should foster the development of mental operations;
2. the task should promote a notion of logical thought sequence for the child;
3. the task should provide for continuous mental involvement;
4. the task should be open-ended; and
5. the task should enable the child to explore with materials.

Such a curriculum Gordon has constructed around six Piagetian areas:

1. discrimination through the five senses
2. conservation
3. spatial reasoning
4. temporal reasoning
5. seriation
6. grouping (Gordon, 1969, p.p. 113-15).

Bushell's Behavior Analysis Model.

Philosophy. The philosophy of Bushell's program is centered on: (1) having children achieve proficiency in reading, handwriting, and computation, (2) motivating children to master the social skills of being a student (Bushell, 1969; Sacco, 1972), i.e., distinguishing between a time to talk and a time to be silent or responding appropriately to the praise of a teacher, and (3) improving children's motivation toward school in general. Bushell believes that these goals can be achieved through the use of systematic positive reinforcement; in this way motivation can be taught. Bushell also believes that the role of teachers and parents should be that of behavior modifiers.

Psychological Approach. Bushell uses the Skinnerian type of positive reinforcement of behavior. Through the use of proper motivational techniques, ". . .extended task orientation and persistence at school-related tasks are aspects of behavior which can be taught" (Maccoby, 1970). The motivational techniques are based on the Premack principle, which states that given two behaviors of different strength, the stronger can be used to reinforce the weaker (Bushell, 1969).

Motivation. The type of motivation used is extrinsic, that is, it comes from outside of the student. This can come in the form of social reinforcement, praise, grades, or material reinforcement, i.e., a token system of rewards like candy or desirable activities that students wish to participate in. Bushell has instituted a token system of rewards (like green stamps) where a given amount of tokens will buy an activity that a child wants, i.e., recess, snacks, stories, art. These tokens are given as rewards for appropriate behavior or proficiency in the classroom (Sacco, 1972, p.p. 15-22).

There are two major advantages to such a system. First, the teacher can provide immediate feedback in tangible ways for large groups of children. Secondly, by recording the number of tokens which each child receives, a teacher has an internal system for evaluating whether or not she is giving each child enough attention.

Bushell argues that any type of reward system can be coercive, and since social reinforcement is necessary for building a positive self-image, this problem persists in all motivational schemes.

Curriculum. Since this program represents a motivational model, it can be used in almost any traditional classroom setting. However, Bushell does advocate the use of programmed instructional materials where possible, because it has a built in reinforcement schedule (Maccoby, 1970).

Bereiter-Engelmann's Academically Oriented Program.

Philosophy. The philosophy of this program advocates teaching children specific and significant educational objectives in the same manner as the elementary and secondary school. It also believes that disadvantaged children would improve their academic aptitude more if training in the formal structural aspects of language were taught. Social attitudes should not focus on competition, but on effort, attention, and mastery.

Psychological Approach. This program also uses a Skinnerian approach with its use of external reinforcement. Language development is taught through a verbal bombardment technique with children throwing back words in unison. The style of such a classroom is rapid-paced and offers highly structured activities with the teacher leading the verbal bombardment with the "gusto of a cheerleader. . . ." The teacher directs her efforts at the lowest performing child to insure that everyone can correctly answer on time. More concepts are presented to children in this program than in most early childhood programs (Bereiter, Engelmann, Osborn, and Reidford, 1966b, p.p. 106-09).

Motivation. Motivation is basically extrinsic and it is believed that such motivation can lead to self-motivation. Rewards should be given for effort and the adherence to rules. Material rewards, such as cookies, might be needed in the beginning because of a child's value system, but the teacher should eventually transfer to the use of social conditioning, using words of praise for appropriate conduct or a harsh tone for undesirable behavior. The best negative reinforcer, Bereiter feels, is isolation and should be used only wh n a child's misbehavior is intentional (Bereiter and Engelmann, 1966a, p.p. 85-87).

Curriculum. The Bereiter-Engelmann curriculum is structured around three basic academic areas: language, reading, and arithmetic.

Language - Language training involves precise pronunciation, since Bereiter feels that this is critical for mastery of grammatical structure. Language is used to describe and classify objects; identity statements are taught, i.e., "This is a block.".

Arithmetic - In this program mathematics is taught as a form of language. Basic number concepts, simple counting, and the operations of addition, subtraction, and multiplication are introduced. The introduction of algebraic equations is employed to draw a parallel between the function of words in a sentence and the function of elements in a mathematical equation. Word problems further stress the interplay between language and mathematics.

Reading - In this part of the curriculum, the Initial Teaching Alphabet (ITA) is used; spelling and phonetics are introduced. Children learn to read stories based upon words they have learned (Bereiter, *et.,al.*, 1966b, p.p. 113-35).

Discussion.

The discussion of these programs will follow the three divisions of programs outlined in the beginning of this section: (1) programs utilizing a Dewey philosophy, (2) programs utilizing a cognitive developmental approach, and (3) programs which are centered on motivation, particularly Skinnerian type reinforcement.

With respect to type 3, programs using a Skinnerian reinforcement approach, several difficulties arise. With the Bushell model, there is no attempt to change the extrinsic motivation used in teaching to intrinsic motivation as there is with the Bereiter-Engelmann model. This produces rather short-term learning which disappears eventually after the children leave the program. According to Riessman (1964), externally motivated behavior is the style of the disadvantaged learner. If we agree that intrinsically motivated behavior is best for sustained learning and its long-term effects, then extrinsic motivation is only feasible when it is used to orient children towards introspective behavior.

The second disadvantage of this type of program (including Bereiter-Engelmann's model) is that the curriculum is either traditionally oriented around subject areas (Bereiter-Engelmann) or is vague and too flexible in terms of specific objectives (Bushell). The Bereiter-Engelmann approach assumes that long-term learning can be effected in children by introducing sophisticated language, reading, and mathematics skills during the preschool period. However, children may initially imitate these concepts, but they lack any real understanding of the process. While the initial results are impressive with the Bereiter-Engelmann approach, long-term results are disappointing.

Concerning type 1 programs, those that incorporate the Dewey philosophy which stresses the integration of cognitive and affective potentialities, they suffer from the lack of an overall philosophy which could provide meaningful integrations of the different facets of the human personality, giving balance to such programs. For instance, the EDC program, Nimnicht's responsive model, Montessori, and the Bank Street model stress the individuality of the child to such an extent that the human environment, which concerns social interactions, as well as the role of the parents is greatly diminished. This unbalance usually results in overpermissiveness and the lack of self-discipline in the child.

Furthermore, all of these programs have failed to build a consistent theory of curriculum by which to identify relevant processes for learning. The EDC program is completely unstructured, while the Montessori, Bank Street, and Nimnicht's model have some structure. The latter two incorporate Piagetian processes, but from their reports, little attention is given to the full development of these processes.

Type 2, the cognitively oriented curriculum model, exemplified by Weikart's and Gordon's models, emphasize curriculum to a greater extent than any of the previous programs. This is especially true of Weikart's program, where extensive learning experiences have been developed for selected Piagetian processes. The major shortcoming of these programs is that an inadequate philosophical base results in an incohesive curriculum. While Piagetian processes are utilized in these programs, they are discontinuous, that is, the processes are not connected in anyway. When outside models are used, like Smilansky's concepts of play and other impulse control activities, they cannot be blended into a unified whole, since Piaget's theory is not comprehensive enough to cover the entire set of human potentialities in all environments.

In Gordon's model the child's affective potentialities and his social development are not developed in a systematic approach. This might be understood when one remembers that the emphasis of this model is on parent training.

The general criticism of these models is that they have not developed a philosophical theory which is broad enough to cover all human potentialities in all environments. It is for this reason that ANISA was developed. The ANISA model serves to integrate all human potentialities into a unified whole so that a child can effectively translate these potentialities into actuality under the guidance of an educational system that provides such total development. In addition, such a model serves to predict where gaps exist and where integrations might be made. For instance, a Piagetian process will be inferred to be a prerequisite for releasing a child's volitional potential later in the dissertation. Without the ANISA model, this connection would not have been inferred.

The general purpose of this dissertation is to integrate four Piagetian processes into a unified whole and to use the ANISA model to project relationships between the cognitive area and other areas of human potentialities. To enhance this development, the basic features of Piaget's theory will be reviewed. This will form the basis for the elaboration and development of the four processes which comprise part of cognitive potential.

Jean Piaget

The work of Jean Piaget has been brought to the attention of American psychologists within the last 10 years, because of the extensive studies that Piaget has done on the growth of intelligence from infancy through adolescence, Piaget has approached his work from interests in biology and epistomology, attempting to integrate the two areas by studying the problem of how knowledge incorporates the structures of biology (Ginsburg & Opper, 1969, p. 2). In 1920, while working with Binet on the standardization of I.Q. tests, and after investigating the works of Freud and Jung, he bagan to see the possibility of combining his biological and epistomological interests by first studying the psychology of human intelligence to discover how knowledge progresses through its development and evolution in childhood. This could involve biological structures, since intelligence can be viewed in terms of an organism's adaptation to its environment. Afterwards, Piaget planned to apply these psychological discoveries to theoretical problems of epistomology (Ginsburg & Opper, 1969, p.p. 3-6).

Some 50 years later, including 30 years spent on the first problem, the basic outline of his work can be described. Piaget's approach to intelligence can be discussed from both a <u>functional</u> and <u>structural</u> (developmental) approach. Functionally, Piaget's theory is strongly environmental in its emphasis, that is, although Piaget has not discounted genetic ability, his investigations are concerned mainly with the effect of environmental influences on the acquisition of knowledge. There are two levels at which the human organism functions, the levels of organization and adaptation. Organization implies an ordering of basic processes into coherent systems, both physical and psychological. Physically, organization manifests itself in the biological structures of the human organism, i.e., muscular or circulatory systems. Psychologically, organization is expressed through the make-up of mental schemes or operations in the human being. Operations are defined as "actions which a child performs mentally and which have the added property of being reversible". Reversibility implies that for each mental action there is an opposite action which the child can perform to return a system to its origin before the initial transformation, i.e., subtraction is the reverse of addition. Examples of such mental schemas are seriation, classification, causality, and conservation.

Adaptation concerns the process of adjustment one makes to his environment. Piaget has identified four environmental factors which influence the growth of intelligence. One factor is physical structure or maturation, which concerns the physical growth process of the nervous system. However, this is only one determinant as there are obvious cultural factors which determine cognitive functioning. Another of these is experience, which involves the acquisition of knowledge by the observation and manipulation of objects in one's environment. Obviously, if a human being has a wide variety of experiences, he has a greater wealth of knowledge to organize. Social transmission is another cultural factor which concerns a child's relationship with other human beings. The fourth factor is equilibrium, which integrates the three previous factors. Equilibrium is considered an internal, self-regulatory process that contains two components, (1) outside stimuli, and (2) the child's own inner mental structure. It includes the twin processes of assimilation and accommodation, which define adaptation. Assimilation involves the incorporation of an environmental event in one's own mental structures without a change occurring in that structure. A physical example would be the digestive system of the human. When food enters the stomach, acids are secreted to change the food into a form that can be absorbed in the blood. A similar example in the psychological world would be an infant using a well-developed shcema of grasping, already internalized, to explore the contour of a new rattle.

Accommodation includes the transformation of one's own internalized structure to incorporate new stimuli. In terms of the baby and the rattle, let us assume that the child has never seen a rattle. He must now change his own mental structure to include the concept of rattles. He may use previous schemas or structures to explore this, i.e., assimilation, but there is also a process of modifying his own structure to include the new event. So, accommodation and assimilation usually occur simultaneously in nature.

There are stages of equilibrium which vary as one progresses developmentally. An example of this involves conservation and the pouring of a liquid from a tall, skinny container into a short, wide one. In the first stage, the child pays attention to height as an important factor, shifts his attention to width in the second stage, begins to oscillate between width and height in the third stage, and finally becomes aware of transformations which influence both simultaneously in the fourth stage (Ginsburg & Opper, 1969, p.p. 17-19).

From a structural viewpoint, Piaget believes that there are certain ordered sequences by which development occurs. Such a position requires that the following assumptions be made:

1. growth develops in a certain ordered sequence
2. earlier stages of growth are prerequisite forlater stages
3. the ordering of stages is invariant (stages cannot be missed)
4. behaviors characteristic of a given stage do not disappear when the infant attains the next stage, but can be modified.

With regard to the specific stages of intellectual development, Piaget has delineated four distinct areas of growth: (1) sensorimotor (0-2), (2) pre-operational (3-6), (3) concrete operational (7-11), and (4) formal operational (12 and above). The ages included in the parentheses are only approximate ages that Piaget found in Swiss children and might be expected to differ in other cultures and societies. What follows is a description of these four stages.

Sensorimotor Intelligence.

The sensorimotor stage of development is the beginning of logical growth in the child. It consists of the evolution of basic reflex schema through primordial motor and sensory responses and their development up to the beginning of verbal and symbolic intellectual thought. This period can be subdivided into six minor levels of development.

Reflex Schemas. This is the first level of development, occurring from birth to approximately one month. These reflexes are based on hereditary structures, e.g., sucking reflex, and these reflexes are slowly modified to fit environmental demands. At this stage the beginning of the assimilation-accommodation equilibrium occurs, assimilation being demonstrated when the infant extends his sucking relfex to other things in his environment, like his thumb or his blanket. Accommodation occurs as the infant begins to find more effective ways of searching for and finding the nipple on his mother's breast.

Primary Circular Reactions. The second level concerns the acquisition of habits involving an infant's own body. This phase extends an infant's hereditary reflexes to a primitive form of imitation. At this level an infant relates to objects passively, but he follows their movement with his eyes, staring when the object disappears from sight (Ginsburg & Opper, 1969, p.p. 29-34). It is these habits which integrate the reflex schemas on the first level with the beginnings of imitation on the second level.

Secondary Circular Reactions. The third level finds the infant focusing on objects and events in his own environment. This level includes the coordination of vision and prehension as demonstrated by the infant's matured view of the object concept. He can anticipate, both visually and tactually, future positions of objects; he can interrupt a reaction involving an object and continue it later; and he can recognize an object that is partially hidden. It is at this level that Piaget sees the initial beginnings of classes and relations, which will result in the operations of classification and seriation in concrete operational thought.

Coordination of Secondary Circular Reactions. This fourth level leads to the establishment of more complex relationships. For instance, a child will remove a screen placed in front of an object which he has seen disappear to get at that object. This means that the object has acquired substance and permanence and has become detached from his own actions. The child can now imitate models using corresponding movements of invisible parts of his own body, e.g., imitating the sound of saliva against one's teeth, even though the infant cannot see what is operating. The fourth level doesn't seem to include any new concepts or schemas, but simply involves an application of past events (Piaget, 1966, p.p. 100-03).

Tertiary Circular Reactions. Level five focuses on an infant's ability to be interested in objects for their own sake, apart from himself or properties of objects which aid him in achieving some goal. At this level, he is capable of creativity. He can produce variations in events and use objects in new and novel ways, transcending the previous stage of mere imitation.

Level Six. Level six is seen as a bridge between the sensorimotor or preverbal stage and that of the representational or pre-operational period. This is the beginning of symbolic thought which forces the infant from his immediate and present world into the world of possibility. In imitation there is a new capacity to represent mentally an object or action not perceptually present (Ginsburg & Opper, 1969, p.p. 63-66). Another type of behavior which shows evidence of representation is the child's ability to engage in symbolic play, e.g., pretending that he is asleep when, in fact, he is awake. During this period he is able to correctly follow a series of invisible displacements to find an object which has disappeared. This suggests that a mental image must have been formed.

In summary, sensorimotor intelligence, which consists of the coordination of successive action schemas, never views these action schemas as fused into a meaningful whole. This stage of intelligence centers on the individual; it coordinates objects or events only in relation to some goal and in no way is reflective. Many of these short-comings will disappear at the next level, the symbol or representational level (Piaget, 1966, p.p. 106; 120-23).

Pre-Operational Thought.

Pre-operational thought can be broken down into two parts, the development of (1) deferred imitation and pre-conceptual thought (3-4), and (2) intuitive thought (4-7), which would bring a child to the threshold of operational thought.

Regarding the formation of preconceptual thought, Piaget sees this level as evolving from imitation. While the child's overt behavior is evident as early as primary circular reactions, towards the end of the sensorimotor period, the child's imitation schemes become more complex and internal during this stage. In order for internal imitation to be successful, the child must represent objects and actions in a symbolic way, i.e., through language or symbolic play. The development of language begins in connection with object representation and is also used to express immediate desires. Gradually, a child grows to use words in a symbolic way in reference to objects not present or to past events (Ginsburg & Opper, 1969, p.p. 72-84). However, it is actions and general schemas of representing objects which are internalized within one's mental structures, not the words or symbols.

At about the age of 4, Piaget found that when questioning children about short experiments, he could get regular answers. He felt that this fact alone indicated the beginning of a new structure. Piaget sees a "coordination of representative relations" or a growing conceptualization which bridges a child from symbolic to operational thought. But until the formation of operations, this type of thought is still pre-logical and is defined as intuitive thought. These are intuitive "centralizations" which are perceptually rather than conceptually centered. A traditional Piaget experiment can demonstrate this. In an experiment on the conservation of continuous quantity, a child must adjust the levels of liquids in two identical containers until he agrees that the levels are equal. Then one of the liquids is poured into a short but wide container and the question of equality is raised. A child, who reasons intuitively, will think that the liquid in the original container is greater than that in the short, wide container because the level of the liquid is higher. He might conclude that the liquid in the short, wide container is greater because the glass is fatter. The explanation, according to Piaget, is that the child can only intuitively "centralise" (focus) on either the height of the liquid or the width of the glass. but not both. Also, he might agree that the amount of the liquids are the same if the two containers are not too different in shape, but there is a point where if the shapes differ too much, the operation of conservation is destroyed by the deceptive demands of intuitive thought.

In summary, intuitive thought falls short of operational reasoning because it is perceptually centered, therefore, unidirectional and incapable of reversibility. Similar reasoning would show that intuitive thought lacks transitivity, associativity, identity, and therefore must lack conservation. Furthermore, intuitive thought is phenomenalistic, copying outlines of reality without an understanding of the internal structures; and it is egocentric, constantly relating to present action (Piaget, 1966, p.p. 129-39).

Concrete Operational Thought.

There come a point in intuitive thought when there is a "thawing out of intuitive structures" to form operations, which are characterized by a sudden mobility that coordinates configurations that were more or less rigid before. This might be demonstrated when temporal relations merge into the concept of a single time, or where elements in a system are conceived of as an unvarying whole, i.e., conservation. In the previous example of the conservation of continuous quantity, there comes a time when the child is certain of conservation, so much so that he is surprised at the question. His answer shows that he can compensate a decrease in height with an increase in the width of a container, or that he can prove that there is no change in the amount of the liquid by performing a physical or mental reversibility by pouring the liquid back into its original container.

During the concrete operational period a child becomes capable of using four types of logical or mathematical processes which are necessary for performing an operation:

1. Combination (closure) - any two elements within a class can be combined to produce a third element, i.e., $x + y = z$;
2. Reversibility - any transformation within a system is reversible; every operation implies a converse operation that allows one to return to the initial starting point, i.e., $a + b = b + a$;

3. Associativity - different operations can lead to the same result, i.e., $(x + y) + z = x + (y + z)$;
4. Identity - an operation combined with its converse can be annulled, i.e., $x + (-x) = 0$.

These four characteristics come together in a mobile equilibrium at the time that major operations like conservation and seriation are established. The child at this point can decenter his attention so that he can coordinate transformations of two or more variables.

Operations can be further classified as having the following characteristics:

1. They involve a transformation.
2. They are generalizable.
3. They are reversible.
4. They are internalized actions.

To illustrate these characteristics, let us use the operation of conservation and the specific example of conservation of mass where a clay ball is changed into the shape of a cylinder without removing any of the clay. First, a transformation occurs when the shape is changed. Second, this operation of conservation is applicable to systems of weight, area, volume, length, order, etc., so that it is a generalizable process. Next, the transformation can be reversed; that is, the cylinder can be rolled back into a ball. Finally, conservation forms a part of children's logical thinking patterns by becoming internalized actions.

Concrete operational thought is not the refined thinking of an adult, however. These operations are concrete; that is, they are tied to action, actual manipulation, as opposed to the mental operation found in hypothetical deductive reasoning. It should also be noted that research has demonstrated that different levels of development occur with these specific concrete materials. For instance, conservation of substance, which is of an intuitive nature, is achieved at the age of seven or eight, whereas conservation of weight comes later (8-9), and conservation of volume even later at about 11. This phenomenon occurs in seriation, where a child can perceptually seriate an assortment of sticks at an earlier age than a series of weights.

Formal Operational Thought.

During the concrete operational stage, the child's reasoning concerned actions or reality on a concrete level, which represented the first phase of operation. On the adolescent level, formal thought involves reasoning about propositions using some of the schemes which appeared in the concrete operational phase.

Formal reasoning involves thought which structures the future or world of possibility. This reasoning often incorporates assumptions which may have no relation to reality and which lead to deductions made on the basis of logical inferences. These deductions contrast sharply with those made during concrete operational thought, where conclusions are based on actual experience. Formal operations may include the same content as concrete thought, i.e., classification, seriation, enumeration, and measurement, but during the formal stage processes consist of inferences and contradictions between propositions rather than deductions based on concrete experiences (Ginsburg & Opper, 1969, p.p. 181-206).

In formal operational thought, we see the appearance of the INRC group, which includes sub-processes of identity, reciprocity, negation, and correlation. It is interesting to note that negation and reciprocity together make up reversibility, one of the characteristics of an operation However, in the formal operational period, this sub-process refers to operations performed on functions (hypothetical propositions) rather than concrete objects. Also, from a base in formal logic, using truth tables, Piaget derived and identified 16 binary operations, which exist in a matrix at this stage, although it is not clear exactly how they function, and if they have educational implications. These two complex relational structures are characteristic of this stage in that they are comprised of operations being performed on operations.

Another characteristic of thought at this level is the adolescent's ability to make possibility dominate reality. No longer is the student concerned with only empirical results, in fact,his primary concern is to derive the possibilities which are inherent in a given situation. Only after deriving these tentative factors can he then use reality to screen out his alternatives. Furthermore, an adolescent can combine relationships or perform operations on operations. He can analyze the interaction of variables on one another, not confining himself only to one variable at a time. Thus, the defining attribute of formal operations is flexibility.

By understanding this period of growth, a clearer comprehension of the basic operations will appear. The teacher can operate on a comprehensive base, realizing that what occurs in preschool is connected structurally to adolescent thought. Furthermore, a clearer definition of how processes such as inference, deduction, extrapolation, etc., emerge and may help to clarify the organizational scheme in the area of cognitive potentialities.

Summary

In this chapter we have reviewed some of the literature pertaining to disadvantaged learners to identify possible areas of cognitive deficiencies. This led us to review some of the preschool programs designed to overcome these deficiencies. Finally, because many of these programs were based on Piaget's work and the direction of this conceptualization is to draw principally from Piaget's theory, the final section reviews briefly some of the basic assumptions of this theory.

In the next chapter four Piagetian operations, seriation, conservation, cognitive space, and cognitive time, will be discussed at length, utilizing the major components of Piaget's theory discussed previously, identifying the developmental stages, and demonstrating how they are integrated to make up part of the domain of cognitive potentialities. In addition, the generalization of these cognitive processes to function in the human environment as well as being prerequisites for the release of children's volitional potentialities will be discussed.

Finally, in Chapter IV the development of these four processes will be traced through adolescence so that teachers and theorists can see the complete pattern of development and realize the importance of these processes in adult life.

CHAPTER III

SERIATION, CONSERVATION, COGNITIVE SPACE, AND COGNITIVE TIME: SELECTED PROCESSES UNDERLYING COGNITIVE COMPETENCE

The major objective of a curriculum based on the ANISA model is to promote learning competence. This can be accomplished by identifying processes which can translate human potentialities into actualities. Processes of cognitive potentiality are concerned with the development of internal thought structures which are used to organize one's physical environment. This is accomplished through the conscious ability to integrate, differentiate, and generalize elements which are reflected in each process. Each process allows humans to break down the complexity of life by isolating elements in their reality into manageable sections (differentiation) and then synthesizing those elements to create a new reality. These processes can then be generalized across environments so that what is applicable in the physical environment also pertains to the human or social environment.

The work of Jean Piaget is particularly useful and appropriate for understanding the nature of these processes. In his book, The Child's Conception of Space, Piaget established two categories of thought processes, logical and sub-logical. Basically, a logical process or operation is concerned with linking individual objects together by finding common points by which they can be interrelated irrespective of their spatio-temporal location. Piaget cites the following example: "A + A' = B; B + B' = C, etc., or A > B > C: etc.. B is then a distinct and recognizable class regardless of the distance between A and A', while the relationship A > B is similarly independent of the spatio-temporal disposition of these elements" (Piaget, 1967, p. 458).

Sub-logical[1] operations function to produce the concept of the object as such, rather than collections of objects. These operations integrate parts of objects within a spatio-temporal continuum to recreate the whole object itself (Piaget, 1958, p. 273; Piaget, 1967, p.p. 450, 458). For instance, a house can be grouped with other houses to form a neighborhood which, when linked with other neighborhoods, constitutes a city. Each neighborhood forms a partial whole which is part of the total city making up the spatial field. Therefore, sub-logical operations have structures which are based on proximity rather than similarity, and the integration of this proximity leads to a complete and continuous

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[1]Piaget used the term "sub-logical" from Russell's theory of types to imply that these operations applied to a lower type than the individual object. This does not imply that sub-logical operations are simpler than logical operations (Piaget, 1964, p. 38). See further explanation on page

whole (city) as opposed to logical operations, which yield discrete and discontinuous wholes, i.e., a collection of blocks grouped according to size implies no relationship of one block for the other (Piaget, 1967, p. 459). Moreover, sub-logical operations contain parts of a spatial continuum while logical operations involve relations between separate elements. As long as the part-whole relationship is spatial or partitive, the collection itself is an object and falls in the sub-logical category; once it ceases to have this characteristic, the part-whole relation is one of logical inclusion or class membership and is a logical operation (Piaget, 1964, p.p. 30, 35).

Logical Operations. Concrete operations of a logical-arithmetical character consist solely of similarities (classes and symmetrical relations) and differences (Asymmetrical relations). Also included in this category is number relations which is a system of relations incorporating both classes and asymmetrical differences. These logical operations occur between discrete objects in discontinuous wholes and are independent of the object's position in a spatio-temporal continuum (Piaget, 1967, p. 450). Specifically, the process of classification, which concerns classes and symmetrical relations, is one component of logical operations; seriation, which consists of organizing asymmetrical relations, is another. Finally, conservation, a process involving the recognition of invariant properties of objects across certain transformations, can be considered a logical operation if the type of conservation performed fits the criteria of a logical operation mentioned above. For instance, conservation tasks involving mass, weight, discontinuous and continuous quantities are examples of logical operations since they involve relationships among individual objects (clay balls) or units of measure (two beakers of water). Other types of conservation such as the conservation of area require subjects to integrate objects in a spatio-temporal environment which is consistent with sub-logical operations.

Sub-Logical Operations. The operations in this category arise from the necessity to arrange objects in space and time. These spatial and temporal operations often involve operations mentioned in the logical group but transformed in a medium of space and time. For instance, one of the key processes in cognitive time is temporal succession. Temporal succession requires an ordering of events on a time continuum. This might be thought of as a temporal seriation. Another example occurs with the concept of speed, which involves both space and time. Children must understand the process of conservation of uniform speeds, that is, an object which travels at one speed will transverse equal distances in equal times.

Sub-logical processes can be classified into categories which pertain to spatial and temporal concepts.

Space	Time
separation	simultaneity
proximity	succession
order	duration
continuity	
enclosure	

Included in this sub-logical category is the process of measurement which is incorporated into both space and time and involves the integration of number relations within a spatio-temporal framework. Causality can also be classified as a sub-logical process.

Summary. The major cognitive processes which have been isolated at this stage in the development of ANISA and to which more will be added are listed below.

Logical Operations	Sub-Logical Operations
Seriation	Time -
Classification	Succession
Conservation	Simultaneity
Number Relations -	Duration
includes concepts of seriation, classification, and conservation	Space -
	Proximity
	Separation
	Order
	Enclosure
	Continuity
	Measurement
	Causality

Since the cognitive part of the ANISA model is the effort of a number of people, only the specifications developed by the author will be included in the curriculum part of this dissertation, namely, seriation, conservation, space, and time. Specifications also have been developed for number relations, classification, and causality and an initial effort to group these processes under the title of "Inferential Processes" has been made.

This chapter will define and describe each process, present the justification for its importance for learning competence, and detail the development of each process in children. Chapter V will describe the prerequisites for the mastery of each process, describe the curriculum in terms of the objectives, and detail prototypical experiences for each process. Chapter VI will discuss evaluation.

Seriation

Definition.

Seriation is a process of arranging on the basis of ordered differences concrete objects and events, as well as abstract ideas and constructs for the purpose of understanding and organizing one's environment. Seriation is a process underlying learning competence in the cognitive area and includes both integrative and differentiative elements. In the case of seriation, differentiation refers to the identification of differences among objects or events and integration refers to the organization of those objects on the basis of the differences. For example, in the seriation of ten sticks of varying lengths, the difference is the variance in length, while integration refers to the organization of those sticks in ascending or descending order based on length.

Elaborate Description.

How does the definition above fit with Piaget's description? Piaget defines seriation as ". . .an additive arrangement of asymmetrical transitive relations" (Inhelder and Piaget, 1964, p. 269). The term "asymmetric relations" implies differences (differentiation), and the term "transitive" adds the notion of order or connection between these differences suggesting a sequence or continuum (integration) (Piaget, 1966, p. 34).

The objects being seriated may be either concrete or abstract. Concrete differences include qualities of objects like weight, volume, area, length, amount, or combinations of these, i.e., density = weight per unit volume. Ordering events includes an understanding of time, particularly through the concept of speed which is a combination of distance and time.

Seriation functions at the abstract level as children approach adolescence. This includes ordering a series of hypotheses[2] in order to discover those factors which influence certain phenomena in the environment. It could involve ordering one's values on a scale of importance, or the events that must take place during a week in order to accomplish a goal.

There are certain discriminations among types of seriation that will be made in the rest of this section. First, simple and multiple seriation will be illustrated since these types of seriation differ in their approach. Then, seriation will be contrasted with classification, its counterpart. Finally, seriation will be discussed in conjunction with correspondence since many studies indicate that these two processes are closely related.

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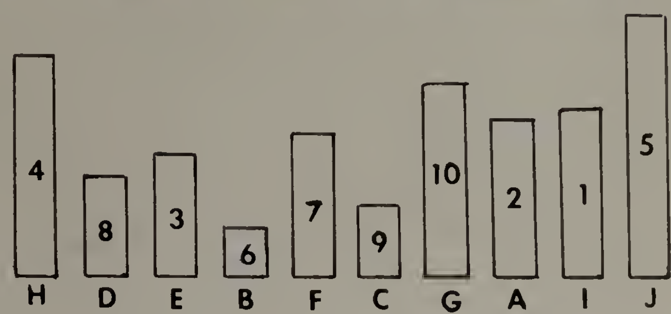
[2]Hypotheses are statements that identify relevant variables which are thought to influence the outcome of an event.

<u>Simple vs. Multiple Seriation.</u> The key distinction between simple and multiple seriation is the number of differences which are ordered simultaneously. Simple seriation entails the ordering of only one difference at a time. For instance, suppose there is a collection of 10 blocks, each of which are different in height and weight. These blocks could be ordered by height either in an ascending

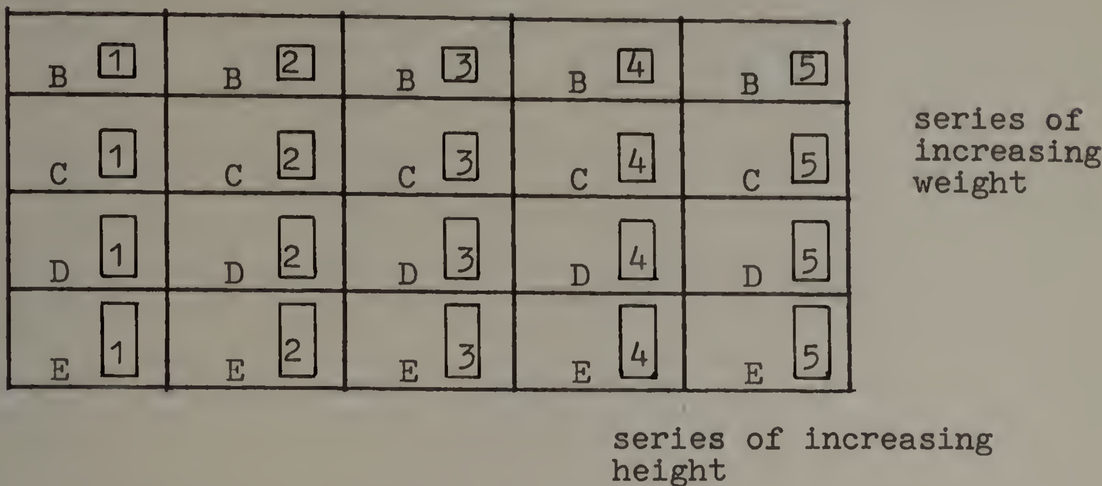
(numbers on blocks refer to their weight)



series, BCDEFAIGHJ, or descending order, JHGIAFEDCB. They could also be arranged by weight, either IAEHJBFDCG or GCDFBJHEAI. However, in both examples the blocks are arranged either by weight or by height, only one difference at a time. It would be inconsistent to begin a series with block B because it is the shortest and then place block F next to it because it is heavier; this would involve two differences arranged in a discontinuous series.

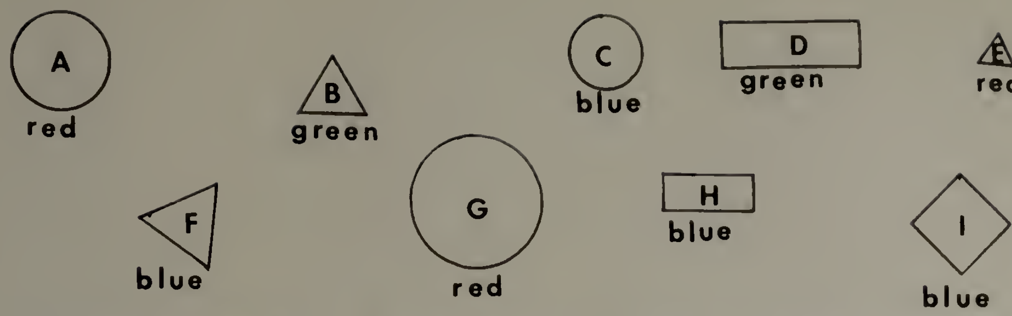
MULTIPLE SERIATION is the arrangement of objects in a series on the basis of two or more idfferences. Using the example of the blocks, a multiple series necessitates that each degree of height would have several gradations of weight associated with it, e.g., there would be five blocks at height B but with weights 1, 2, 3, 4, and 5.

Using only four blocks in the series and assuming that each height has five degrees of weight associated with it would produce the following matrix. On the horizontal



plane there is a series of increasing weights, while on the vertical plane there is a series of increasing heights. In each direction there is a series of ordered differences. Matrices could be constructed using a decreasing series of heights and weights or a decreasing series of one difference coupled with an increasing series of the other.

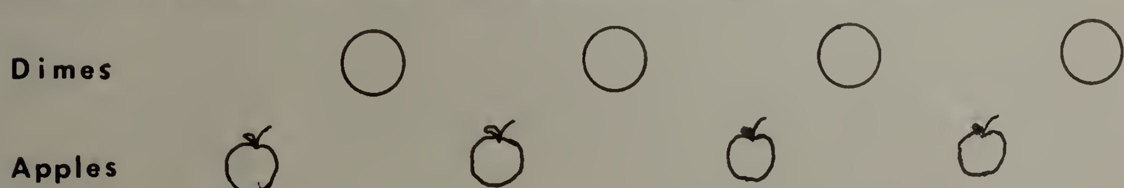
<u>Seriation vs. Classification</u>. Classification consists of the arrangement of objects on the basis of likenesses or similarities, while seriation is based on the ordering of differences. An example would involve grouping the following objects. These objects could be grouped by shape, that is, the circles -- A, C, G -- would constitute one class, the triangles -- B, E, F -- another, and the rectangles -- D, H, I -- would be a third class. These objects might be grouped by color, forming classes of



(1) red objects -- A, E, G, (2) blue objects -- C, F, H, I, and (3) green objects -- B and D. This grouping by similarities of objects or ideas is not transitive in nature, that is, there is not the continuity or order between the colors of red, blue, or green that is demonstrated with the pattern of decreasing size or height in seriation tasks. However, if the objects varied in size they could be classes of large, medium, and small.

<u>Seriation and Correspondence.</u> Because seriation tasks very often are combined with correspondence tasks, it is important to identify this process. Correspondence is a process of pairing objects together on the basis of some relationship which exists between them.

The nature of this relationship is dependent upon whether correspondence is combined with a symmetrical or asymmetrical order. If it is combined with a <u>symmetrical</u> order as shown in the figure below, either of the four



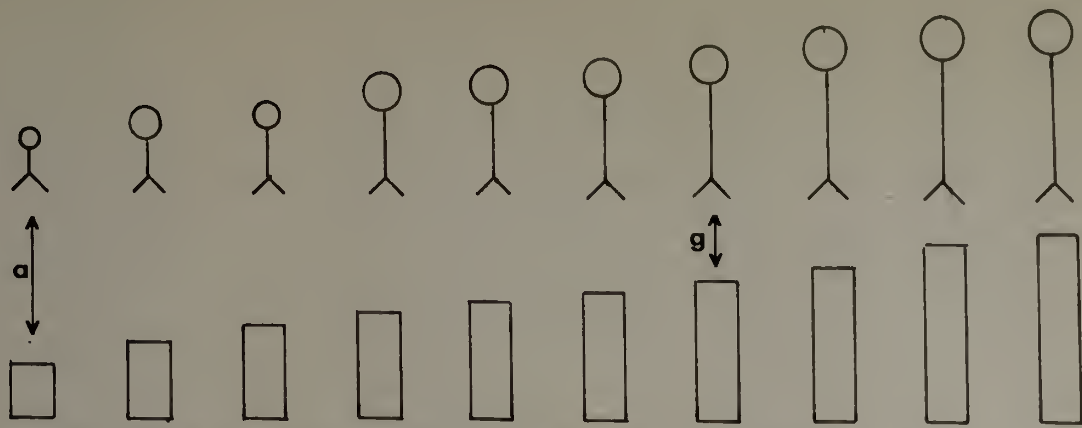
elements of dimes or apples may be first or second in their group, therefore, the order is disregarded. When a comparison is made as to the corresponding pairs between these two groups of dimes and apples, a child could establish a one to one correspondence between any apple and any coin, discovering in the process four pairs of elements. This process is named <u>cardinal correspondence</u> since the pairing is established irrespective of order (Piaget, 1965, p. 96).

On the other hand, when correspondence is combined with asymmetrical order (seriation) where there is a definite order, the nature of the pairing is determined by the position of each element in the series. In Piaget's experiments with correspondence, a series of 10 dolls, each of different heights, and a series of 10 sticks, each of different lengths, were used. In this task whildren are to find a possible correspondence between the following series:

(1) the series of dolls arranged by increasing heights paired with the series of sticks arranged by increasing lengths, and

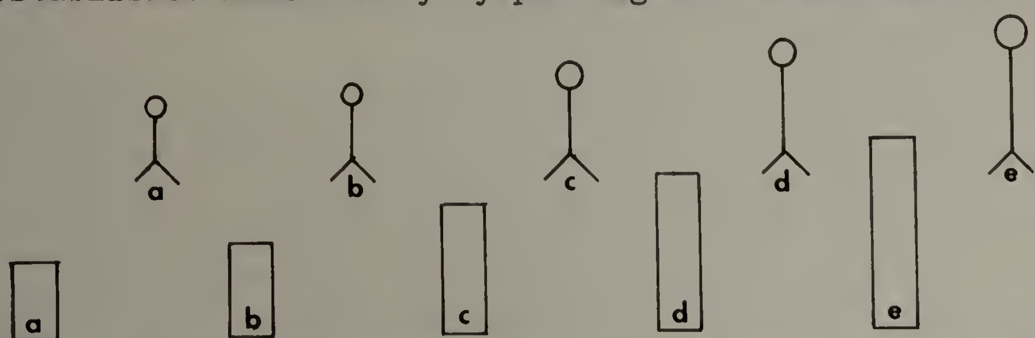
(2) the series of dolls arranged by decreasing heights paired with the series of sticks arranged by decreasing lengths.

If the series of dolls and sticks are arranged according to the figure below, then a correspondence can be established between the doll and the stick which is opposite



from one another in the series, e.g., pairs a and g. This type of correspondence, which is dependent on the proximity of the doll and its corresponding stick is known as _serial correspondence_.

If either series were altered so that the proximity with their corresponding member was changed, then a correspondence would have to be established on a numerical basis and the similarity between the two series is generalized to a succession of units (Piaget, 1965, p.p. 98-99). For example, in the figure below a correspondence could be established numerically by pairing doll c with stick c



because they are both the third member of a series of five members, which means that each member has a position in the series, either 1, 2, 3, 4, or 5. This type of correspondence is named _ordinal correspondence_ and is determined by considering that ". . .each element counts as one unit, equivalent in all respects to the others except for its psoition in the series, and every relation of order linking two elements is equivalent to any other "(Piaget, 1965, p.p. 112-13).

Since serial and ordinal correspondence forms the basis for many of the experiences in promoting competence in seriation, three approaches of organizing such a comparison will be illustrated here and their implications for growth will be cited later in the development section. The approaches for ordering the dolls and sticks can take three directions: (1) double seriation, (2) simple seriation with correspondence, or (3) direct ordinal correspondence. Double seriation occurs when children initially seriate either the dolls or the sticks, then form another series with the remaining objects, and finally deduce the corresponding pairs from the position of each member in the series. In simple seriation with correspondence, the child seriates one of the sets of objects, i.e., either the dolls or sticks, and then finds a correspondence between the members of the unseriated set and the seriated set. Finally, with direct ordinal correspondence there is immediate correspondence without any visible seriation occurring. In this method, small and large elements of each series are paired together before their position in the series is determined. This method is sometimes termed <u>direct correspondence</u> (Piaget, 1965, p.p. 99-101)

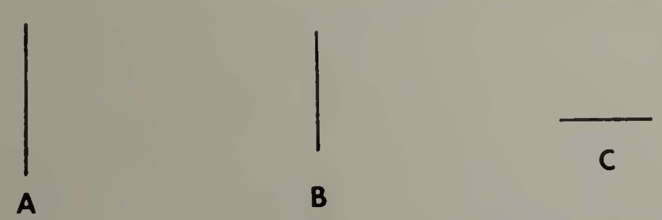
<u>Justification.</u>

Seriation is an integral part of learning competence in that it gives children a tool by which they can construct patterns out of differences, thereby reducing the complexity of their environment. Later in adolescence, seriation allows children to arrange abstract constructs and ideas within a system of priorities or by order of importance. In fact, the process of thinking in terms of relations (differences) only occurs when a child is capable of seriating since ". . .a transitive asymmetrical relation, such as $A < B$, could not exist as a relation. . .were it not for the possibility of constructing a whole succession of serial relations such as $A < B < C$. . ." (Piaget, 1966, p. 35).

Mathematically, seriation is a part of knowledge which Piaget termed "logical-mathematical operations". Seriation is the basis of ordinal correspondence which in turn is fundamental for the construction of the integer and number system in general (Piaget, 1965, p. 102). Ordinal correspondence allows children to understand number sequences or series, e.g., 1, 2, 3 or 10, 11, 12, which give number systems their continuity and allow children to get from one number to another. For example, if children want to find the difference between "9" and "4" and they know the sequence -- 4, 5, 6, 7, 8, 9 -- they can mark off five numbers beginning at "4" and moving in increasing order until they arrive at "9". Likewise, to get from "9" to "4" they count five numbers in decreasing order.

In early childhood seriation involves the beginning attempts of children to group objects in global categories like: big-little, long-short, fat-thin, smooth-rough, loud-quiet, strong-faint odor, or hot-cold. Therefore, global seriation provides very young children with an initial scheme for differentiating objects in their environment.

An isolated experiment by McManis (1970) indicates that seriation is a basic part of the process of making transitive inferences of inequality (transitivity). Referring to the figure below, transitivity is the inferential step which must be made in deducing the relationship between A and C from the knowledge that A is greater than B and B is greater than C, which is derived by actual manipulation of the sticks. McManis found that out of



80 normal and 80 retarded children, approximately 60 percent

of each could do both seriation and transitivity, while 40 percent succeeded in seriation but failed in transitivity. No one succeeded on transitivity tasks while failing to seriate. These results suggest that seriation is necessary for transitivity, but that transitivity does not have to be mastered for seriation (McManis, 1970, p.p. 789-92). Since both the tasks of seriation and transitivity were done with length differences, these data suggest an independent relation between the two processes. However, there is the need for confirming studies as well as similar experiments using other types of differences, such as weight and number, before a final generalization of the relationship between seriation and transitivity is determined.

Developmental Considerations.

Ability to seriate begins in early infancy and reaches its highest form, theoretically, in middle to late adolescence. In this section, the advances of seriation at each Piagetian stage from the sensorimotor through the concrete operational will be described. Formal operational seriation is developed in Chapter IV.

Piaget has identified two major levels in the development of this process. The first is the perceptual level which occurs during the sensorimotor and preoperational stages. Success at this level is a prerequisite for the second level, concrete operations, defined as a mental action which can be reversed (Piaget, 1965, p. 102).

Sensorimotor Seriation (0-2 years). "Seriation exists at the sensorimotor level even if the relevant behavior is unsystematic. A necessary condition appears to be that the difference between the elements in a series must be fairly sizable so that the child can pick them out just by looking at the material" (Inhelder and Piaget, 1964, p. 248). This difference in size is the first indication that children discriminate differences.

During stage 3 of the sensorimotor period, secondary circular reactions (4-10 months), Piaget hypothesized the beginning of primitive relations, when he observed that his daughter discriminated between the quiet and loud noises produced by her rattle. Later in stage 4, coordination of secondary schemes (10-12 months), he observed further refinements. His daughter would now systematically search for objects that disappeared from her view, even to the point of removing a screen or other obstacle which might be positioned in front of the object. This relationship between the obstacle and the goal of finding the object indicates an early understanding of relations since children were able to discriminate a relationship where the obstacle was in front of the object they were searching for.

Also, during this stage Laurent began to distinguish an element of quantity which occurred when she imitated the sounds of syllables her father repeated to her, words such as "papa" or "papapapa" (Ginsburg & Opper, 1969, p.p. 48, 53-54). Although this might indicate a simple memory task, it does require a discrimination of differences, a factor in seriation, and in all learning.

From these experiments Piaget has found that the beginning of seriation exists at the sensorimotor level as gross discriminations between the size of objects, sounds, and any other easily perceived difference. It is the manipulation of objects which begins during this period that allows the child to make perceptually based discriminations later.

Pre-Operational Seriation (3-7 years). In Chapter II it was mentioned that thought at this level of development was mainly perceptual and intuitive and that children would imitate patterns of reality without understanding the internal or deep structure. For instance, children at this level can imitate the seriation of three objects of different sizes by repeating the seriation demonstration. However, if the number of objects increases to seven, children fail to repeat the seriation task because they cannot remember the positions of that many objects, and they do not have the internal structure to recreate the series.

With reference to seriation, activities of this intuitive nature take place in three sub-stages. Between

3-4 years Piaget found that 53 percent of his children made *no* attempt at *seriation* (Inhelder and Piaget, 1964, p. 250). In another study Holowinsky (1970) found that children or three or four years would not even draw a series given a collection of sticks and an illustration of a series. Instead, they created all types of objects constructed of sticks.

In the next sub-stage, *global comparison*, the formation of uncoordinated small series of three and four elements are constructed from collections of at least 10 objects in drawings consisting of sticks of different heights. These drawings pass through the following phases:

1) drawings of sticks parallel to one another but whose ends are uneven (figure 1)
2) drawings where sticks are seriated in collections of two (dichotomous stage -- figure 2) and three (trichotomous stage -- figure 3), and
3) drawings where every stick is a different length and there is a correct cluster of three and four sticks seriated properly (figure 4) (Kamii, 1971, p. 299).


(1)


(2)


(3)


(4)

In the last stage children progress so that more and more sticks are arranged in proper order until the complete series of 10 is constructed. This stage is called <u>perceptual seriation</u> and is accomplished through a trial and error method at around 4-6 years (Inhelder and Piaget, 1964, p. 250).

The above tasks refer to simple seriation alone. However, with the tasks involving serial correspondence, Piaget found that pre-operational children <u>did not</u> experience increased difficulty. This suggests that the process of correspondence aids in achieving competence in seriation.

Piaget found three developmental levels for both serial and ordinal correspondence of which the first two are pre-operational. In serial correspondence, children of 4-6 years are involved in a <u>global comparison</u> stage where there is not yet exact seriation or one-to-one correspondence. In fact, the teacher eventually constructs the series for children by asking many exploratory questions. Once the series of dolls is established, the children will attempt to form correspondences between the tallest and shortest sticks. Some children try to establish corresponding pairs without forming any series. Generally, at this stage children only proceed by the method of <u>simple seriation with correspondence</u>, being unable at this point to conceptualize the method of <u>double seriation</u>.

The next stage of serial correspondence is called intuitive progressive seriation and correspondence (5-7 years). At this stage children succeed in constructing a correct series with a certain amount of trial and error and without the intervention of the experimenter. When children attempt to find a correspondence with a second series, they begin with the method of simple seriation with correspondence, but they eventually solve the problem by double seriation.

With ordinal correspondence children progress through similar stages. In the global comparison stage (4-5 years), children fail to maintain correspondence when one of the series is modified by either pushing its members closer together, increasing the separation between each member, or by reversing the order. In the figure on page 77, children would pair together stick c with doll b because of their physical location. Children at this stage do not analyze the positions of the series systematically. Later the level of intuitive progressive seriation and correspondence allows children to establish correspondence even though there might be a large separation between the corresponding elements. Children achieve the proper pairing by empirical means or counting. With empirical means children will match up elements in each series by pointing to each element with their fingers and pairing up the corresponding elements by sight. Another method is to count through a series until the appropriate number is found. If children were asked to find the match between the stick and the eighth doll in the series, they could count the dolls up to the eighth number (establishing its position) and then count through the row of sticks until the eighth one was reached.

Thus, children at this stage can establish correspondence based on ordinality through a trial and error method. However, children cannot combine their notions of ordinality with cardinality at this stage. They do not realize that both of the series are equivalent in the number of elements regardless of their appearance. Even if they count up to 10 members in each series, they fail to realize that 10 dolls and 10 sticks are equal in number. Nevertheless, it is the perceptual discriminations gained at this stage which are internalized and evolve at the operational level in the next stage.

Concrete Operational Seriation (7-11 years). At this operational stage children's thought achieves a flexibility which was not possible earlier. Competence at this level is reflected in children's ability to think on a more abstract level apart from their perceptions and the objects of their perceptions. With simple seriation children at the concrete operational level are able to order a series of 10 elements immediately or with little hesitation. The major advancement at this stage is that children construct a schema, such as an increasing slope, for efficiently ordering the series. In the figure below,

children would mentally construct an increasing slope line which would allow them to quickly position the elements correctly in the series. The same occurs for a decreasing series except that the slope of the line is now reversed.

With serial correspondence, a new method for finding the corresponding pairs emerges at the stage of concrete operations. Not only do children easily use the methods of double seriation or simple seriation with correspondence, they now find a one-to-one correspondence between the dolls and the sticks without previous seriation, since they now consider the relationship between all elements. This is the method of direct correspondence and is characteristic of this level.

Finally, with ordinal correspondence, the combination of both the ordinal and cardinal aspects of the elements in the series are integrated. Children consider each element of one series as being equivalent to a single member of the other series, e.g., one doll = one stick. This concept allows children to understand that each position of each element in the series constitutes a number and that this number is inseparable from the total series. It is at this point that the nth element in a series represents both the nth position (ordinality) and has the value n (cardinality) (Piaget, 1965, p.p. 113-14).[3]

Other Developmental Studies in Seriation.

Linked with the previous studies are Piaget's experiments in which children are instructed to draw a series to find out whether children can anticipate the series before they can physically construct it through manipulation of the sticks. In this experiment children were given the doll-stick problem mentioned. The dolls were arranged; children were to order the sticks by making drawings, first in black and white and then using colored crayons that could be matched to the sticks. Afterwards, children were allowed to seriate the sticks physically. The results show that 89 percent of the children at four years of age could not anticipate or do the physical seriation. By age 6, 73 percent of the subjects had achieved global seriation, constructing a correct drawing in black and white but not in color. When this same group was allowed to perform the actual seriation, 36 percent achieved perceptual seriation,

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[3]Piaget has explored the relationship between ordinal and cardinal correspondence more completely in an experiment in which the dolls and sticks are not separated into rows. Questions are then asked of parts of the series (Piaget, 1965, p.p. 114-21).

22 percent operational seriation, while the remainder failed to seriate. By age 7, 80 percent of the children achieved complete anticipation, that is, they could make a drawing showing the correct seriation complete with the corresponding colors. During the actual seriation, 80 percent of the children achieved operational seriation on the actual task, while 20 percent could perceptually seriate, and no one failed to seriate (Piaget, 1964, p.p. 252-53). It has been hypothesized that the drawing of the anticipated seriation is abstracted from the "subjects own actions in relation to seriable objects instead of being directly abstracted out of his perception" (Inhelder and Piaget, 1964, p. 260). The drawings are then an internalized reproduction.

Further investigations to determine whether the drawings represented internalized actions were conducted. In these studies children were allowed to seriate the sticks through their tactile senses. The results showed that anticipation[4] was achieved before actual seriation, as in the visual experiment. Furthermore, the general age at which the various levels of seriation by touch was mastered lagged behind the visual experiment when the same series of 10 sticks were used. However, when the size of the series is reduced to five elements and the difference

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[4]The drawings to evaluate anticipation were done visually by the children.

between the elements is increased, the results of tactile seriation of 4-5 year old children were superior to that achieved in both the tactile and visual test given with the 10 rods. These results support the assumption that anticipation evolves out of the organization of actions as well as perceptions (Inhelder and Piaget, 1964, p. 268).

In the few studies of seriation using different dimensions, i.e., length, size, weight, Holowinsky (1970) found that preschool children (3-4 years) were incapable of generalizing whay they learned on serial tasks of size to serial tasks of length. By age 6, children achieve a correlation of + .75 in their abilities to work in two modalities.[5] Piaget found that children, working on the seriation of weight tasks, reached operational competence two years after they had achieved the same competence in seriation of length (Inhelder and Piaget, 1964, p. 251).

Finally, Piaget found that <u>multiple seriation</u> tasks are mastered at around 7-8 years in Western European and North American children (Inhelder and Piaget, 1964; MacKay, 1970, p. 787). Bruner and Kenny (1966) experimented with the age at which different tasks in multiple seriation were mastered. They constructed a 3 x 3 matrix of glasses that varied in three degrees of height and three

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[5]An r = + 1.0 means children can work with a perfect transfer between two modalities.

degrees of diameter. Children were given three different tasks to perform: replacement, reproduction, and transposition. In the replacement task children were asked to put back into the matrix the three glass beakers which they had seen the experimenter remove. This was accomplished for the majority of children at around five. With reproduction the glasses are scrambled and children must reproduce the matrix as they originally found it. This is accomplished at about age six. In transposition one corner glass is moved to an adjacent corner of the matrix and children are asked to complete the matrix with the glass in its new position. This is more difficult because children must transpose the pattern in their mind. Competence in transposition begins at about seven years.

This concludes the theoretical portion of seriation. The importance of seriation as a process of learning competence which provides for the organization of differences cannot be underestimated. Seriation provides a beginning point for other processes, for without the ability to differentiate and integrate both differences and similarities (classification), children would be incapable of understanding a more complex process like conservation which requires both seriation and classification to understand how a characteristic of a system can remain unchanged despite physical changes in its appearance.

Conservation

Definition.

Conservation is a process of reasoning applicable to physical and biological systems in the environment as well as abstract concepts by which an invariance or constancy is maintained across a transformation. More explicitly, this refers to a characteristic of those parameters like weight, volume, or area, which remains unchanged despite physical changes in their appearance such as shape, water level, density of objects, etc.. Moreover, conservation is part of learning competence since children must identify the relevant parameters of an object or group of objects (differentiate) and then recognize the invariance of that parameter during different transformations (integration), i.e., clay ball = clay cylinder.

Elaborate Description.

Research concerning conservation defines the process in the following ways. It is:

1. the principle of identity which is implied explicitly or implicitly by every notion, whether it be scientific in origin or a matter of common sense (Piaget, 1965, p. 3), and

2. the mental act of maintaining quantitative constancy and the result of this act by an equilibrated cognitive structure (DeVries, 1969, p. 2).

These two definitions can be integrated with ANISA's concept of learning competence which will yield a refined and comprehensive notion of this process.

In any conservation system an equilibrium is established. In the experiment with the clay ball, the equilibrium is between the amount of clay in the clay ball and the clay cylinder when the shape is changed. This equilibrium reduces the complexity in the environment since it results in the formation of interrelationships.

In terms of learning competence, conservation contains two components, a differentiative aspect and an integrative aspect. The differentiation comprises the identification of what quality remains invariant as opposed to the qualities that vary. With the clay ball/clay cylinder experiment, it is the amount of clay. However, if the child focuses on the shape, there is really no conservation, since shape is not conserved.

The integrative component is the ability of the child to follow this quality across a transformation and see its invariance. The clay ball is squeezed into a cylinder, but since no clay is removed, the amount stays the same (is conserved). Amounts are compared and found to be the same, or invariant.

Another component of learning competence is generalization which is limited in capacity until the child reaches the period of formal operations. Previous to that stage children who attain conservation of the amount of substance such as clay cannot generalize that experience to the amount of water or any other liquid. The only generalization they are capable of is with the substances which are very close to those used in the successful task, i.e., solids like mud, wet sand, or rubber. Children definitely do not generalize something like conservation of matter to conservation of area since in the latter instance, area requires some competence with spatial forms.

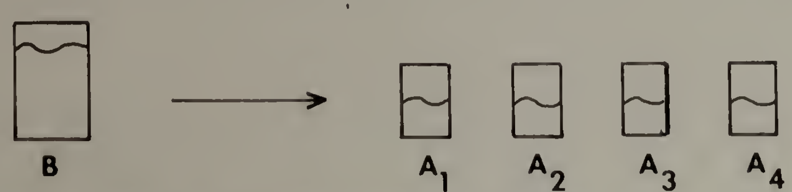
Research on conservation has demonstrated that several patterns of thought emerged in those children who were successful conservers. These patterns are characteristic of what Piaget terms reversibility. In addition, certain key concepts reappear frequently regarding the distinction between qualitative as opposed to quantitative constancy, identity as contrasted with equivalence conservation, and first-order versus second-order conservation. These subjects, together with a section of examples of the more frequently used conservation tasks, comprise the contents of the next sections.

Conservation and Reversibility. Reversibility is a characteristic of thought which enables children to comprehend equilibrium systems like conservation through the knowledge that a cognitive operation can return to its point of departure (Piaget, 1966, p. 113; Brainerd and Allen, 1971, p.p. 129-30). There are two types of reversibility understood by elementary school children which are important for the preschool teacher to know. These are:

(1) inversion or negation which is the cancellation of an operation through a combination of the original operation with its inverse, and

(2) reciprocity which is the cancellation of an operation by compensating one effect by an offsetting factor.

Examples of inversion and reciprocity can be demonstrated in the experiment on conservation of liquids where water is transferred from a large container to four smaller ones.

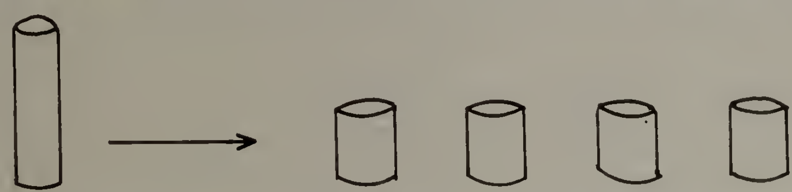


Children can perform the process of inversion or negation by pouring the water from the four beakers back into the large beaker, thus cancelling the operation by reversing the transformation. Inversion also involves additive compositions characteristic of class relationships. In the example, B is differentiated into subcomponents or parts, A_1, A_2, A_3, and A_4. By recombining the parts (integration), the system can be returned to its point of departure, $A_1 + A_2 + A_3 + A_4 = B$.

In the transformation from the large container into the smaller ones, there is an increase in area as the water is subdivided, which gives preschool children the notion that the amount of water has increased. However, within each smaller container the water level is lower than in the larger container leading to the opposite notion that there is a decrease in water. If children can put these two occurrences together, the increase in surface area can be compensated by the decrease in the height of the water. Such reasoning is an example of reciprocity which consists of a system of compensations between relationships or differences.

Qualitative and Quantitative Invariants. The difference between these cognitive invariants concerns both the attributes of the objects and the nature of the transformation. Qualitative invariants include properties like color and shape, attributes which are not readily measureable. Qualitative invariants also include the existence of physical objects or living beings across transformations, a conservation of the permanent qualities of that species (DeVries, 1969, p. 2). This includes the belief in the existence of an object when it has disappeared from one's perceptual field or the growth of a living species over a period of time. In the latter case a tree, two years old with no leaves, maintains its existence as a tree two years later even though it is full of leaves and has a vastly different appearance.

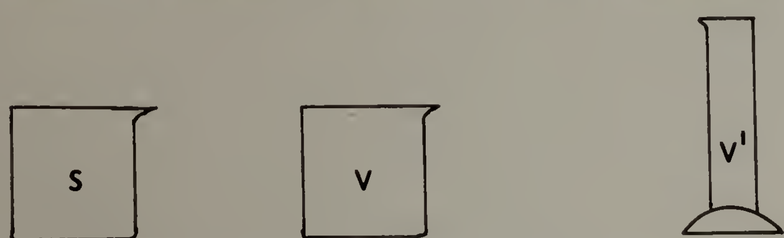
Quantitative invariants involve attributes that specify "how much" and which are measureable, for example, length, number, weight, and volume. These invariants make up systems where there is a change in the physical appearance of an object but no change in the amount of that object. Such a system occurs when water is transferred from a tall glass into four smaller containers. The number of smaller containers gives the appearance that there is more water in the four glasses combined than in the one original glass,



when, in fact, the quantities of water are the same.

The second difference between qualitative and quantitative constancy is that the process of thinking necessary for understanding conservation between these two is different. Since qualitative invariants are not readily measureable, processes of seriation and class inclusions (which involve additive compositions) are not understood by children at this level. Therefore, processes of reversibility such as inversion and reciprocity are non-existent at this level. Instead, children use a simpler process called <u>identity</u>, which consists of determining the attributes of the objects before and after the transformation. If these attributes remain unchanged, then children will reason that conservation has taken place. With <u>quantitative invariants</u> both classification and seriation are easily understood so that reversibility in the form of inversion and reciprocity are now the patterns of thought (DeVries, 1969, p. 2). Reversibility can then be used to conclude that changes of amount are not occurring.

<u>Identity and Equivalence Conservation.</u> Elkind (1970) has identified two stages in a typical conservation task which can be demonstrated as follows. In the experiment on conservation of continuous quantity, two beakers of water are shown to children and they can adjust the level of water in the beakers until they conclude that the amount of water in each is equal, standard (s) = variable (v).



Water is then poured from v into a tall cylinder (v') and children are asked to compare the amounts of water in s and v'. This comparison Elkind called <u>equivalence conservation</u>. However, children must also compare the amount of liquid in the graduated cylinder (v') with the same liquid when it was in v. This comparison Elkind named <u>identity conservation</u>. Both of these comparisons involve amounts or qualitative invariants which means that identity conservation as used by Elkind in no way implies the process of identity previously mentioned in the last section.

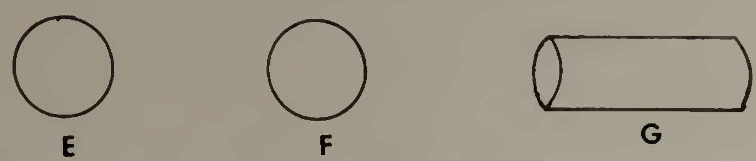
Many studies have been done to determine which type of conservation occurs first, but the results of these investigations are in conflict. Elkind (1967), Hooper (1969), and McManis (1969) have evidence which supports the priority of identity over equivalence conservation. On the other hand, Piaget (1952), Inhelder and Piaget (1963), and Northman (1970) contend that the two concepts occur simultaneously. While these studies have not resolved the matter, it is important for the ANISA teacher to be aware of the separate steps of identity and equivalence since the different comparisons could be used in diagnosing students who experience difficulty with the concept of conservation.

It should be briefly mentioned that Bruner (1966) has found that preschool children at very young ages (3-4 years) believe that the quality of water changes during transformation. He found that when a toy duck and the water it was in (called a pond) was transferred into a different container, children believed that the water was not the same, that it was "different water". Bruner calls this constancy in the property of water "identity" which is confused with the word "identity" used by Elkind and others. Bruner's notion of identity is concerned with qualitative invariants and is understood to mean "process of identity" which was previously mentioned. This is contrasted with Elkind's "identity" and "equivalence" which are understood through the process of reversibility, namely, inversion and reciprocity.

First-Order and Second-Order Conservation. The essential difference between first-order and second-order conservation involves the types of reversibility and the degree of abstraction which are required for their understanding. First-order conservation, which encompasses parameters like weight, area, continuous quantity, number, etc., can be understood by either the inversion or reciprocity form of reversibility, and these types of conservation are rather easily demonstrated by concrete objects in the physical world. Second-order conservation, which includes concepts like volume, density, uniformly accelerated motion, etc., necessitate the use of inversion and reciprocity simultaneously (called correlation), and examples of these types of conservation are not easily demonstrated concretely since they are more theoretical or abstract notions created to understand more complicated phenomena. Second-order conservation is discussed in detail in Chapter IV on formal operational thought.

Types of Conservation. In order to assist the teacher in understanding the universality of conservation in the physical world, some of the common conservation tasks are described below. All normative data will be given in the section on development.

Conservation of Substance (Mass). This type of conservation is performed with two clay or plasticene balls of equal size and weight. Children are allowed to add or subtract clay until they agree that the amount of clay in

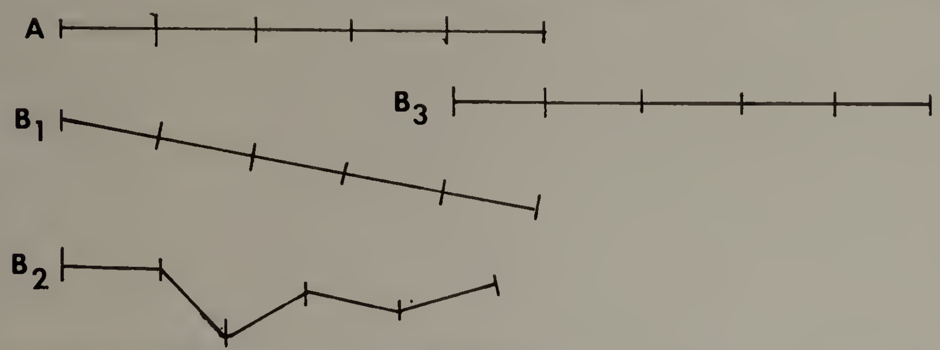


E is the same as that in F. Then one of the balls (F) is transformed into a different shape, e.g., a sausage, or a pancake. Comparisons are made between F and G. Certain shapes lead to specific intuitive answers depending on the individual child. A pancake may appear to have lost substance, while a cylinder gives the impression that the amount of clay has increased. Children must learn to disregard these perceptions in order to solve this conservation task.

Conservation of Weight. This task is given in exactly the same manner as conservation of substance, except that a scale is introduced to determine the weight. There is less intuitive reasoning with this task because the scale can be the final proof that weight is conserved if a child is familiar enough with its use (Brainerd and Allen, 1971, p. 135).

<u>Conservation of Length.</u> One variation of this task is to arrange two parallel rows of 10 match sticks so that their ends are perfectly aligned and the equality of length

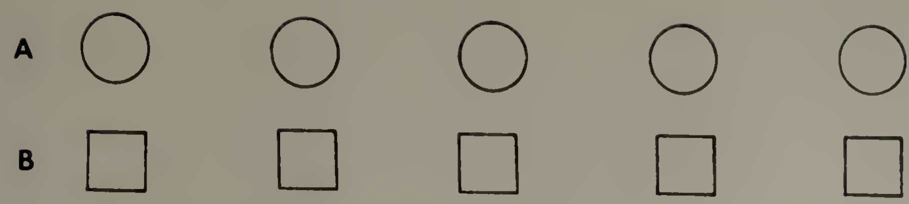
between row A and B is obvious. Then a number of transformations are performed and the sticks in row B can be arranged in a slant (B_1) or a zigzag pattern (B_2), or moved



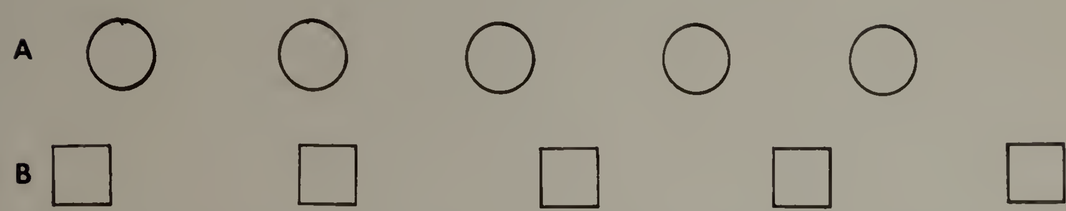
so that the ends are no longer aligned (B_3). A question is asked about the equality of each transformation in comparison with row A. This question might be phrased, "If you were traveling on one of these roads, on which road would you have to travel the farthest?".

Conservation of Number. Number conservation entails the following procedure:

1. two rows of objects containing equal numbers of elements are placed before children as illustrated, and they are asked to confirm their equality;

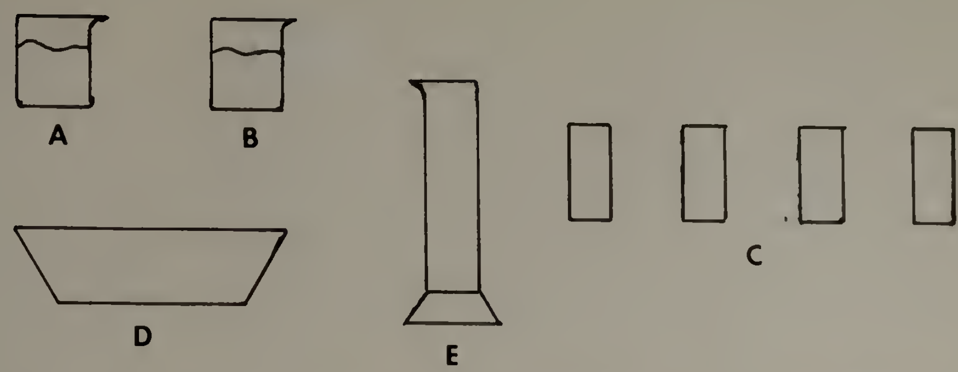


2. the distance between the objects in one row is increased or decreased so that the rows are of unequal length and the child is asked, "Does one row have more objects than the other or are there the same number of objects in each row?".



This task involves the use of one-to-one correspondence and the cardinality of numbers (Brainerd and Allen, 1971, p. 132).

<u>Conservation of Continuous Quantity.</u> This task has been introduced earlier in the paper in the experiment where water was transferred from a large container into four or more smaller ones. In this task an initial comparison is made between water in two containers of the same size, A and B, before the transfer is made to container C. Other variations include transferring the water from container B into: (1) a container which is shorter but wider than the original (D), and (2) a container which



is taller but thinner than the original (E). These three variations are presented in sequence and the child must consistently be convinced of conservation to be competent at the concrete operational level (Ginsburg & Opper, 1969, p. 162).

Conservation of Discontinuous Quantity. This task is identical to the conservation of continuous quantity with the exception that beads are used in place of the liquids. Beads can be thought of as discrete discontinuous particles since the total volume of beads can be subdivided into individual units. By using beads, the effect of one-to-one correspondence is introduced as a factor influencing the attainment of conservation.

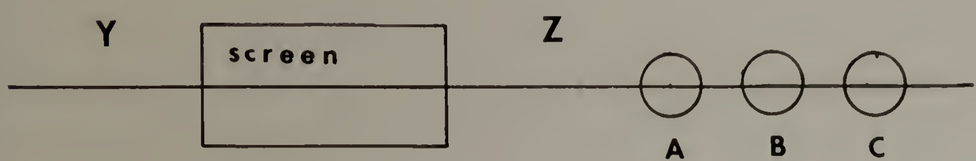
The task begins with a comparison of the amount of beads in containers A and B (refer to previous diagram).[6] Children are allowed to adjust the heights of each container

[6] In the experiment, different colors of beads are used for each container for clarity.

until they become convinced of their equality. Then, transformations are made to containers C, D, and E and children are asked whether necklaces made from the beads in each of these containers would be equal in size.

One-to-one correspondence can be introduced by repeating the above steps after children have initially placed the same number of beads in containers A and B. Research by Piaget indicates that one-to-one correspondence is not sufficient for conservation, but it is an intermediate step (Piaget, 1965, p.p. 25-50).

Conservation of Order. This task contains the use of three elements, e.g., balls of various colors labeled A, B, and C and strung on a wire. These objects are



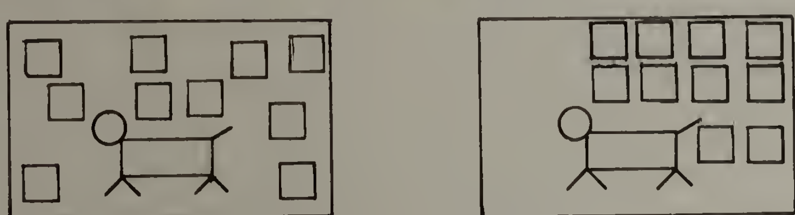
passed in order, A--B--C, behind a screen and they emerge at the opposite end Y. The following questions are introduced with their respective tasks:

1. In what order will the balls emerge from end Y?
2. In what order will the objects reappear if they travel through the tunnel in the reverse direction, emerging at end Z?

3. The questions are repeated after the child moves to the other side of the screen (in back of it).
4. The three balls are placed in the experimenter's hand and in full view of the subject they are rotated 180° so that ball C is in the position where ball A is in the diagram above and vice versa.
5. Task 4 is repeated only the balls are rotated 360° leaving the order unchanged.

The major focus of this task is to discover whether children recognize that the order of the balls remains unchanged when emerging from the tunnel at side Y and that the order is reversed when the balls emerge from side Z.

<u>Conservation of Area.</u> This task involves the comparison of two equal areas of space with respect to the amount of grass a toy cow has to eat. The grass is simulated by equal rectangular sheets of green cardboard or blotter paper, and the experiment proceeds by introducing identical



A_2 A_1

wooden blocks, which represent barns, one at a time into areas A_1 and A_2. The blocks in A_1 are placed next to one another while the blocks in A_2 are spread apart. As each block is placed into the areas, the question of which cow has more grass to eat is asked.

Justification.

In the beginning description of conservation, it was mentioned that children must recognize parameters that remain constant during transformations in order to be competent conservers. Therefore, by its differentiative character, it is a key process of learning competence.

Piaget views conservation ". . .as a necessary condition of all experience and all reasoning." He claims that the process of reasoning achieved through the building of a system of abstract concepts ". . .requires a certain permanence in their definitions" which the operation or process of conservation fulfills.

Piaget and others speak of conservation as forming the basis of mathematics and the resultant systems of measurements. Piaget has written that ". . .a number is only intelligible if it remains identical with itself, whatever the distribution of units of which it is composed . . ." and the set,[7] another fundamental concept in number systems, ". . .is only conceivable if it remains unchanged

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[7]A set is defined here as a collection of objects which are grouped together on the basis of some criteria which all members of that set share.

irrespective of the changes occurring in the relationship between the elements, i.e., conservation (Piaget, 1965, p.p. 3-4). Regarding systems of measurement, Lovell and Ogilvie (1960) have stated that ". . .the notion of invariance is essential to any kind of measurement in the physical world."

Conservation forms the basis of the physical sciences. "Conservation of rectilinear and uniform motion made possible the development of modern physics. . .(while) conservation of matter and energy made modern chemistry possible" (Piaget, 1965, p. 3). In addition, conservation has broader implications in the sciences if the relationship between man and his environment is viewed as a equilibrium system (ecological conservation). Such a system is fundamental to the belief of the American Indians that whatever man does to shape his environment must be accomplished without destroying this delicate balance between the physical and biological world.

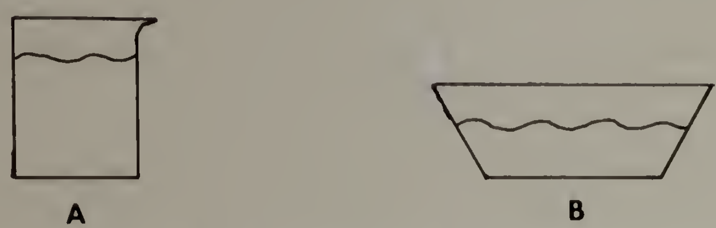
Systems of conservation apply in other domains besides the cognitive. For instance, in the affective domain love is a very important emotion. Yet, there can be much diversity in its expression. The behaviors which characterize the love between parents and children can vary from the warm reassurance of parents during times of stress to firm guidance in periods of discipline. One might say that the expression of love is conserved in this transformation and that although the outward behaviors are perceptually different, the inward concern of parent for child (love) is the same. This conservation in one's emotional life is just as important for growth to children as conservation in the physical world is.

Development.

In this section first-order conservation is discussed as it pertains to the sensorimotor, pre-operational, and concrete operational stages of growth. The sensorimotor and the early part of the pre-operational growth periods involve qualitative invariants while quantitative concepts are developed in the later preschool ages, but are not mastered until the concrete operational stage.

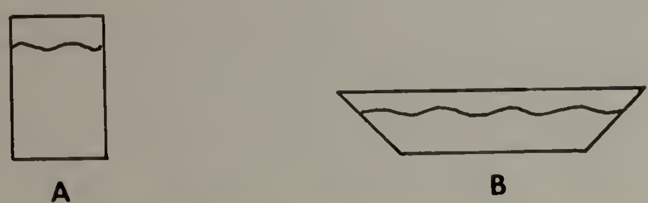
Sensorimotor Growth (0-2 years). The beginnings of conservation are found in children's mastery of object permanence. Object permanence concerns the belief that an object exists even though it cannot be seen or heard. This is in a sense an early conservation task where an object undergoes a transformation of being removed or hidden from one's senses. Yet, it still exists as the original object. Without the conviction of permanence in the physical world, children are ill-equipped to handle the more complicated transformations which regular conservation demands.

Pre-Operational Growth (3-7 years). Growth during this period can be divided into two parts. One is growth in understanding the conservation of qualitative constancies; the other concerns the growth of quantitative invariants. With regard to qualitative invariants, research has shown that identity as defined by Bruner is achieved between the ages of 4-5 years as children internalize the process of "identity" which comprise transformations which have no effect on the quality of a substance, e.g., water being poured from container A to container B is the same water (Bruner, 1966).

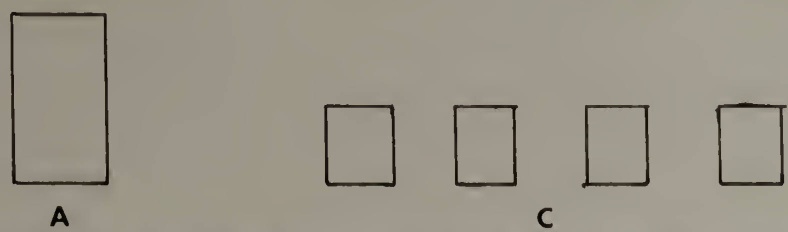


Another type of conservation acquired at this stage is generic identity, which is the belief that the identity of a living being is constant across transformations (DeVries, 1969, p. 56). In DeVries' experiment, masks of different animals were placed on household pets to examine children's beliefs in constancy. Although this experiment has been criticized as inconclusive because of the methodology, her experiment raises the question of constancy among living things. It becomes very important in children's understanding of the growth process over time, e.g., the contrasting appearance of a plant two months after planting does not alter the identity of the plant.

As qualities begin to be differentiated, they form differences which children can measure,and this marks the beginning of the quantification (Piaget, 1965, p.p. 10-11). During this pre-operational stage, two distinct phases have been isolated: (1) the stage where there is an absence of conservation (3-5 years), and (2) a stage of intermediary reactions (5-7 years). During the stage where there is an absence of conservation, children find it natural for solids or liquids to vary in quantity according to the shape of the object of the container it is placed in. So when the water is poured from container A to container B it is

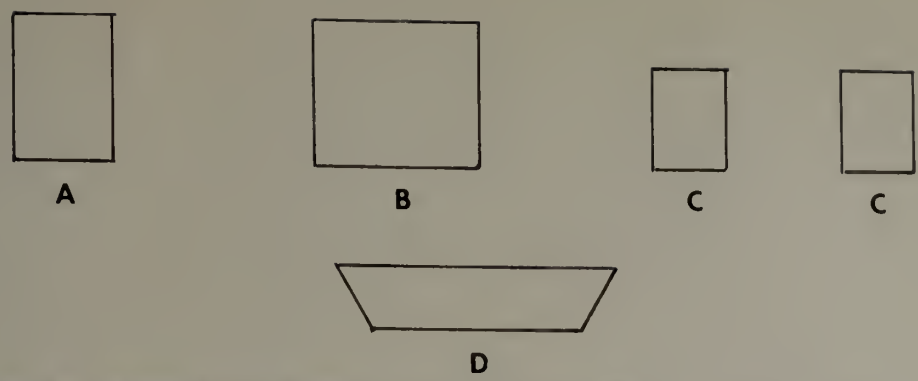


perfectly reasonable to expect the amount of water to change because one level is lower than the other. Because quantification is confined to estimates based on perception, children do not understand the inverse relationship which exists between a decrease in height and an increase in width as demonstrated in container B. Moreover, these perceptual estimates are not characterized by combination. This prevents children from understanding the relationship between the whole and the sum of its parts. When children see a liquid being poured from container A into containers C it is perfectly consistent with their level of thought to assume that there is more water in the four containers,



which present a perceptually overwhelming arrangement, than in the single container A. Children at this stage have not grasped the fact that a liquid can be partitioned into smaller and equal units while remaining quantitatively the same. Furthermore, they do not realize that the quantity of a liquid does not depend on variables like height or cross-section of the containers, number of containers, etc. (Piaget, 1965, p.p. 5-13).

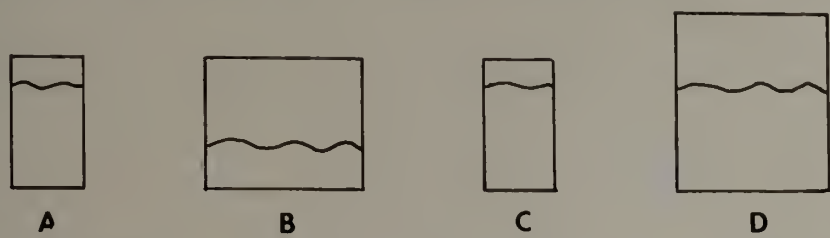
In stage 2, that of intermediary reactions, children believe in constancy across transformations as long as the perceptual disparity between the beginning point and end points is not too great. Children attempt to coordinate the changes in the height and breadth that occur when water is transferred between beakers A and B or A and C and succeed when the transformation is slight. In A and B the water levels are only slightly different and children will be convinced that the quantity of water has not changed



during a transfer between the two. This conviction is lost when a container like D is used, which results in a greater difference in levels.

A parallel situation exists with containers A and C. As long as only two C containers are used, children comprehend the invariance because they understand that a whole remains identical with itself when it is subdivided into two halves. However, when three or four containers are used, perceptual influences become predominant, and the ability to conserve is impaired. One child at this level has said that the more a given quantity is subdivided, the more there will be of it (Piaget, 1965, p.p. 13-17).

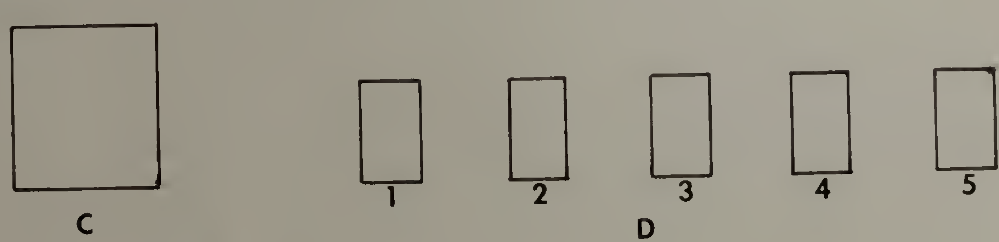
Concrete Operations (7-11 years). During this period of growth, the stage of necessary conservation is mastered. During this time children's answers reveal a very natural belief in conservation irrespective of the number and nature of the changes made. This belief in conservation occurs because children are now able to comprehend the logical multiplication of relations and simple proportions involving numerical partitions. Multiplication of relations allows children to compare the change in amount of liquids transferred between two containers or forms from two different points of view as long as: (1) the two relationships vary in the same direction, (2) one remains constant while the other varies, or (3) both remain constant. To illustrate, containers A and D are examples of two relationships varying in the same direction, since container D



is both taller and wider than container A; containers A and B illustrate the case where one relationship is constant, the height, while the width varies and containers A and C illustrate the case where both height and width remain the same. However, logical multiplication does not allow children to compare the increase, decrease, or invariance of quantities when relationships vary in two opposite directions simultaneously, e.g., when container B is shorter in height, but wider than container A.

The second process which emerges at the concrete level and which complements logical multiplication is that of simple proportionality and arithmetical partitions. This process allows the coordination of at least two relationships that vary in opposite directions, e.g., a container that increases in height while at the same time decreases in width, or a quantity of liquid that decreases in level while the width of the container increases. Children can eventually coordinate such relationships because with the schema of proportions or numerical partitions, asymmetrical relationships of differences can be equated. For example, children can, at this stage, understand that a difference in height can be compensated or equated with a change in width. It is this combination of equality of asymmetrical differences that defines proportionality.

Moreover, proportionality implies partitions. When differences are equated, the whole is structured as a combination of its parts, that is, when an increase in the level of a liquid is equated with a decrease in width, the whole is no longer viewed as a qualitative totality whose value changes with the shape of the container. At this stage, children can now comprehend the constancy in the quantity of a liquid when it is poured from container C into containers D. Numerical partition is then also an



equating of the different levels in the D containers, which are shorter in height, narrower in width, and lower in level, to the whole amount of liquid in C, which is taller in height, wider, and higher in level, $C = D_1 + D_2 + D_3 + D_4 + D_5$. It is this schema which, when combined with a number system, provides the basis for understanding more complex phenomena at a later period of growth.

Unfortunately, an understanding of conservation on one task does not insure that the conservation of other types will also be understood. There is a horizontal <u>decalage</u>, e.g., gap or lag, or a different period at which each of the concepts are understood, for example, the conservation of number and area are not understood at the same time. Studies demonstrate that we must be cautious in assigning age norms for different conservation tasks since children proceed in their development in different ways, depending upon their experience. Thus, all age norms assigned to the stages of growth are only approximate and not specific.

Referring to specific conservation tasks, the conservation of number appears to be the first process mastered. Brainerd (1971) and Piaget (1965) found that children achieved competence in this area between the ages of 5-7 years. In addition, training studies by Wallach and Sprott (1964) report that conservation of number was successfully taught using first grade children between the ages of 6½-7½ years.

There are three conservation tasks which can be discussed together since they involve children's concepts of space, namely, the conservation of length, of area, and of order. Conservation of length, which might be considered the conservation of space in one dimension, was found to occur between 5-7 years by Brainerd (1971) and between 7-8 years by Murray (1965), although Murray's experiment could be discounted because it was not the traditional Piagetian one. Conservation of area, which demands coordination of relationships in two dimensions, was found to occur sometime after 7 years of age (Beilen and Franklin, 1962). Finally, conservation of order is achieved at different times, depending on the complexity of the task. For instance, simple order -- question 1 (described on page 106) is mastered at 4 years; reverse order is contemplated between 5-6 years; and the complete experiment together with the rotation sections is understood at about 7-8 years (Piaget, 1970, p.p. 3-32).

With regard to the conservation of solids and liquids, Elkind (1961) found that conservation of substance was understood at 7-8 years. He found the age range for competence in conservation of weight to be around 9-10 years, which conflicts with Furth (1964) who found that his sample of $6\frac{1}{2}$ year old normal subjects were able to conserve weight while his sample of deaf children succeeded at 8 years. Finally, both conservation of continuous and discontinuous quantities occur after the conservation of substance, since the shape of the containers which hold the liquids offer a greater perceptual distraction to children.

This concludes the theoretical discussion of conservation. Both seriation and conservation form a base for understanding logical thought. In the previous section, these competencies were viewed for the most part as logical operations, differentiating and integrating objects in the physical world apart from considerations of time and space. This chapter now proceeds to a discussion of time and space relations where both seriation and conservation will reappear as sub-logical processes.

Cognitive Space

Definition.

Cognitive space is comprised of a system of processes which enable children to coordinate objects in their environment with respect to their location and orientation within their surroundings. This understanding rests in knowing procedures for: (1) comparing objects in isolation from the remainder of the environment (topological space), (2) coordinating objects from different viewpoints within the environment (projective space), and (3) locating objects within the total environment with respect to a well-defined reference system (euclidean space). Each of these processes requires a differentiation of objects into their subcomponents to create a total spatial framework. For example, in the comparison of two triangles to determine their congruency, a differentiation is made so that lines which represent the sides of the triangles and the angles of each triangle can be compared. Then by matching (a form of integration), congruency can be determined (i.e., whether the amount of space which each of these figures enclose is equivalent).

Elaborate Description.

The development of children's conceptions of space progresses at two distinctive levels, perceptual and cognitive. These levels are analyzed in the beginning of this section to clarify what cognitive space includes.

Perceptual Space. The development of perceptual space rests on the interaction of children with their environment on the sensory level and the evaluation of the organization which results from the feedback provided by one's motor behavior. Perceptual space does not include representation of space with internal mental symbols since this is the concern of cognitive or operational space. Perceptual space is concerned with phenomena such as illusions, thresholds or sensitivity, the general concerns surrounding the growth of sensitivity of human sense receptors, and simple imitation. Simple imitation involves the repetition of a stimulus in the environment through motor behavior while that object or event is being perceived (visually or otherwise). While this involves the use of symbols in the sense that the child's imitation symbolizes a part of the environment, imitation at this level does not involve the reconstruction or reorganization that cognitive space does.[8]

Perceptual space utilizes symbols at the index level. This means that an object or event is symbolized by a part of that same object or event. If a child discovers the handle of his rattle, the handle becomes the symbol for the complete rattle. Likewise, footprints in the snow may

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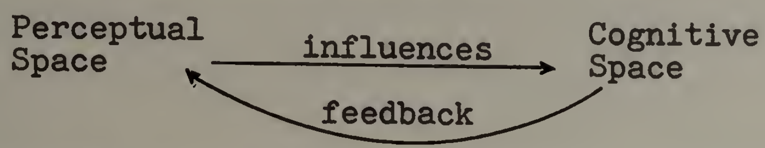
[8]Cognitive space requires an internal structure composed of mental symbols.

symbolize the event of walking through the snow (Opper & Ginsburg, 1969, p.p. 80-82).

Perceptual space is not confined only to early childhood but progresses throughout life influencing, while at the same time being influenced by, competence in cognitive spatial processes (Laurendeau and Pinard, 1970, p.p. 9-12).



The diagram above illustrates the interdependence between these two forms of growth.[9]

<u>Cognitive Space.</u> Cognitive space is synonomous with the terms "representational space" or "operational space". Cognitive space depends upon the use of internal mental symbols which allow observed actions to be accommodated (internalized). This is first evident in children's imitation. Children who competency in cognitive space are capable of delayed imitation, which is the reproduction of an object or event after a length of time has passed. Eventually, children's capacity for imitation is increased through the use of images which in turn symbolize that set of objects or events. Any subsequent psychomotor behaviors, which would

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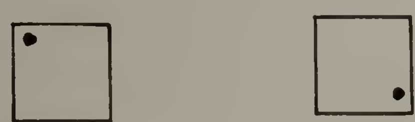
[9]Piaget indicates that topological, projective, and euclidean space have a perceptual as well as a cognitive aspect. However, he does not elucidate beyond these statements.

indicate the presence of these images, is reduced to slight muscle movements and eventually cannot be directly observed. Spatial concepts, then, are more than mental symbols; they are internalized actions which represent space as a set of displacements (Piaget, 1967, p. 451; Laurendeau & Pinard, 1970, p.p. 9-12). These actions are recalled by a means of signs[10] and symbols which actually represent the logical processes children use to comprehend their environment. For instance, in the figure below children at a certain stage of growth would conclude that figures A and B are equivalent by the proximity of the parts of A and B to their respective wholes, that is, the distance of the dots to the corners of each square. This process then becomes internalized and can be repeated mentally for all similar comparisons (Piaget, 1967, p. 452).



A B

Levels of Cognitive Space. The development of children's understanding of space from the introduction of their first rattle and continuing to sophisticated concepts of geometry can be subdivided into three levels mentioned in the definition section above. These three levels consist of understanding components of the environment in three different

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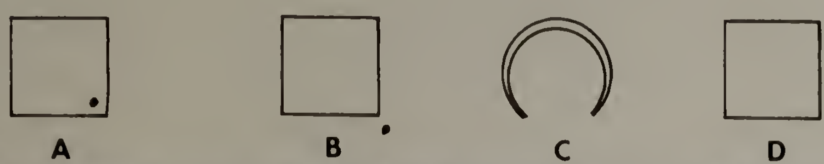
[10]Signs are symbols of objects or events, i.e., footprints in the snow indicate that someone walked through the snow, the handle of a rattle indicates the presence of the complete rattle.

ways: (1) in isolation from the rest of the environment (topological space), (2) from different perspectives within the complete environment (projective space), and (3) within a framework of a reference system (euclidean space).

Topological space is the study of comparisons between spatial boundaries and other parts of figures generated in isolation from the rest of the environment. For example, in the figures below A and B can be differentiated since the point is inside the square in A and outside in B.



Figures C and D can be differentiated in different ways: (1) C is an open figure and D is closed, (2) D has four sides while C is continuous, or (3) C is round and D is not. From these examples, one can conclude that the comparisons are manifested on the basis of one-to-one correspondence between the parts of the figure (Piaget, 1967, p. 153). The figures are compared by focussing only on the objects involved apart from their relationship with their surroundings. The resolutions of these spatial equivalences, determined by point-by-point correspondence form the basis for the study of topology.

In contrast to the other levels of space, topology does not define the shape or the orientation of figures with respect to planes or perspective as is the case with projective space. Furthermore, it does not include the construction of stable figures and the relationship between these figures which formulates a frame of reference characteristic of euclidean space (Piaget, 1967, p. 467).

Piaget has isolated five processes which develop competence in topological space when mastered: (1) proximity, (2) separation, (3) order, (4) enclosure, and (5) continuity (Piaget, 1967, p. 153).

These five processes probably develop with respect to all three levels of space (topological, projective, and euclidean).[11] These processes will be described after the sections on projective and euclidean space.

"Projective space .... begins psychologically at the (moment) when the object or pattern .... is viewed in relation to a 'point of view'." This 'point of view', known as perspective, can be that of the subject, or that of other objects"(Piaget, 1967, p.p. 153-54). Projective space also involves the coordination of perspectives of different observers. One example would involve the identification of how the location of objects in the environment would appear when viewed from different perspectives, for instance, a range of mountains viewed from different directions. Congruent with the character of sub-logical operations, projective space "is concerned with the intercoordination of objects

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[11] It should be noted that this is not Piaget's viewpoint but that of the author. Although Piaget hints that these five processes might occur at all three levels he never clearly specifies this.

separated in space, rather than the analysis of isolated objects" (Holloway, 1967, p. 28; Piaget, 1967, p. 154).

In contrast to later development, projective space does not include the process of conservation with respect to parallel lines, geometric angles, or linear and circular distances. These concepts develop later and conclude with the formation of reference systems characteristic of euclidean space.

The transition between topological and projective space occurs with the differentiation of lines into categories of straight and curved. Children begin to initiate such differences by coordinating a series of points so that they line up behind or in front of one another thus defining a straight line. This physical coordination results in the formation of a projective straight line.

Piaget distinguishes between projective lines and lines formed according to perspective by maintaining that the projective lines are initiated by perceptual discriminations while perspectives are formed through children's power of imagination (Piaget, 1967, p. 171). In other words, a projective line is constructed based on perceptual judgments that the points which make up the line are alighned physically with one another, which perspective construction requires a creative orinetation based on one's imagination. For instance, the perspective a circle, rotated 90° about its diameter, is a straight line, and this process requires that the action of rotation would take place mentally with the result being inferred from that mental action.

After Piaget studied how children conceived of isolated objects such as straight lines and circles in perspective as they were rotated, he studied topics like the projection of shadows and the coordination of perspectives. These studies were coordinated to give comprehensive information on children's reactions toward viewing objects in perspective. One of these, the <u>projection of shadows</u>, allows children to see whether their imagination matches their perceptions since this experiment provides the perceptual answer to the question of how different objects appear when they are viewed from different perspectives. Another, the <u>coordination of perspectives</u>, allows children to imagine how the appearance of objects would look if they were in different positions with respect to the objects. It includes several objects instead of just one, evident in the previous experiments, and children must coordinate in three dimensions the position of these objects relative to one another.

<u>Euclidean space</u> can be studied as a transition from projective space or topological space. Considering its transformation from projective space, Piaget hypothesizes a series of intermediate processes that build the framework for the use of reference systems characteristic of euclidean space. These intermediate steps consist of affinities and similarities. <u>Affinities</u> are defined as transformations of figures

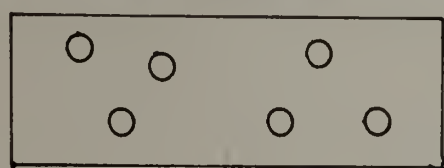
in which parallel lines are conserved. These are introduced by studying the sides of a square since it is easier to understand parallelity where there are two lines perpendicular to a third line. Next, children progress to understanding the parallelity of the sides of a rhombus as its angles are increased (see figure), and finally they are introduced to isolated pairs of projected lines, such as railroad tracks

drawn in perspective. In order to understand these instances of parallelity children begin to construct a reference system by determining whether the distance between two lines is constant since this defines parallelity (Piaget, 1967, p.p. 301-319).

The next intermediate step is an understanding of similarities, first involving affinities to construct the conservation of angles and then using movements, which are similarities conserving distances. The conservation of angles is constructed by determining the parallelity of two sets of intersecting lines which form the angles and gradually leads to a crude, non-metric understanding of proportionality between similar triangles and other geometric figures (Piaget, 1967, p.p. 320-74).

These steps conclude with the construction of distances which are the origin of truly euclidean space in its progression from projective space. In an experiment requiring children to place a doll on a diagram that is rotated 180° from the copy diagram, children solve the problem by imagining that the map is rotated. This process entails a

coordination of perspectives, rather than a mathematical locating of the doll according to a system of coordinates. In another experiment requiring a copy of a model showing the distribution of buttons, children first duplicate the



model using one-to-one correspondence, without locating the distances properly, that is, without conserving the distances. In order to properly duplicate the model children must use the edges of the paper on which the buttons are located to establish the approximate distances. Finally, with the appearance of mathematical relations, children duplicate the diagram exactly by the use of measurement.

This study shows the continuity in children's understanding between projective and euclidean space. A corresponding continuity exists between topological and euclidean space. This transition can be followed by observing the growth of children's notions of distance and changes of position. Distance is first understood as a subdivision of straight line intervals, e.g. the line AC being subdivided into intervals AB and BC. Changes of position are understood in terms of rank orders between various reference points, i.e., that point B lies between points A and C on path AC. moreover, children must also understand that paths AB and BA are equal, a form of conservation of length or distance. These processes occur in a linear or one-dimensional surrounding and are understood qualitatively (non-metrically) at first.

The corresponding processes also occur with two- and three-dimensional surroundings.

At the second level of understanding children use measurement to quantify distance and coordinate changes of position regardless of their location, orientation, or size. In this respect, the relationship between measurement, distance, and changes of position parallels that of number with regard to classification and seriation. Number allows quantification of classes and serial orders while measurement quantifies concepts of distance (classes) and changes of position (rank orders). However, while measurement is used to calculate linear distances and areas by coordinating the dimensions of the displacements, children do not comprehend the space enclosed by area or volume until adolescence. This final level in the transition from topological space to euclidean space is discussed in Chapter 4 of the thesis, which describes only adolescent thought.

In summary, one can follow children's early notions of distance, understood by topological concepts, and progress to euclidean notions. With a topological line children understand that point A precedes B, B precedes C, that interval $AB < AC$, and that B lies between A and C. Finally, topological understanding does not imply the conservation of distances (lengths), e.g., $AB + BC = AC$ or $AB = BA$, but it does provide the initial understanding for more sophisticated competence in comprehending distance and changes of position (Piaget, 1964, p.p. 389-408).

Processes For Understanding Space. It was previously mentioned that Piaget isolated five processes[12] of space: (1) proximity, (2) separation, (3) order, (4) surrounding, and (5) enclosure. Although Piaget discusses these processes chiefly in connection with topological space, the author believes that these processes are developed at all three levels. A description of each of these processes follows.

Proximity is a process of comparing figures or objects on the basis of the near-byness of the elements within their spatial configurations. It expresses the most fundamental

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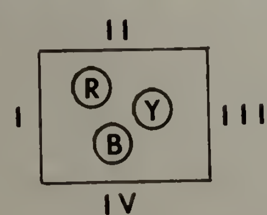
[12] The term process used here is the author's own conceptualization since he believes they meet the requirements of being reversible, resistant to extinction, and show an increased complexity with growth. However, Piaget calls these processes spatial relationships.

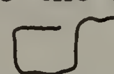
characteristic of the actions generated by children to understand the notion of space (Piaget, 1967, p.p. 6, 80, 86).

An example of proximity occurs in an experiment requiring children to duplicate a model consisting of a rod on which seven vari-colored beads are placed. Children are asked to duplicate the model on a separate rod. In early childhood they can place the correct colors on the rod but cannot place them in the correct order. This happens because children cannot preserve the proximal relationships originating in the model. Later, they can coordinate pairs, i.e. a red bead is correctly placed next to a blue one, but in general they lack overall coordination. It might be argued that this experiment involves a mere perceptual replication, however, to reconstruct a number of beads as large as seven requires that children function on the basis of "internalized actions" and schemas, which is definitive of cognitive space.

The above represents an understanding of proximity on a topological level. On a projective level, relationships involving the analysis of objects according to proximity are dependent on the point of view of the observer. In the diagram below, object Y is positioned between objects R and B if viewed from perspectives I and III; however, when viewed from perspectives II and IV, object B is located between



objects R and Y. Regarding euclidean space, these objects could be established precisely in metric terms since a well-defined reference system would be present. Proximity would take on a mathematical exactness which would provide unlimited comparisons with other objects (Piaget, 1967, p.p. 42-43).

Separation like proximity is the most elementary of spatial processes. Together, they are the first processes to emerge in the psychological development of cognitive space. Separation is a process of analysis which is the analog of proximity. This analysis involves the differentiation between elements of a figure for the purpose of comprehending the relationship between the parts and the whole (Piaget, 1967, p. 462). For example, in the development of children's reproduction of a triangle, children first differentiate the fact that it is a completely closed figure  and then their drawings indicate that they recognize the straight lines although they may be rectangular in shape  . Later in development children recognize the three angles  although the sides may not be completely straight (Piaget, 1967, p.p. 55-59). Thus the process of separation is demonstrated as it unfolds in children's conceptions regarding triangles.[13]

With the onset of projective space, objects are no longer viewed in isolation from their surroundings. This means that the process of separation becomes fused with other processes such as enclosure, spatial order, etc., so that it is

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[13]The triangle is analyzed as being a closed figure with straight sides having three angles.

difficult to study as an isolated process. This fact is important for the comprehension of true relationships occurring in perspective. When children observe two parallel lines such as railroad tracks converging in the distance they must use the process of separation to fixate their attention on the distance between the rails and integrate this perspective with their past experience. Only then can they discern the true relationship which exists between the rails and which represents parallel lines.

With regard to euclidean relationships, separation like proximity, takes on a metric character in terms of the association between the parts and the whole. Well-defined reference systems allow analysis through a separation of much greater distances because of the use of coordinates which utilize metric dimensions as characterized by maps which locate specific parts by referring to a set of coordinates.

Spatial order consists of the integration of the processes of proximity and separation within a framework that provides a sense of direction or orientation. Competency in spatial order consists of children being able to:

1) reproduce a model which has its elements arranged in a definite linear order, e.g., a necklace of seven differently colored beads (Piaget, 1967, p.p. 87-91);
2) translate circular order into simple linear order, e.g., using a necklace which is fastened to

construct the order of multi-colored beads in a lin
linear series (Piaget, 1967, p.p. 91-102);

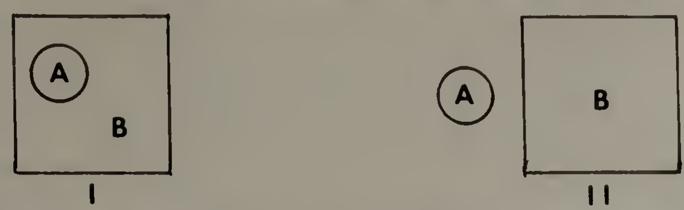
3) construct the reverse order of a given linear or circular sequence (Piaget, 1967, p.p. 84, 92, 98-99);

4) construct the reverse order of a set of objects which are stacked vertically (Piaget, 1967 p.p. 93-96);

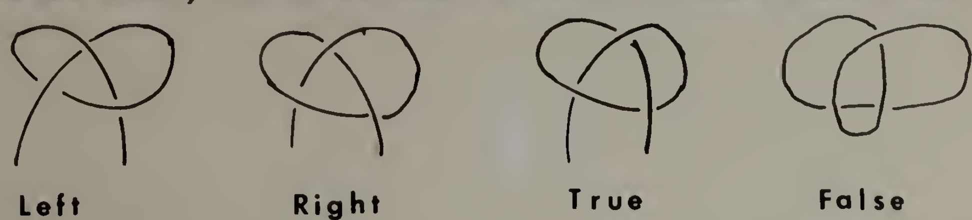
5) translate a series of objects constructed in a figure eight into a linear series (Piaget, 1967, p.p. 93-96).

At the topological level children can only correctly order objects spatially if the model they are asked to replicate is visually simple enough so that they can form a one-to-one correspondence between the elements of the model and the new construction. Later, as projective ideas become a part of children's competency, they are able to imagine different viewpoints so that they now become adept at constructing reverse orders of models or translating circular orders of objects into linear series. Euclidean space allows children to comprehend the reversal in order which occurs in the translation of the figure eight into a linear series since some frame of reference is needed to detect this change, e.g., clockwise versus counter-clockwise.

Spatial enclosure is a process which differentiates elements in terms of their surroundings in order to clarify spatial relationships. In one-dimensional linear relationships elements might simply be expressed as existing between surrounding elements, a type of proximity. In two dimensions enclosure is used to describe the location of objects which lie within boundaries of other objects, i.e., object A



lying outside of object B in figure II while is is inside or within the boundaries of object B in figure I. In three dimensions enclosure can be observed by studying children's encounters with knots. Knots are constructed from what appears to be a one-dimensional line or string which is transformed into a three-dimensional surrounding. In order to distinguish between a right and left-hand clover or a true from a false knot, children must discern three-dimensional



concepts like <u>under</u> and <u>over</u> which define the surroundings of the knots and distinguish them. In the examples above, the difference between enclosure and other processes, like proximity and order in the case of the linear arrangement of objects, might be obscured since enclosure is the integration of proximity, separation, and order. This more complete system allows children to comprehend complex phenomena like knots.

Since children cannot use reference systems or perspectives at the topological level, they understand dimensionality in a unique way. The location of a point between two other points defines a line and designates a one-dimensional surrounding; a point located inside of the walls of a closed figure or outside of that figure designates a two-dimensional surrounding; and a point located inside or outside of a box or other similar object defines a space or three-dimensional object (Piaget, 1967, p. 80).

The process of enclosure together with spatial order differ from proximity and separation in that they result in true Piagetian "operations" such as those of positioning which produces an ordered series, establishes correspondences (enclosures), and produces simple and multiple classes and relations. In contrast, proximity and separation are general notions of space prerequisite for operations (Piaget, 1967, p.p. 125-26).

It has been demonstrated that spatial order and enclosure are mainly extensions of seriation in the field of logical relations. In contrast, the final process of continuity is a higher level of the general notion of separation, and it is the sub-logical counterpart of the logical operations involved in separation and the unification of classes.

<u>Spatial continuity</u> is a process which allows children to infinitely subdivide objects and differentiate them into their basic constituents, and to integrate these basic

elements to form the whole. In terms of a concrete example, spatial continuity allows children to subdivide a 2-inch square into smaller and smaller squares, realizing that the basic characteristics of a square are present whether it is size A or size E. Eventually, children can see the most

infinite subdivision as being reduced to a point. It is at this time that children can see the synthesis of this series of points extended in different directions to reform squares of an infinite number of sizes.

The conceptions of continuity thus frees children from understanding space only through material content and is prerequisite for abstract spatial reasoning (characteristic of formal operations) which transcends ideas of visible subdivision and synthesis. These abstract notions extend the mechanism of analysis and synthesis beyond any physical limit (Piaget, 1967, p. 147).

Spatial continuity provides for the integration of proximity, separation, order, and enclosure. It conceives of the opposing processes of proximity and separation as a subdivision of neighboring points. It also provides for understanding order and enclosure in a general coordinated way that is equally applicable to lines, surfaces, and three-dimensional spaces since all of these constructions can be thought of as an integration of points. Thus continuity provides a rational reason for comprehending the previous processes in an integrated form (Piaget, 1967, p. 149).

As children develop, they begin to comprehend continuity on a projective and euclidean level. The ability to coordinate objects from different viewpoints allows objects to retain their distinguishing characteristics no matter that their size or view, while euclidean space provides a more structured and analytical approach since it provides such tools as <u>measurement</u> and <u>reference systems</u> for understanding continuity. A square retains its squareness as long as its sides are equal and are joined by right angles. Relationships between different geometric figures can easily be understood. A square can be transformed into a rectangle by extending the points on two of its parallel sides. Thus, continuity is a process which provides overall coordination and allows children to extend their concrete notions, which were based on material objects, onto the abstract level.

<u>Justification:</u>

Cognitive space promotes learning competence because it gives children the ability: (1) to organize objects in their environment with respect to their size and shape, (2) to coordinate the relationship of objects from different points of view, and (3) to locate these objects with respect to one another. This understanding is accomplished through differentiating parts of objects for purposes of comparison and integrating the parts to construct the total relationship between these objects. This is aptly demonstrated in the discussion of processes of spatial order and continuity.

Cognitive space includes the extension of logical-mathematical operations like seriation, classification, and number relations (which in their purest form coordinates objects apart from the environment) to coordinate associations of objects within the total environment, the world. Thus, seriation plays a part in spatial order and continuity, classification a role in spatial enclosure and continuity, while number relations becomes a tool of measurement for understanding euclidean relationships (Piaget, 1967, p.p. 466-67).

Space also relates to other sub-logical operations such as time. As objects undergo movement they are characterized by speed, and speed or velocity comprises the coordination of space in terms of distance moved with that of time as measured through duration. As children become competent in the coordination of these two operations, they are able to grasp new associations which are dynamic (involve movement) rather than static. This new dimension increases children's effectance in interacting with their environment (Piaget, 1967, p. 450).

Competence in combining spatial processes is important in the moral environment, specifically in terms of world communication. Spatial distance for communication, spatial arrangements exhibited by architecture and art, and feelings of security within spatial confinements are all characterized by spatial concepts of specific cultures (Hall, 1959, p.p. 148-164).

Contrast the ways in which several different cultures handle the problems of enclosed space concerned with the living conditions and individual privacy. When assigning space, the Germans as a culture have a very definite order in their handling of space. They want clearly delineated authoritarian instructions regarding the space that certain types of people can occupy; they tend to see space as a very individual thing to be shared only by the person who has been allocated to a certain region. They tend to keep doors closed to their offices within the business world, whereas Americans, who have a sense of sharing space, tend to keep their doors open (Hall, 1959, p.p. 134-37). In contrast to the Germans and Americans, Arabian society deemphasizes privacy, particularly in the home, preferring as few partitions as is necessary; Arabs prefer tremendous space and rooms with extremely high ceilings.

In a different manner, Japanese society tends to emphasize variety and flexibility in living space to the point that the walls of their homes are flexible, creating many different atmospheres. It is not unusual for one room to serve as the function of a living room, kitchen, and bedroom with a rearrangement of furnishings (Hall, 1959, p.p. 150-51).

Similar patterns exist with feelings of security and distances used in communication. Hall found that Latin Americans prefer a closer social distance when conversing than Americans, and that when the distance becomes too close, Americans withdraw from a sense of insecurity. As a consequence, Latin Americans sometimes interpret this to mean that Americans are cold and unfriendly, while Americans feel that the Latins crowd them. Such causes of disunity could be resolved if humans were aware of the different concepts of space within cultures (Hall, 1966, p. 164).

Development:

Perceptual vs. Representational Space. Developmentally, perceptual space develops far more rapidly than cognitive space, reaching projective and euclidean levels several years before similar conceptual structures become evident.

With cognitive space the interplay between images and action, which undergoes continuous transformation, can be followed progressively as a child develops. In the later part of the sensorimotor stage, images are just traces of muscular adaptations involved in action. On the conceptual and pre-operational level, imitation is a set of symbols by which physical actions can be recalled. This symbolic representation is how internal actions are used to assimilate spatial concepts. At this level, delayed imitation becomes predominant.

At the concrete operational level, images become less indispensable, since the appearance of reversible combinations of mental and internal actions are very logical and precise. During formal operations, images are outdistanced by abstract thought and are no longer adequate for operational thinking (Piaget, 1967, p.p. 455-56).

Stages of Spatial Concepts. Luquet (1927), investigating children's concepts of space through the observation of their spontaneous drawings, identified three levels of spatial conceptualization: (1) synthetic incapacity, (2) intellectual realism, and (3) visual realism. In the first stage (0-5 years), children can construct topological relationships, but their drawings are devoid of projective or euclidean concepts. During the stage of intellectual realism (5-7 years) a deeper understanding of relationships of proximity, separation, order, enclosure, and continuity emerges, but projective and euclidean concepts are still undeveloped. Beginning at 8 or 9 years drawings take into account perspective (projective space), proportions, and distance (euclidean space).

When Piaget investigated children's drawings[14] of geometrical figures, the ages at which certain spatial concepts appeared were differentiated as follows:

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[14]The response to draw is initiated by: (1) asking children to copy a figure, (2) by initially guiding their hands and then asking them to repeat the drawings, or (3) by asking them to construct figures composed of lines, using match sticks.

Stage 0 (0-3) - During this age period, only scribbling is shown. It is impossible for the child to make differentiations in figural forms at this age.

Stage IA (3-3½) - Different types of scribbles are made depending on whether the figure copied is open or closed.

Stage IB (3½-4) - Open figures are distinguished from closed figures, i.e., (+) from (○). Simple topological relationships are evident.

Stage IIA (4-6½) - By this stage, curved shapes are distinguished from straight-sided shapes; this is the transition level between IB and IIA. During the stage, shapes are differentiated on the basis of their angles and dimensions, i.e., squares are distinguished from triangles, circles, from ellipses. This marks the beginning of the recognition of euclidean space.

Stage IIB (4-6½) - The rhombus  is successfully reproduced, and circumscribed figures, i.e.,  are drawn with the proper points of contact.

Stage III (6½-10) - All figures can be drawn including the composite figures,i.e.,  (Piaget, 1967, p. 56). At this stage there is a complete reconstruction of the physical

> space which ultimately relies on a mental image achieved through the coordination of a child's action (Holloway, 1967, p. 14).

Fishet (1965), attempting to verify Piaget's findings, suggests that children have a tendency to comprehend linear as well as topological concepts early in their development. Another study, which clarifies why spatial concepts develop in the order in which Piaget suggests, reports the approximate ages at which children possess a specific vacabulary of spatial terms (Ames and Learned, 1948, p. 82-83). Other studies done to verify Piaget's findings report that:

1. The sequence of stages are confirmed (Page, 1959; Peel, 1959; Laurendeau, et.al., 1970);
2. Age limitations are not clearly supported (Peel, 1959); and
3. The sequence of stages and general nature of thought regarding the spatial concepts is found in normal and mentally deficient children, although the actual age at which a stage is reached is significantly delayed in the latter group (Woodward, 1962, p.p. 35-37).

Topological Space. Regarding the different levels of space, topological concepts are the first to emerge. It was emphasized earlier that Piaget studied the processes of proximity, separation, order, enclosure, and continuity mainly in conjunction with topological space. Among these five, the processes of proximity and separation are the first to occur, however, Piaget did not do the extensive studies on these that he formulated on the last three, where he isolated well-defined stages of growth. Since an in-depth discussion of all five processes is beyond the scope of this thesis, detail will be given only for continuity to illustrate the developmental differentiation.

The development of the <u>process of continuity</u> is illustrated using the following Piagetian task.

Task:
- I. To construct a square (1) larger and (2) smaller than the one drawn on paper,
- II. To subdivide a figure, i.e., square, triangle, etc., until its smallest part is reached,
- III. To construct the end product of II,.
- IV. To recognize that a whole (straight line) is equal to the sum of its parts (points).

Stage I (0-4) - No ability is shown regarding the subdivision of a square or recognition of the continuity in the sizes.

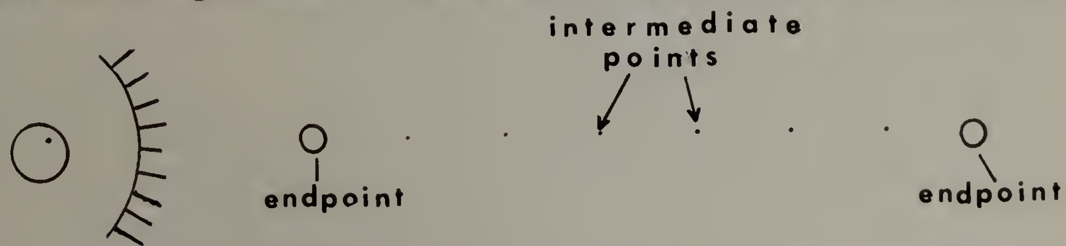
Stage II (4-7) - Children can draw a series of smaller or larger squares, but they arrive at the smallest subdivision by a method of successive approximations. The continuity at this stage is intuitive and primarily perceptual. Children consider that a subdivision, too radically performed (large difference in size), will break the continuity of the series, since they do not envision a square as being a collection of points.

Stage III (7-10) - Operational synthesis is possible with the onset of reversibility allowing children to differentiate the whole into its parts and to integrate the parts into a whole. They discover that the smallest subdivision is a point, however, they cannot comprehend infinite subdivision which goes beyond the point. Furthermore, children can only perform these operations on a concrete level, e.g., once the object is invisible, they are unable to function.

Stage IV (11-15) - At this level, analysis and synthesis operate on an abstract, hypothetical level, i.e., a line and a collection of points are equivalent. At this stage, continuity is the synthesis of the relationships of proximity, separation, order, and enclosure (Piaget, 1967, p.p. 125-49). Infinite subdivision and extension are possible at this stage.

Projective Space. The general progression of projective space begins with the construction of a straight line and extends to the representation of objects in perspective, e.g., a circle, as it progressively rotates from a vertical to a horizontal position (Piaget, 1967, p.p. 155-73), or the projection of conic sections through the use of shadows. Eventually, children progress to where they can coordinate many objects from several different points of view, whether it be mountains, geometric sections, or the rotation of surfaces (Piaget, 1967, p.p. 194, 211, 271, 247). In order to present a developmental pattern within projective space, one of these major topics, the development of the perspective of a straight line, will be sketched.

The perspective of a straight line can be used to construct such a line in two distinct ways. First, children can construct such a line by using a system of aligning their eye with the two points to be joined, locating intermediate points in the process. This method is used at the projective



level. Alternative ways are: (1) to join the end points using another straight line as a reference point, or (2) to measure the shortest distance between the end points. This involves the construction of parallels in the first instance, which necessitates a combination of projective and euclidean concepts, while he uses a system of measurement, a purely euclidean construction. Therefore, the construction of a straight line confined to projective concepts occurs through a process of alighment.

Task: This projective task demands that the child:

1. Construct a straight line using match sticks and a table, whose surface is made of plasticene (the tables might be round and square shaped);
2. Rearrange a curved or zig-zagged line into a straight line on a round table (Piaget, 1967, p.p. 156-57).

Summary of Results:

Stage I (0-4) - A child is incapable of constructing a straight line with a square table, although he can distinguish a circle from a square perceptually.

Stage II (4-7) -

IIA - A child can form a straight line when it is lined up with the edgs of a square table; he is heavily influenced by the perceptual cue of the shape of the table.

IIB - The child overcomes obstacles through trial and error.

Stage III (7-10) - A straight line is spontaneously constructed, no matter what the shape of the table or position of the match sticks, through a process of aiming, i.e., the child places himself in line with the two posts to be linked by the straight line.

Transition Between Projective and Euclidean Space. In a previous section of space describing euclidean space, transitional stages between projective and euclidean space were pointed out. These stages follow a developmental pattern since an early stage is prerequisite for a later one, i.e., similarities are not understood until affinities are mastered. These stages have been fully described in that section (p.p.

Level I. Affinities - Conservation of Parallels

Level II. Similarities - Conservation of Angles
- Proportionality of Similar Figures

Level III. Movements - Conservation of Distance

Euclidean Space. Euclidean space is developed in three distinct stages and was previously described on p.p. These are briefly mentioned here because they are developmental in nature.

Level 1. (Concrete Operational Level) - Conservation of length and distance[15] are understood at a qualitative level, that is, the length of an

[15]Length and distance imply the same notions of space. Length is a static property characteristic of an object at rest; distance is a dynamic property referring to objects in motion.

object remains the same no matter what its orientation or change in position (Piaget, 1964, p. 68).

Level 2. (Concrete Operational Level) - A quantitative understanding of the conservation above is achieved by the introduction of measurement. The following processes are realized at this time. However, children do not think of this quantification in terms of enclosed space.

1. the measurement of space in one, two, and three dimensions, using straight lines,
2. the measurement of angles and curves in all dimensions,
3. the construction of metric coordinate systems such as the use of rectangular coordinates in graphing (Piaget, 1969, p. 152).

Level 3. (Formal Operational Level) - Operational constructions of area and volume as concepts of enclosed space (Piaget, 1964, p. 260).

This concludes the discussion of spatial relations which forms the foundation for the next section, time. It is when space is combined with a unit of time that the concept of speed is conceived. As previously mentioned, it is through the observation of objects in motion (speed) that competence in the basic processes of time is achieved.

Cognitive Time

Definition:

Cognitive time is the ability to differentiate events and integrate them in sequential order so that any part of the total succession of events is understood to be of shorter duration than the total succession. For instance, this process is reflected in children's ability to determine the sequence between breakfast, lunch, and dinner within a single day (succession) and to conclude that the length of these events would take less time than the passage of the whole day (duration) (Piaget, 1971a; Montroy, McManis, & Bell, 1971).

Elaborate Description:

Philosophers have generally conceived of time as a universal phenomenon which exists and is characteristic of the environment. In order to understand such an abstraction one must know how it can be quantified and how events in the environment could be coordinated with that system of measurement. Previous to 1950 most of the studies of time centered on the use of clock time, that is, the ability to estimate intervals of seconds and minutes and the construction of time lines used in arranging historical events in a sequence (Ames, 1924; Bromberg, 1938; Buck, 1946; Harrison, 1934; Oakden and Sturt, 1925; Friedman, 1944). However, Lovell and slater (1960) have pointed out that "while the ability to tell time on the clock may be an indispensable social asset, it tells nothing about (children's) internalization of the basic concept of time." Even though children can read time on the clock, it does not indicate that they understand basic concepts such as the notion that the duration of each minute or hour is equivalent to every other minute or hour.

In 1927 and again in 1946 Piaget completed two studies on time which remained in obscurity until the French versions were translated into English in 1969 and 1970 becuase of a sudden interest in Piaget. In these works Piaget conceives of time as an internal, intellectual construction of relationships between an action and the speed with which these actions occur (Piaget, 1971c). He further believes that time is "one of the essential aspects of the logic of things", and it is the result of operations like classes and logical relations (Piaget, 1971a, p.p. 1-2). However, Piaget classified time as a sub-logical or infralogical operation that is not dependent on the constant state of objects as seriation, classification, and conservation are, but instead concerns the change of position or state of objects (transformations) in the environment. With logical operations the position of an object in the environment is not considered, i.e., the position of a glass is independent of its position in space when seriating, classifying, or conserving. With time the movement of the glass from position A to Position B at a certain speed

would constitute the concept of duration. Lovell (1960) defined time as a "...limited stretch of continued existence, the interval between two events, and the interval through which an action, condition, or state continues." This definition sums up the Piagetian concept that time cannot be separated from its contents, e.g., events. This explains why Piaget's experiments involve the comparison of objects at various speeds as well as the comparison of the occurrence of isolated events. By adopting Piaget's approach to time, teachers can expose children to activities that will allow them to achieve an understanding of time at their developmental level with much greater effectiveness than previous methods of teaching time.

In the remaining part of this description, space and time will be differentiated from one another, since space is an important factor in this definition of time. Once the description of time is refined, then the two major processes which constitute time, succession and duration, will be described. Finally, several important differentiations between qualitative and quantitative, physical and psychological time will be briefly described so that the reader is aware of these dimensions during the development of children. Finally, a brief section on where relativity fits into this definition of time is included.

Space and Time. Piaget studied children's conceptions of time by recording their observations of objects traveling at certain speeds. It is within this content that space and time can be distinguished. Space is conceived as the part of the environment transversed when an object travels at a given speed for a certain period of time. This involves a coordination of positions between two points in time.

Time, on the other hand, is the "limited stretch of existence" that it takes an object to move a certain amount of space at a given speed. In a sense it is space in motion. Piaget makes this distinction between the two. Space consists not only of the coordination of simultaneous positions, but also implies that these positions involve the notion of displacement or movement. Time is the coordination of these displacements or successive spatial states. He concludes that "space is a still of time, while time is space in motion -- the two taken together constitute the totality of the ordered relationships characterizing objects and their displacements" (Piaget, 1971b, p. 2).

Piaget cites three differences between these two concepts that further clarify this distinction. First he says that time is irreversible, while space is not, that is, once the present moment has passed, one cannot go back and repeat it. With space a change of position can be reversed; a movement from city A to city B can be retraced as a movement from City B to city A.

Secondly, space can be considered separately from its contents, while time cannot. This relationship holds true only in formal operational thought where the mind gradually learns to perform spatial operations apart from the experiences or contents of which it is composed. This constitutes the science of pure geometry, which is not limited by physical space, and which is pure logic. For instance, such geometrical construction consists of forms and figures in four or five spatial dimensions, while objects in four or five dimensions are inconceivable in terms of concrete objects.

On the other hand, Piaget argues, that in most instances, time cannot be conceived as independent of velocity or speed. When a displacement is conceptualized without taking its speed into account, it becomes a spatial construct, thus losing its temporal significance. The one exception to this occurs when small velocities are involved, but even for this, time has to have been constructed before it is thought of as an independent system. It is "in the course of its construction (that) time remains a simple dimension inseparable from space and part and parcel of that total coordination which enables us to correlate the kinetic transformations of the universe" (Piaget, 1971b, p. 2).

The third difference is that space is easier to comprehend psychologically. With space the whole geometric figure can be perceived simultaneously; however, within a given moment one is either at the beginning, the end, or the middle of the time interval (Piaget, 1971c, p.p. 60-61).

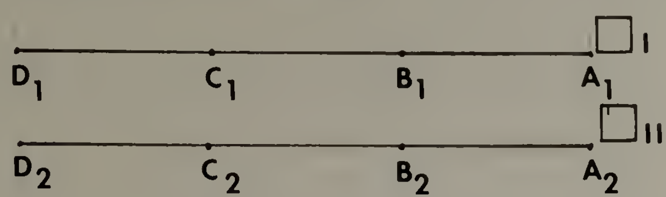
Succession and Duration. Time consists of three major elements:

1. sucession -- which is the coordination of events on the basis of their occurrence,
2. duration -- which is the comparison of intervals of time determined by finding the length between the beginning and end of an event, and
3. the coordination of succession and duration to produce a sequence of intervals within an event or between two or more events.

In addition to these three processes,the concept of simultaneity, the special instance of two events occurring within the same time interval, needs to be understood.

Temporal succession and duration are extremely important processes in children's understanding of age relationships. At an early stage of growth, children see age as independent of the order of birth. For instance, it does not matter to children at a certain age that John was born before Otis, because in 20 years they believe that Otis will be older or the same age as John. They also believe that age differences (duration) disappear with time, that is, if John is 12 years older than Otis, in four years he will only be one year older. To arrive at the correct conclusion, children must be competent in their use of succession and duration.

Another Piagetian experiment is illustrated below to point out the factors which interfere with children's understanding of <u>temporal succession</u>. In the figure below



there are two vehicles, I and II, which begin at the same point simultaneously and travel at the same speed. Vehicle I travels the distance A_1D_1 and stops while vehicle II travels the path A_2B_2. After vehicle I has stopped, vehicle II continues to travel from B_2 to C_2 where it stops. Piaget used two different objects in his experiments because for him "it is only with the correlation of <u>two</u> or <u>more</u> motions that succession becomes a temporal problem." For Piaget, spatial succession involves only <u>one</u> motion (Piaget, 1971b, p.p. 90-92).

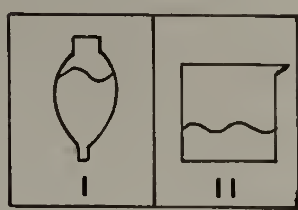
In this experiment children are asked to compare vehicles I and II as to which one stopped first and which one travelled a greater distance. The sequence or succession of events, i.e., A_1D_1 and A_2B_2 took place at the same time while B_2C_2 came after the other events, is not understood by young children because of perceptual or spatial distractions. Children in this experiment correctly perceive that vehicle I stopped before vehicle II, yet when told that I stops at lunch time and asked if II stops before of after lunch, they assert that II stops before lunch or sooner than I. Piaget concludes that this occurs because children confuse time with space. Children conclude that II stops before lunch because it travelled a shorter distance than I and therefore stopped before I. This reasoning is true if there was only one motion. For instance, if object I makes two trips at the same speed, one from A_1 to C_1 and the other from A_1 to D_1, it can be correctly reasoned that the time it takes to travel the path A_1D_1 is longer than A_1C_1. However, with two motions, spatial succession and temporal succession do not necessarily coincide, and children's reasoning fails when they apply the format of a single object in motion to that of two objects in motion.

With problems of duration, children confuse velocity with time. In the experiment above, if object I travels path A_1D_1 in the same time that object II travels between A_1 and C_1, young children will believe that object I travels a greater length of time (duration) than object II because it transverses a greater distance and therefore more time is needed. As children develop they begin to concentrate on observing the beginning and end points of an event and comparing these with the respective points of other events to determine if these events are synchronous or occur in a temporal sequence.

With the comparison of non-synchronous events, children must combine their abilities of succession and duration. When these processes become intertwined, children begin to comprehend the relationship between a whole event and the sum of its parts or sub-components. This is known as the colligation of durations in Piagetian terms (Piaget, 1971b, p.p. 83-86).

Simultaneity is a concept that is understood as a special instance of there being no sequence between events (zero succession), since both events take place at the same, exact time, i.e., event A_1D_1 equals A_2B_2 in the first experiment. This applies when the time interval is relatively large. However, when the intervals become smaller, children comprehend simultaneity as a case of synchronous durations. Children deduct this by noting that the beginning and end point of an interval of time is synonomous with that of another interval.

Qualitative and Quantitative Time. Qualitative time is composed of groupings of events which are derived through (1) the seriation of partial durations of these events and (2) the colligation (integration) of classes of these durations. In order to illustrate these groupings of events, Piaget's experiment on isolated motion will be introduced. In this study water flows between two containers, I and II, which are different in shape. This difference complicates the perceptual events so that children are forced to use a higher level of thought. At equal time intervals, the flow of water is stopped and the levels are recorded on predrawn cards. This continues until there are six or seven drawings of the levels of water in containers I and II, marked respectively I_1, I_2, I_3, I_4, I_5, and I_6 which corresponds to II_1, II_2, II_3, II_4, II_5, and II_6. These



drawings are separated during the course of the experiments so that children are forced to coordinate the two levels (Piaget, 1971b, p.p. 5-11).

The two processes of seriation and colligation of classes of events characteristic of qualitative time can be illustrated with these levels. Seriation occurs when children are able to arrange the levels of water in each container according to the time of their occurrence while being transferred, e.g., I_1-- I_2-- I_3-- I_4, etc. or II_1-- II_2-- II_3. The second process, colligation of classes, is demonstrated when children realize that levels I_1 and II_1 occurred at the same time (simultaneity) during the transfer. Furthermore, a second aspect of this structure is that children discover the relationship between the parts of an event and a whole, termed by Piaget the colligation of partial durations, i.e., $I_1 - I_2 + I_2 - I_3 = I_1 - I_3$. This competency does not mean that children can compare successive durations; this does not occur until quantitative time is understood. These two processes, seriation and colligation, are separate and immobile at the qualitative level and they prevent the comparison of the two durations which are not synchronous to one another.

It is not until a unit of time is established that durations become mobile and can be compared to successive or non-synchronous durations. Such a unit of time, utilizing a number system, can be substituted for any other within the class or series. A duration of one second which occurs between the sixth and seventh second of one event can now be compared to the duration of one second which occurs between the eleventh and twelfth second of another event. This unit of time is characteristic of quantitative time and represents the fusion of succession and duration. The introduction of measurement which results from the use of "units of time" changes the structure of the seriated events into a system of displacements which represent a seriation of durations or intervals. In terms of the experiment, this means that the series of $I_1 - I_2$, $I_2 - I_3$, and $I_3 - I_4$ can be constructed and compared to $II_1 - II_2$, $II_2 - II_3$, and $II_3 - II_4$. This now means that children can comprehend that intervals of time which occur simultaneously are equal, or as Piaget phrased it, children understand the equalization of synchronous durations. This only occurs when time can be quantified (Piaget, 1971b, p. 148).

Likewise, the colligation of classes is transformed into the colligation of successive durations so that $I_1 - I_2$, $I_2 - I_3$, and $I_3 - I_4$ can be compared in terms of length. Finally, the concept of displacement is integrated with the colligation of durations so that children have the flexibility to compare any of the durations of the two events, i.e., $I_1 - I_4$ with $II_2 - II_4$ (Piaget, 1971b, p.p. 189-92).

These notions of qualitative and quantitative time can be used to understand how children comprehend clock time, which is based on the three fundamental attributes of rational time: homogeneity, continuity, and uniformity. Both homogeneity and continuity are qualitative characteristics and result from processes which operate at the qualitative level. For instance, homogeneity results in the concept that the same interval is equivalent no matter what event is occurring, i.e., that time spent watching a minute sand timer empty is the same as a minute spent at play.[16] This requires colligation of classes, specifically that two events occuring in the same time interval are equivalent. Homogeneity also means that children understand

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[16]Psychological factors mentioned in the next section interfere with children's concepts of homogeneity.

the relationship between the parts and the whole, i.e., that a minute is composed os sixty seconds. Parallel to homogeneity is continuity which implies that time does not stop but continues indefinitely and at all times. Continuity is also understood through qualitative colligations. With the knowledge that the additive composition of the parts of an interval, children realize that the time of the whole interval is the sum of smaller components and is continuous.

Finally, in comprehending uniformity children must use quantitative time since this entails knowledge that successive periods of clock time can be equal (equality of successive durations), i.e., the duration between one and two seconds on a clock is equal to the duration between 14 and 15 seconds on the clock. This in turn leads to an understanding that a minute on one clock is the same as a minute on every other clock (Piaget, 1971b, p.p. 189-213).

Physical vs. Psychological Time. The distinction between physical and psychological time is that physical time involves motions of external objects in the environment, while psychological time is concerned with motions of the subjects or individuals and/or their thoughts. Both conceptions of time consist of successions and durations; however, in psychological time these processes involve "lived events" rather than events separated from personal action characteristic of physical time (Piaget, 1971b, p.p. 305-06). However, physical and psychological time are not easily separated. Piaget found that children coordinate their own time by putting their actions (psychological time) in the context of physical time, while they coordinate physical time by integrating observed actions with the knowledge of changes in the environment that their memory provides (psychological time) (Piaget, 1971b, p. 262).

There are three distinguishing factors of psychological time which help to define it. The first factor is the occurrence of illusions, which are systematic errors that arise because of inner tensions or emotional states which exist at the time durations are evaluated. These illusions are internal expressions of the errors due to the egocentric conception of physical time. Unlike physical time, some of these illusions persist into adulthood. For instance, if children are asked to draw carefully a number of strokes for 15 seconds and then asked to repeat the task working as quickly as possible for the same amount of time, children confuse the number of sticks drawn with the length of time it takes to draw them. Children will reason that it took longer to draw the larger number of sticks, because they had to work harder. This is an example of psychological time. The illusions also exist if children observe other children performing the task (physical time), only now the illusion is just an error with no emotional or other direct internal referent (Piaget, 1971b, p.p. 261-62).

The second factor is the reaction to the illusion. This can vary from complete acceptance of the perceptual data in very young children (preschool), i.e., more sticks take more time, to a stage where children make gradual corrections of what they observe. These corrections are made either by the use of perceptual controls that increase with age as children have experience with perceptual errors, or by comparisons between the observed actions and impressions or feelings gained during the action itself.

The third factor is the coordination of children's impressions of duration while the action is occurring with the evaluations based on memory or reasoning (introspection). When many actions occur within the same duration, an illusion that the interval passes quickly is created during the event. However, in retrospect, the action may seem to have taken a long time because of the analysis of the many events. On the other hand, a period of idleness may seem long, while it occurs, but may have been a short duration in the memory because nothing occurred in that time span. This initial impression, balanced by introspection, are all components in evaluating subjective durations (Piaget, 1971b, p.p. 273-74).

Relativity. Relativity or relativistic time involves the coordination of motions in the same manner as regular time. The distinguishing characteristic of relativity is that it involves the coordination of great degrees of velocity, e.g., the speed of light, which is evaluated according to the motion of the observers and the speed of the events they are observing (Piaget, 1971b, p.p. 305-06). Further discussion of relativity is beyond the scope of this paper since this facet of time cognition is not understood until the child reaches the period of formal operations.

Justification:

Time is a fundamental concept of science and mathematics since it forms the basis for observing phenomena like chemical reactions, freely falling objects in motion, growth changes in the body, and many more. Time is also important for understanding past events as well as present changes. In terms of organizing the past, Harrison (1934) notes that "without a grasp of time children cannot comprehend historical sequence" (organization of the past). Furthermore, children must have these well-defined notions or concepts of past, present, and future in order to understand any dynamic event. In fact, says Fraisse (1963), "It is temporal pressure that is the framework within which our personality is organized."

In order to be competent morally, comprehension of time is needed to integrate oneself into society. From birth, children are taught social time so that they can order events in their lives and so adapt to a specific society (Fraisse, 1963, p. 289). But on the larger scale of the world many different ways of integrating time are present since in many cases time is heavily influenced by culture (Hall, 1959). These ways must be understood and respected if one is to function as a morally responsible world citizen.

Time is also important in the affective domain, for it is the harmony of time in one's personal schedule that helps the individual manage extreme anxiety and other forms of emotional stress. Integrating the structure of social time into one's own internal structure allows the individual to relate to other members of that society; it creates a greater sense of unity and unity represents a way of maintaining emotional balance.

Cognitive time is a basic complement of volitional competence. Without a well-ordered sense of past, present, or future and a good sense of duration, completed intentions cannot be differentiated from uncompleted, being intended, or in the process of being carried out.

Although normal children can be expected to gain experiences that provide a certain level of cognitive time, providing special experiences insures a greater grasp of this process. In a sense, every individual suffers from being exposed to certain social considerations of time. For instance, in the West, many Americans have a very rigid and controlled sense of time which is not experienced in the East. Providing diverse experiences in integrating and differentiating successions of durations of events can enlarge everyone's sense of time and in the process can create new patterns for releasing potentialities.

Development:

Because time has been studied from amny different viewpoints, it is impossible to present all the developmental data as an integrated whole. Consequently, this section is divided into four parts in order to give a comprehensive yet coherent exposure to this topic. The four parts are:

(1) general comments on time development with specific emphasis on space and time;

(2) treatment of clock time and the ages at which children attain certain competencies;

(3) the developmental sequence established for the process of temporal succession and duration established by Piaget; and

(4) general stages in children's concepts of growth and age.

The ages given for levels of competence should not be considered exact since the studies cited are of varying degrees of quality. However, the ages are listed so that the teacher might compare the approximate stage of development a child is at with each concept.

Space and Time. Initially, time concepts are slow in developing because of their abstract nature (Harrison, 1934). Generally, before five, the following are characteristic of the child's temporal notions:

1. Time and space are not distinguished in the child's mind, i.e., children believe that a long trip takes a large amount of time regardless of the speed traveled;
2. Uncoordinated notions of before and after exist, i.e., children do not realize that an event can occur both before one and after another event;
3. Time is tied to particular objects, locations, and events; it is not understood abstractly;
4. Children can produce isolated elements in a sequence of events, but are unable to coordinate a whole sequence (Jahoda, 1963); and
5. Intuitions of speed which are not based on a ratio of space and time appear, i.e., children thing that an event that involves objects in motion which takes place quickly, travels only a short distance or occurs in a relatively small amount of time; they do not coordinate the two.

After five, an ordering of past events and concepts of earlier and later emerge (succession); this ordering depends on the child's familiarity with the object or event (Lovell and Slater, 1960; Bradley, 1964). From early conceptions of intuitive time will emerge notions of operational succession (7-8), characterized by reversibility;

after this, thought depends on mastery of conventional time divisions (Jahoda, 1963). Finally, at about 9-10 years speed is conceived as an integration of space and duration (Piaget, 1970).

Clock Time. This section will not only document developmental data on the understanding of clock time, but on the differentiation of the parts of the day, seasons of the year, and other time sequences which affect children. Below is a chart showing when various concepts of time appear during the ages of 4-13, as described by several authors. Many studies were observational and dependent on how frequently children used certain key words.

AGE	CONCEPTS
Infancy - 3	The infant's earliest words refer to present events and up to 21 months the child lives only in immediate present. At 24 months words like 'wait', 'soon' are added to indicate sense of future, while at 30 months his vocabulary includes reference to past events (Ames, 1946).
3½ - 4	Expressions of past, present, and future are used in conversation to an equal extent (Ames, 1946).
	The child uses the terms 'morning' and 'afternoon' (Ames, 1946).
5 - 6	Children know what day it is, the order of the days of the week, and they can project how old they will be on their next birthday (Ames, 1946).
6 - 7	1. Time is related to personal experience (Sturt, 1925). 2. Four seasons are known (Ames, 1946).

5 - 8	1. The sense of past time is refined, while before five, present and future were the most immediate concern (Stern, 1924). 2. Concepts of past appear (Stern, 1924). 3. Children have good grasp of one second (Lovell, 1960).
7 - 8	1. Temporal concepts of years and seasons are mastered (Jahoda, 1963). 2. Children can tell time (Ames, 1946). 3. Children can tell season, month, and specific clock hours (Ames, 1946).
8 - 9	Conventional time words used in calendar and organization of week are internalized concepts (Sturt, 1925).
11 - 12	There is a rapid improvement in all types of time knowledge (Oakden, 1922).
13 -	Children understand time as an abstraction independent of functioning of clock, e.g., age is associated with passing time (Jahoda, 1963).

Piaget's Conception of Time. Before discussion various stages in the development of cognitive time according to Piagetian theory, a distinction should be made between intuitive and operational time. Intuitive time is limited to successions and durations obtained by direct perception. Speed at this level is not based on a ratio of spatial interval to an interval of time (duration), but is based on being able to correctly identify the fastest object when traveling (Piaget, 1970, p. 62).

Operational time includes the co-seriation of successive stages of events which are then coordinated with the colligation of durations, both qualitatively and quantitatively. Operational time is also characterized by operational reversibility of thought, that is, the ability to reconstruct time once in the past (Piaget, 1971b, p. 77).

Listed below is a chart of the concepts of time arranged according to piagetian developmental stages.

Sensorimotor (0-2)

1. Children differentiate between temporal and spatial order (Montroy, et.al., 1971).
2. Simple ideas of sequence are grasped (Ames, 1946).
3. Primitive order of succession and duration occurs with respect to feeding time while waiting to be fed (Piaget, 1971a).
4. Succession of events, like feeding, gives rise to motor responses.

Pre-Operational (3-6)

1. Child's judgments of succession depend upon the equality or inequality of speed.
2. Duration is based on speed and distance traveled (Montroy, et.al., 1971), e.g., children think faster means a longer period of time (Piaget, 1970).
3. Words of duration appear and time period is gradually extended to include a year (Ames, 1946).
4. Children can order successions and colligate duration of a single series.
5. A gradual extension of temporal notions emerges to embrace future, past, and present events, and a

transformation occurs when the future merges into the present and the present merges into the past (Piaget, 1971b).

6. Time is localized in that it is still confused with spatial order (Piaget, 1971b).
7. Child can comprehend simultaneity (6-7 years) (Lovell, 1960).

Concrete Operational (7-11)

1. Coordination between the succession and duration of events occurs.
2. The child organizes systems of measuring time (quantitative time).
3. The child develops logical understanding of time (Montroy, *et.al.*, 1971).
4. In mentally defective children time duration as a precept is present (Gothberg, 1949).
5. Temporal succession becomes divorced from spatial succession (7-8 years).
6. Correlation of one's time with that of others (psychological) and physical time appears.
7. Children's systems of time are reversible, have ceased to be egocentric, and are bound up with current events (Piaget, 1971b).
8. In mentally defective children, processes of duration and succession begin to be comprehended first at ages 10-11 (Gothberg, 1949).

8. Double temporal succession arises; it is the same as double seriation without duration, i.e., the ability to correctly determine the sequence of intervals of two events which occur simultaneously; this does not include the comparison between the durations of the intervals of the events, $I_1 - I_3 = II_2 - II_4$ (8-9 years).
9. Children can coordinate two motions with correct estimate of durations (Lovell, 1960).

Lastly, a thorough description of the stages of succession, duration, and simultaneity are described to help in the evaluation of some of the prototypical experiences.

Succession. In the description of those stages, reference will be made to the experiment on the flow of liquids described on page 161. Children's ages are given in parenthesis.

Stage IA. (5)	Complete failure to seriate complete sets of drawings of liquids is shown.
Stage IB. (6)	Ability to seriate original unseparated sets of drawings by trial and error methods is evidenced.
Stage II. (7-8)	Correct seriation of the unseparated sets of drawings through trial and error appears.

Stage III. (8½-9) This stage includes the ability to co-seriate the separated sets of drawings by using a principle of correspondence and the resultant grasp of succession (Piaget, 1971a, p.p. 17-25).

<u>Duration.</u> This sub-process is explained in reference to the experiment on the flow of liquids.

Stage I. (6-7) In this stage notion of duration is vague and undifferentiated. In the above experiment children do not see the interval $I_1 - I_2$, as being equal to $II_1 - II_2$ because of rapidly changing level in $II_1 - II_2$ due to the different shapes of containers. Children also fail to grasp that the shorter the period of time an object takes to trasnverse a given distance, the greater its speed.

Stage II. Duration becomes differentiated, but without overall coordination with succession. This stage is referred to be Piaget as "the equalization of synchronous durations", and it can be broken down into two sub-stages.

Stage IIa. (7-9) Children discover the inverse relationship between velocity and time; they can distinguish time intervals from speed;

they co-seriate durations between event I and II, but still believe the duration $II_1 - II_2$ is longer than $I_1 - I_2$ because of the unequal rise in liquids.

Stage IIb. (7-9)

This stage concerns the qualitative colligation of durations and their measurements. Children can combine and understand relationships between durations dealing with flow of one vessel, i.e., $I_1 - I_2$ is shorter in time than $I_1 - I_4$. He cannot compare durations across two levels, i.e., $I_1 - I_2$ and $II_1 - II_4$.

Stage III. (8-9)

Concerns the operational construction of qualitative durations and the measurement of time which terminates in the correlation of the intervals mentioned in IIb, i.e., children can now properly understand both sequence (succession) and length of time between events I and II (duration). The child is capable of (1) the equalization of synchronous durations ($I_1 - I_2 = II_1 - II_2$), (2) the colligation of unequal durations ($I_1 - I_2 + I_2 - I_4 = I_1 - I_4$), and (3) the integration of the events of these durations by co-seriation of successions ($I_1 - I_4 = II_2 - II_5$) (Piaget, 1971a, p.p. 36-76).

<u>Simultaneity.</u> Explanation of these stages will require reference to the experiment with the two cars and their respective tracks.

Stage I. (4½-5) Child has no sense of simultaneity because duration is discriminated to be proportional to distance, that is, even though the cars begin and end at the same time, the child misjudges these end points because one car travels further than the other, leading him to believe it traveled for a longer period of time.

Stage II. Child differentiates intuitive conceptions where duration is now conceived of as inversely proportional to distance. This can be subdivided into two stages.

Stage IIa. (5-6) This stage is subdivided into three categories depending on the level of mastery regarding <u>simultaneity</u> and <u>synchronous durations</u>. In one case neither sub-process is grasped; in the second, simultaneity is recognized but the equality of synchronous durations is not, while the reverse is true in the third case. In other words, the subject might realize that the cars start and stop together but that they do not travel for the same period of time.

Stage IIb. (6-7½) — The child can understand simultaneity as the equality of synchronous durations through trial and error, i.e., car I and car II travel for the same length of time because they start and stop together.

Stage III. (7½-8½) — The "direct coordination of simultaneity and synchronous durations" is possible. This involves immediate recognition rather than a system of trials and errors (Piaget, 1971a, p.p. 106-19).

Concept of Age. Another way of studying time and its developmental components is to examine how a child's concept of age is refined as he grows older. In general children do not envision time as a perpetual or continual process, but as a process of change that progresses toward certain fixed states. Once these states are reached, age or time does not progress but stops. Piaget identifies three stages of development in understanding the concept of age:

Stage I. (4-6) — Child believes that age is independent of birth, e.g., if he was born two years after his friend, he could still be older than his friend at some later time (succession). Child also believes that age differences are modified with time; that is, he might be two years older than his friend today, but next year he might be five years older (duration).

Stage II. (4-7)	In this stage children grasp either the successional ordering of age from birth or the problem of duration (age differences being mentioned).
Stage III. (8-9)	In this stage successions and durations become coordinated on an operational level (Piaget, 1971a, p.p. 220-21).

In summary, children before seven confuse ages of plants, animals, and human beings with their size and believe that the process of aging ceases with the attainment of one's full height. Between seven and eight the idea of aging is dissociated from size and height and is treated as a function of time (Piaget, 1971a, p.p. 231-33).

Thus, the theoretical foundation has been presented for constructing a preschool science curriculum based on processes of seriation, conservation, space, and time. In Chapter V prototypical experiences that can enhance children's development at each stage of growth will be described. These descriptions will also include experiences concerning interaction with the human and unknown environments in addition to the physical environment.

CHAPTER IV

THE GROWTH OF SERIATION, CONSERVATION, SPACE, AND TIME IN ADOLESCENSE AND THEIR RELATIONSHIP TO EARLY CHILDHOOD

In Piagetian terms adolescent thinking represents the culmination of structures of thought which have been formed during the preschool and elementary school years. Growth at this age level can be described in terms of the growth of logical thought.

The contents of this chapter will elaborate on the structures of logical thought which Piaget envisioned for formal operational reasoning. The chapter is divided into three sections. The first section defines the two new basic structures which emerge during this growth period, the INRC group and the 16 binary operators. The second section will explore the meaning of these structures for the processes of seriation, conservation, time, and space relations. The concluding section will show how the knowledge of the structures of formal thought can be beneficial to teachers of children in earlier stages of growth.

The INRC Group

Piaget has described the development of two structures during the period of formal operations, the INRC group and the 16 binary propositions, both of which represent the integration of processes developed in earlier stages of growth. These structures are theoretical and are used to explain the complicated reasoning of adolescents on an abstract level. Specifically, the INRC group is an attempt to outline the rules an adolescent uses in manipulating abstract propositions[1] (Ginsburg and Opper, 1969, p. 196). This group also governs the 16 binary propositions since every binary proposition has an inverse, reciprocal, and correlative aspect to it.

The INRC group includes four sub-processes: I = identity, N = negation or inversion, R = reciprocity, and C = correlation. Examples of these different processes are given below.

<u>Identity</u>

Identity is a sub-process of operation which leaves a system unchanged when it is utilized. In mathematics, it is the zero operator, which, when used in conjunction with a function utilizing addition, leaves the system unchanged. For example, if the function is $(X + 8)$ and zero represents the value of X, then $0 + 8 = 8$, and the value of the system is unchanged from its initial value. Likewise, if the function is 8x, then one (1) is the identity operator since $8(1) = 8$.

How does the identity operator function outside of mathematics: If one wants to travel between two towns, A and B, as shown in the diagram below, one could go by several different routes. Suppose one chooses to travel to

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[1]Propositions are hypothetical statements that adolescents use in explaining phenomena in their environment.

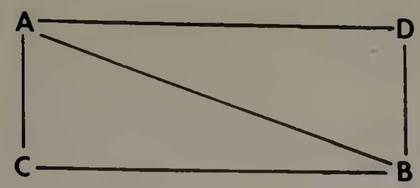


figure 1

town B by driving through town C and returning through town D. Then the complete trip ACBDA would constitute an identity operation since one has returned to the original destination by taking this route.

How does identity play a part in the construction of logical thought? The operation of conservation is an example of an identity operation since conservation implies a transformation which does not change a certain quality of an object. When a ball of clay is changed into the shape of a sausage, the amount of clay remains unchanged. Therefore, conservation is an identity operation which explains the constant nature of the amount of clay when its shape is changed.

<u>Negation-Inversion</u>

Negation is the cancellation of an operation through the combination of the direct operation with its inverse, thus returning it to its original starting point (Piaget, 1958, p.p. 272-73). In mathematics the operation of subtraction would be the inverse of addition and vice versa. Likewise, multiplication and division are inverse operations. For example, if one has 2 oranges and to this added 6 oranges (2 + 6), this operation could be cancelled by its inverse operation, the taking away of 6 oranges (-6), so that 2 + 6 2 + 6 - 6 = 2 and one returns to the starting point.

Referring to the example of the trip between towns A and B (figure 1, p.183), if one travelled to B directly (path AB), this trip could be negated by the inverse trip BA, again returning one to the starting point.

In logical thought many examples of inversion abound. When water is poured from a short, fat beaker into a tall, slender cylinder, this transformation can be negated by simply pouring the water back from the cylinder into the beaker. Likewise, class inclusion serves as an example of inversion. In a class inclusion problem consisting of a set of four differently colored blocks, one can classify the set as follows:

A = class of red blocks,

B = class of blocks of all colors other than red, and

C = class of all blocks.

Suppose a child recognizes that the combination of classes A + B equals C (A = B = C). If the child was asked what would be left if all of the red blocks were taken away from the set of blocks, C - A = B, this would constitute the inverse of the original combination B + A, i.e., B + A = C; C - A = B, since the origin B is reached through the cancellation of the original operation of + A.

Reciprocity

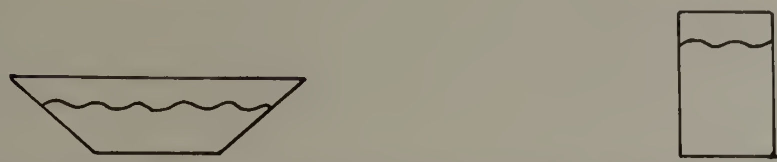
Reciprocity is the cancellation of an operation by a process of combining the initial operation with another which compensates for its effects. It might also involve offsetting a transformation through the recognition of a compensation of differences (Piaget, 1958, p.p. 272-73). Thus if one has

two rectangles, X and Y, of equal areas, $A_x = 4(3) = 12$; $A_y = 6(2) = 12$, it can be demonstrated that an increase in the length of Y when compared with X (from 4 to 6) is compensated or cancelled by a decrease in the width of Y as compared to X (from 3 to 2) with the result being that there is no change in the area in the transformation from rectangle X to rectangle Y.

Returning to the diagram of the four towns (p.183), if one travels to town B by way of town C, path ACB, this trip is compensated by a return trip BA, allowing the driver to reach his starting point. In this sense path ACB and BA are reciprocals or offsetting factors.

In logical thought, conservation tasks offer many examples of reciprocity. In the case where water is poured from a short, fat beaker into a tall, slender cylinder there is an accompanying increase in height. Yet, the amount of water has not changed, because this increase in height is compensated by a decrease in the width of the container.

Original Transformed



During the concrete operational stage inversion and recirpocity are not integrated as they are in formal thought, but are confined to a specific aspect of logical thought. Inversion is the type of reversibility characteristic of class groupings. This process permits subjects to add two classes, which possess similarities, to form a single class or to subtract a class of parts from its whole, i.e., the class of red blocks can be subtracted from the total class of blocks. Subjects can also multiply classes ($A_1 \times A_2 = A_1A_2$) or abstract one class from the whole ($A_1A_2 : A_2 = A_1$).

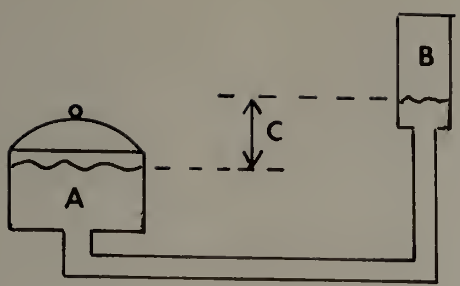
Reciprocity does not appear in classification systems during this stage but is instead the type of reversibility that is characteristic of concrete systems of relations. These systems involve the coordination of equivalences if they involve asymmetrical relations (A B). This system also includes multiplicative relations (correspondence). For example, a symmetrical relation, A = B, is equivalent to its reciprocal, B = A. An asymmetrical relation A B implies a difference between A and B; if this difference is compensated by a difference in the opposite direction B A, then the equivalence A = B or A = A is reached. These systems of relations cannot incorporate reversibility by inversion since inversion is based on the terms of the relation (qualitative difference), i.e., a class, and not the relation itself (quantitative difference), i.e., one stick is taller or equal to another (Piaget, 1958, p.p. 274-75).

Correlation

Briefly defined, correlation is an operation, which gives the negative reciprocal of a system. This represents the combination of negation and reciprocity, which is characteristic of formal thought. While operations of identity, negation, and reciprocity are present independent of one another during the concrete operational period, correlation does not come into existence until formal operational thought.

How could correlation be explained using the previous illustration of the four towns? Referring to figure 1 on page 183, consider the trip to B via path ADB and its return via path BCA. Paths ADB and BCA are reciprocals, that is, if one travels the distance of one of these paths it can be compensated by using the other path to return to the origin. But ADB and BCA are also inverses of one another, ADB = -BCA. It is evident that AD and BC, DB and CA are inverse to one another, i.e., AD = -BC, DB = -CA. Therefore, BCA is the negative reciprocal of ADB.

An example demonstrating the use of correlation on the propositional level will now be illustrated with the experiment on communicating vessels.



A & B - two vessels of different capacities and shape with a tube connecting the two; enough water is used to fill both vessels at half volume when A and B are at equal levels (C = 0).

C = the difference in height between the vessels A and B, i.e., C = B - A

figure 2

In this experiment as vessel B is raised, water increases in A and there is a corresponding decrease in the level of water in B due to a change in pressure. As vessel B is raised there is an increase in pressure from P_B^o (pressure when both are level)[2] to P_B^1 (pressure at new level). At the same time there is a correspondingly equal decrease in pressure in vessel A from P_A^o to P_A^1 so that $P_B^1 - P_B^o = P_A^o - P_A^1$. This is a reciprocal relation and can be rewritten $P_B^1 - P_B^o = R(P_A^o - P_A^1)$.

The process of negation is present in this situation since a readjustment of the vessels so that they are at equal levels will negate the increase and decrease in pressures. This repositioning of the vessels is done by the adjustment of water levels which indicate the volume in each vessel. For instance, suppose in figure 2 above vessel B has a volume V_B and vessel A has a volume of water V_A. The

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[2]P_A^o and P_B^o refer to pressures in vessels A and B where $P_A^o = P_B^o$ when both vessels are adjusted so that their water levels are equal.

inverse process can be achieved by adjusting the height of the vessels until $V_B = V_A$.

At the concrete operational level, children see the changes in pressure and the increases and decreases in water level separately. They do not see the causal relationship between the change in pressure and water level. During formal operations children come to understand this causal connection which represents the fusion of negation and recirpocity, namely, correlation. With the understanding of correlation, adolescents can explain the apparent change in volume in the two differently shaped containers.

In terms of logical thought, correlation changes _disjunctive_ relationships to _conjunctive_ relationships and vice versa. In the above example, adolescents can see _separately_ the relationship of pressure change and/or the change in water level. Eventually, they see the relationship between the pressure change and change in water level. In logical terms, it is a change from an "or" relationship (disjunction) to an "and" relationship (conjunction).

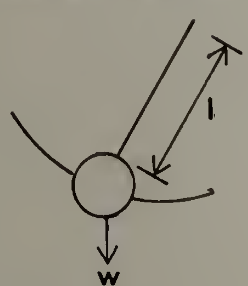
Summary

The INRC group is an attempt to outline the rules which an adolescent uses in manipulating functions (Ginsburg & Opper,1969, p. 196). It is used when two distinct reference systems have to be coordinated, as when two independent variables are studied to discover their combinatorial effects. It has psychological importance because it corresponds to fundamental structures of thought at the formal operational stage of growth (Piaget, 1958, p. 208).

Finally, the INRC group forms a commutative cluster of transformations among itself. Correlation has already been demonstrated to contain N and R. Relationships also exist between other members of the group as follows: R = CN or NC; N = CR or RC; I = RCN or CRN; IR = CN. These transformations govern the binary propositional operations as will be demonstrated later in this chapter.

The 16 Binary Propositions

The binary propositions form a qualitative model that is integrated like the INRC group to explain the possibilities of manipulating relationships with two or more variables. Piaget derived these propositions from a set of truth tables, deriving 16 combinations which can be broken down into eight unique operators and their respective inverses. A pendulum can be used to explain how these operators function. The number of swings a pendulum makes in a certain amount of time (period) depends on the length of the string from which it is suspended. However, other irrelevant variables[3] are



[3]Assume the absence of air friction.

present: the weight of the bob, the height from which the bob is dropped, and the amount of push given to start the swing. Suppose we are investigating the behavior of this pendulum and want to discover whether the weight of the bob or the height of the string or both influenced its period. We could project the following possibilities that could occur with these two variables. From these possibilities a truth

Possibilities That Exist in Pendulum
Experiment With Two Variables, Chart

Possibilities	Variables[4]		Conclusion
	Length (p)	Weight (q)	
1	p	q	length and weight are relevant factors
2	p	$\bar{q}$	length only is a factor
3	$\bar{p}$	q	weight only is a factor
4	$\bar{p}$	$\bar{q}$	neither length or weight are factors

[4] p - means that p is a factor; $\bar{p}$ - means that p is not a factor

table can be designed to show all possible combinations that exist among these hypothetical statements. For two variables that have four possibilities there are 16 possible combinations known as the binary propositions.

Truth Table of 16 Binary Propositions
Possible in Pendulum Experiment

Variables	Possibilities			
Length (p)	1	2	3	4
Weight (q)	p	p	$\bar{p}$	$\bar{p}$
Name of Operation	Possible Outcomes			
1. Independence of p to q	T	T	F	F
2. Inverse of independence of p to q	F	F	T	T
3. Independence of q to p	T	F	T	F
4. Inverse of operation 3	F	T	F	T
5. Conjunction	T	F	F	F
6. Incompatibility (Inverse 5)	F	T	T	T
7. Conjunctive Negation	F	F	F	T
8. Disjunction (Inverse 7)	T	T	T	F
9. Negation	F	F	F	F
10. Tautology (Inverse 9)	T	T	T	T
11. Reciprocal Implication	T	F	F	T
12. Reciprocal Exclusion	F	T	T	F
13. Converse Implication	T	T	F	T
14. Inverse of 13	F	F	T	F
15. Implication	T	F	T	T
16. Non-Implication	F	T	F	F

T - True; F - False

Chart from Ginsburg & Opper, 1969, p.p. 200-201.

In the following sections each of these operations will be defined and their relationship to the INRC group will be specified.

<u>Independence of p to q; q to p; and Their Inverses: Operations 1 - 4.</u>

The first set of combinations involve the independence of one variable from another. Regarding the first operation, the independence of p from q, the combinations which exist are $(p.q) \vee (p.\overline{q}) = p(p \vee \overline{q})$.[4] This logical statement means that q (weight) is unimportant as a factor in changing the period of the pendulum. Stated in simple terms it means that no matter if the bob is heavy or light, the pendulum's swing will be unaffected.

Operation 2, the inverse of operation 1, affirms the possibility of $(\overline{p}.q) \vee (\overline{p}.\overline{q}) = \overline{p}(q \vee \overline{q})$. This possibility, explained in terms of reality, indicates that irrespective of the weight, the length of the pendulum has no influence on its period.

Operation 3, the independence of q to p, finds that $(p.q) \vee (\overline{p}.q) = q(p \vee \overline{p})$possible. This translated means that weight is an influencing factor regardless of the length of the pendulum.

The reverse of operation 3, operation 4, includes the possibility of $(\overline{p}.\overline{q}) \vee (p.\overline{q})$ or $\overline{q}(p \vee \overline{p})$ occurring. This

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[4]The symbol (.) and ($\wedge$) means "and", the symbol (v) means "or".

means that irrespective of the length of the pendulum,weight is not a relevant variable.

Conjunction/Disjunction and Their Inverses.

Relationships that are conjunctive express a combination of factors which are necessary to explain some phenomenon, whereas disjunctive concepts indicate a separation of factors -- factors that might be alternatives to one another. Disjunctive concepts are "either/or affairs" (Bruner, 1956, p. 160). For example, the expression that 'both length and weight are relevant factors in determining the period of the pendulum' expresses conjunctive factors. The expression 'either length or weight influences the period of the pendulum' expresses disjunctive factors.

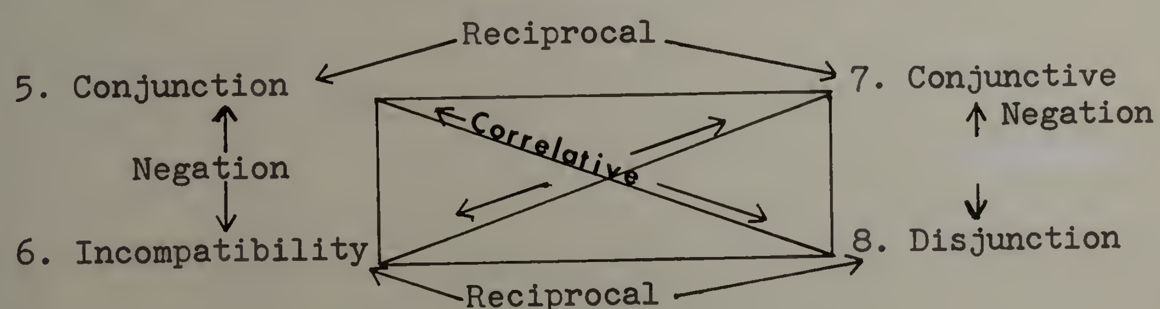
Referring to our chart on the binary propositions on page 192, the conjunctive operation affirms that (p.q) is possible. Restated, this simply means that both length and weight are the relevant factors.

On the other hand, operation 8, disjunction, asserts that $(p.q) \vee (\bar{p}.q) \vee (p.\bar{q}) = p(q \vee \bar{q}) \vee (\bar{p}.q)$ are factors. Translated into a hypothesis, a disjunctive operation would state, 'either a heavy or light bob with a long or short string attached to it are possibilities for explaining the period of the pendulum.' Stated in another way a disjunctive operation finds as a possibility any hypothesis which includes as one factor either the length or the weight as influencing the pendulum's period. Here, the 'either - or' relationship previously connected with the disjunctive operation is demonstrated.

The inverse of the conjunctive operation, <u>incompatibility,</u> gives $(p.\overline{q}) \vee (\overline{p}.q) \vee (\overline{p}.\overline{q}) = (p.\overline{q}) \vee \overline{p}(q \vee \overline{q})$ as hypothetical possibilities. Restated, the hypothesis is that the effect of the length of the pendulum is incompatible with the effect of the weight of the pendulum's bob, and that the pendulum will not be influenced by a change in the weight of the bob. The reverse is also true -- the effect of the weight of the bob is incompatible with the length of the string.

Finally, the inverse of the disjunctive operation is <u>conjunctive negation</u>, $(\overline{p}.\overline{q})$, which states that the period of a pendulum is not influenced by either the length of the string or the weight of the bob. If $\overline{p}$ and $\overline{q}$ are thought of as the absence of factors, then the hypothesis $\overline{p}.\overline{q}$ states that both the length of the pendulum and its weight are absent as factors contributing to the hypothesis.

It is interesting to note the relationship between operations 5, 6, 7, and 8. From the diagram below, the



function of the INRC group and the binary operations becomes evident. Conjunction is the correlative of disjunction; incompatibility is the reciprocal of disjunction; and conjunctive negation is the inverse of disjunction. This pattern is repeated for each group of four binary operators with the exception of operations 9, 10, 11, and 12.

Negation - Tautology.

The operations of negation and tautology allow a subject to discard length and weight as relevant factors since the operation of negation gives no possible hypotheses while the operation of tautology affirms all possibilities. In terms of the INRC group, negation is the inverse of tautology. The reciprocal of negation or tautology produces no new operations because both operations are symmetrical, that is, looking at the pattern of true-false statements in the chart, both the middle terms and the end terms of these operations are identical. When this occurs, the reciprocal of the operation produces the same operations. It might be said that the reciprocal in these special cases acts as an identity operator.

Reciprocal Implication - Exclusion.

Another pair of operations, which function together like negation-tautology and not in a system of four, like conjunction/disjunction is comprised of the operations of reciprocal implication and reciprocal exclusion. Reciprocal

<u>implication</u> finds $(p.q) \vee (\bar{p}.\bar{q})$ as possible hypotheses. Any time the term $(p.q)$ exists, the hypothesis is stated that p implies the presence of q, or that the presence of length as a variable implies that weight is also a variable, $p \gtrless q$. This reciprocal, $(\bar{p}.\bar{q})$, means then that the absence of length as a variable implies the absence of weight as a variable, $p \gtrless q$.

Referring to <u>reciprocal exclusion</u> the terms $(p.\bar{q}) \wedge (\bar{p}.q)$[5] are the possibilities. The hypotheses may be phrased as follows, 'The presence of length as a variable implies the absence of weight as a variable or the presence of length excludes weight as a factor' and that reciprocally 'the presence of weight as a factor excludes length as a relevant variable.' Since the relationship of exclusion exists between p and $\bar{q}$ and $\bar{p}$ and q, their reciprocals, it is called reciprocal exclusion. This operation is the inverse of reciprocal implication.

<u>Implication.</u>

Operations 13 - 16 are a group of four which can be identified by using all of the operations of the INRC group. <u>Implication</u> $(p \supset q)$ identifies $(\bar{p}.q) \vee (\bar{p}.\bar{q}) \vee (p.q)$ as relevant factors. Restated, this translates to mean that the presence of length as a factor implies the presence of weight as a factor. The term which is left out is $p.\bar{q}$ which means

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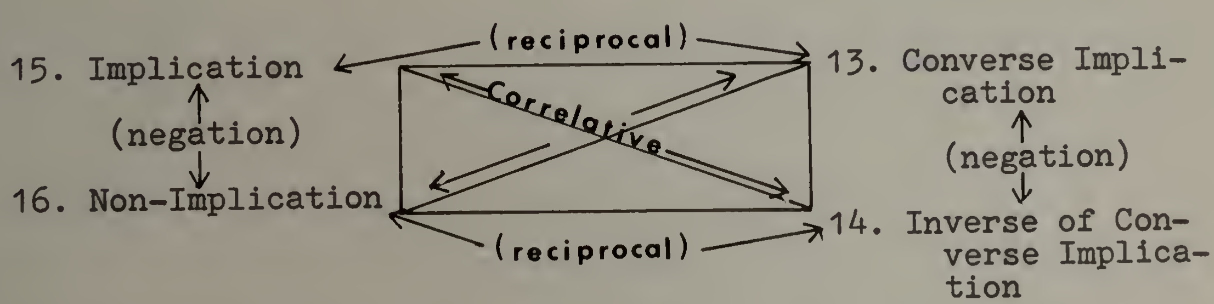
[5]The symbol ($\wedge$) means "and"; the symbol ($\subset$) or ($\supset$) means "implies".

that $p \supset \bar{q}$, which is contrary to our hypothesis. With the term $\bar{p}.q$ it could be argued that $q \supset \bar{p}$, but this is the reciprocal relationship and this term is consistent with the original statement that $p \supset q$. The inverse or negation of implication is $\bar{p}.q$ which is named <u>non-implication</u>. This operation states that the absence of length as a factor implies that weight must be a factor.

The third relationship that is possible is the reciprocal of implication, <u>converse implication</u>, which would include the terms $(p.q) \vee (\bar{p}.q) \vee (\bar{p}.\bar{q})$. This relationship states that $q \supset p$, weight implies length. The inverse of converse implication, $(p.\bar{q})$, states that $\bar{q} \supset p$ -- the irrelevance of weight as a factor implies that length is a factor.

These four types of implication incorporate all of the components of the INRC group in the same manner as the four conjunctive-disjunctive operations discussed earlier in this section. The diagram is shown below.



This concludes the introduction of the INRC group and the 16 binary operators.

The Role of Seriation, Conservation, Time, and Space in Formal Operations

In this section the role of the four processes or operations, which constitute our initial outline for the preschool science curriculum, will be explored as to their growth in adolescent thought. During this description, the use of the 16 binary operators will be cited, where appropriate, to give the reader further examples of their significance.

Seriation

In the transition from concrete to formal thought, there is a progression from operations like seriation and classification, which provide transitions for understanding objects and events for their own sake to a more complex arrangement. In formal thought, operations are used to project the possibilities inherent in a given situation of objects in their environment. Thinking in terms of parts and wholes, concrete thought is concerned with the relationship of parts to parts; formal thought provides the link between the parts and the whole (Piaget, 1958, p. 17).

Regarding seriation, Piaget briefly describes formal seriation as consisting of serial orders of serial orders or relations between relations and designates these operations as permutations. These permutations occur in two forms. The first is the form of an explicit math operation, specifically the operations involved in proportions; the second is in the form of a set of implications made up of relations, which are to be serially ordered and can be considered in the separation of variables (Piaget, 1958, p.p. 252-54).

Proportions.

In the example of the balance pictured below, a relationship can be discovered between a series of weights and

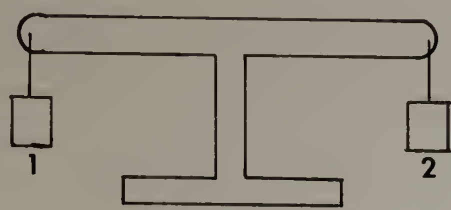


figure 1

the corresponding lengths that must be used to balance one another. In a sense there is a series of weights and lengths and one must discover the relationship between the two. This task involves the discovery of the multiplicative arrangement between the weight and length (W x L). If the relationship between side 1 and side 2 is written as a combination of reciprocal relationships, the relationship would be $W_1 \times L_1 = W_2 \times L_2$, and this can be converted to the proportion $W_1/W_2 = L_2/L_1$ or an inverse relationship is shown between weight and length, $W \propto 1/L$.[6] This means that for the series of weights of 5, 10, 15, and 20 there is a corresponding series of lengths of 4, 2, 4/3, and 1. This relationship is more than a one-to-one correspondence found during the

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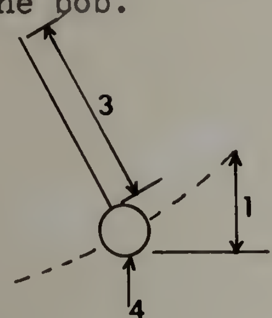
[6] $\propto$ means "implies".

concrete operational level. It is a relationship which involves the deduction of a set of proportions from a set of hypothetical statements.

Series of Implications.

The second use of seriation which occurs during adolescent thought is the formation of a series of implications used in the separation of variables. Specifically, take the example of the pendulum. How could the various factors be separated and the relevant causes sorted out. Concerning the pendulum, the variables or factors that might affect its swing are:

1. the height of the release point,
2. the force of the push given by the subject,
3. the length of the string, and
4. the weight of the bob.



In order to record the hypothesis, the following symbol system will be used:

l - statement that the length is changed

$\bar{l}$ - absence of a change in weight

w - statement that weight is changed

$\bar{w}$ - absence of change in weight

h - statement of change in height of drop,

$\bar{h}$ - absence of change in height,

f - statement of change in force of push,

$\bar{f}$ - absence of change in force,

x - proposition stating that there is a change in the frequency of oscillations, and

$\bar{x}$ - absence of change in frequency.

The purpose of the experiment is to see which factors (length, weight, height, or force) or combination of factors will result in a change in the frequency of oscillation of the pendulum. In order to isolate the relevant cause, the subject must separate and *seriate* the factors which are possible causes. All possible hypotheses must be generated and then tested to find which of them are true. This is what Piaget means by a serial order of implications. The implications are the hypotheses.

In order to exclude certain factors, subjects must hold all factors constant but one. The combination, $1.w.\bar{h}.\bar{f}. \subset x$ (a change in the length of the string and the weight of the bob results in a change in the frequency of the pendulum) does not tell one whether it was the combination of (1) the length *or* the weight, $1 \vee w$ -- disjunction, or (2) the length and weight together, $1.w$ -- conjunction, which caused the change. In order to determine the correct combination of factors, the combinations $1.\bar{w}.\bar{h}.\bar{f}$ and $\bar{1}.w.\bar{h}.\bar{f}$ would have to be tested. The total number of possibilities are given by the set of 16 binary operators, i.e., either conjunctive, disjunctive, reciprocal implication, etc.. By using the binary operators, subjects can adequately design the entire set of possibilities, whether the problem involves, two, four, or any number of factors, for the problem.

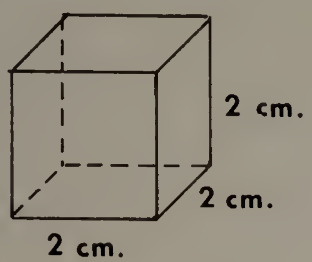
Conservation

Many types of conservation are mastered during formal operations, such as the conservation of volume, the conservation of density, and the conservation of uniform speeds. Formal operational conservation involves what Piaget terms "sub-logical operations" which means that these concepts are not separated from their environment but are intertwined with concepts of time and space. In the above conservations, volume and density necessitate a mastery of spatial concepts, while uniform speed is concerned with temporal ideas. Both the conservation of volume and uniform speed will be described in this section since they are the best documented of the three in Piaget's work.

Conservation of Volume.

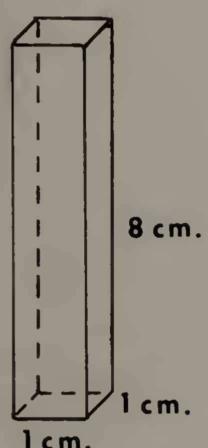
In many ways volume is less of an abstract concept that either length or area because everything a child sees in his environment is three-dimensional and has volume. However, when children look at an object, they do not necessarily realize the dimensionality of it. If very young children are given a cube, they might note the topological features of its being entirely closed or they might pay attention to the squareness of one of the faces. However, while volume is less of an abstract concept than a measure like area, it does not follow that it is a less difficult concept (Piaget, 1964, p. 360).

What problems does a change in the shape of an object present to a child who is trying to determine what is happening to the volume? Suppose a cube, which is two centimeters



Length of a side = 2 cm.
Surface area = 6 sides x 2 cm. x 2 cm. = $24\ cm.^2$
Volume = 2 cm. x 2 cm. x 2 cm. = $8\ cm.^3$

on a side is modified to form a parallel-piped with the dimensions 1 cm. x 1 cm. x 8 cm. as shown in the figure below. Here there are two figures of very different shapes.



Length = 1 cm., 8 cm.
Surface Area = 2 sides (1 cm. x 1 cm.) + 4 sides (8 cm. x 1 cm.) = $2\ cm.^2 + 32\ cm.^2 = 34\ cm.^2$
Volume = 1 cm. x 1 cm. x 8 cm. = $8\ cm.^3$

In the process of modification, there is a change in length and surface area, yet the volume remains the same (Piaget, 1964, p. 371). This fact causes a perceptual interference that confuses the child who is not able to separate variables. In fact, because the child does not focus on volume as being the amount of space that is encompassed by a figure, subjects cannot master conservation of volume before formal reasoning occurs.

During concrete operations, there is a preliminary conservation of volume in which volume is based on a child's notion of the invariance of a quantity of matter instead of the idea of enclosed space. When a figure is changed, i.e., from 

, the child at this level realizes that the matter that makes up object 1 is the same matter which makes up the modification (object 2). What is conserved is interior volume, which relates to the content of the object rather than the volume of the container. Children do not relate this type of conservation to problems which involve volumes created by water displacements, and which were previously mastered at a previous stage. If one places an object in a bucket of water (figure 1) and then asks the children where the water level will be when it is repositioned

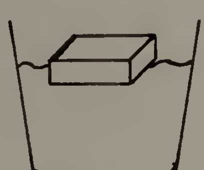


Figure 1

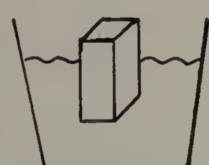


Figure 2

(figure 2), they do not comprehend the similarity because they do not conceive of the object in terms of occupied volume which encloses space.

During formal operations a new dimension is added, that of measurement. While children understand the multiplication of relations in terms of compensations (a decrease in length can be compensated by an increase in height) at the concrete operational level, it is not until they master mathematical multiplication of three-dimensional measurements that they fully comprehend true volume.[7] It is with this concept of volume that an object is viewed in terms of its surroundings.

The key to the understanding of conservation of volume is the subject's ability to handle proportions. Proportions lead to an understanding of the invariance of modifications in volume as follows. Suppose an object of dimensions x, y, and z is transformed to an object with dimensions x', y', and z'. If volume is conserved, the mathematical equality $xyz = x'y'z'$ exists. If the mathematical product xy is thought of as the area of this object and z as its height, the equality can be rearranged so that a relationship exists between the areas of the objects and their heights, i.e., $\frac{xy}{x'y'} = \frac{z'}{z}$. This proportion can now be used in understanding how a constant volume is maintained even though there is a change in the shape of a container. It is simply a reciprocal relationship between area and height with an increase in one dimension (area or height) being compensated by a decrease in

[7]True volume is volume that is thought of as occupying space.

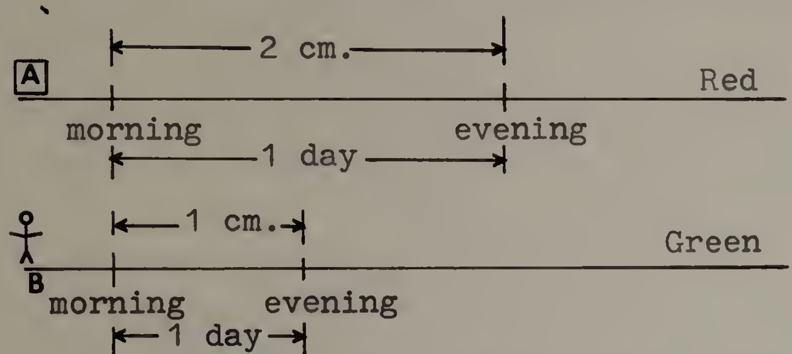
the other factor (height or area). If children are given a model of a building 2 cm. x 4 cm. x 3 cm. and are asked to construct a building which has the same space but with its base dimension 2 cm. x 2 cm., the subject realizes that this decrease by a half in the area of the base (from 8 cm.^{2} to 4 cm.^{2}) must be compensated by an increase in height, i.e., a doubling, or 6 cm.. Mathematically, this could be proved since $2 \times 4 \times 3 = 2 \times 2 \times 6$.

There is another aspect to this relationship between area and height that makes clear the fusion of reciprocity and negation at this stage. If the change in area is separated from that of height, the student will understand the transformation of areas $x \cdot y \longrightarrow x' \cdot y'$ as a process of reciprocity, that is, a compensation between an increase in the width and length. The change in height, $z \longrightarrow z'$ can be conceived in terms of addition and subtraction or expansion and compression of the height of the figure. This type of thinking involves the process of negation, that is, one can negate the effect of the height by canceling its increase or decrease. Therefore, when students use proportions to show the relationship between the area and height, $\frac{x \cdot y}{x' \cdot y'} = \frac{z'}{z}$, both reciprocity and negation (correlation) are used simultaneously as processes.

While it is evident that the INRC group plays a role in the conservation of volume, and one can see how Piaget's theory of groups and lattices is supported by what occurs in actual development, it is not clear how the 16 binary operators function in the conservation of volume. This results because Piaget has only speculated on the existence of the propositions and has not studied their development as he has done with the INRC group.

Conservation of Uniform Speeds.

The use of the binary propositions in handling formal operational concepts becomes clearer in the description of the conservation of uniform speeds. The experiment is designed as follows. Two tracks (lines drawn with different colored



markers) are placed on a table. Then a car, object A, and a doll, object B, are placed on these tracks. Object A is set to travel a distance of 2 cm. in a day, while object B travels at half that speed or 1 cm. in a day. In the experiment, the student is shown how far objects A and B travel at these speeds: (1) during the first day, (2) during the second day, and (3) during half of the third day. The child is then questioned as follows:

1. How far did A go on the second day if it starts and stops at the same times and travels at the same speed as the first day?

2. The question is repeated for the doll.
3. How far does the car travel on the last day? Where does it stop?
4. The question is repeated with the doll.
5. How many days will it take the doll to catch up to the car if the car stops after the second day?
6. "Does the distance between the stopping points of the car and the doll stay the same at the end of each day or does it increase regularly?" (Piaget, 1971, p.p. 253-54)

Discussion of Questions.

In the beginning, Q(1), children must demonstrate their understanding that at equal speeds and times an object will travel equal distances. In Q(2) they must show this conservation taking into account the fact that the doll is traveling at a different speed from the car. Answering Q(3), Q(4), and Q(5) necessitates the use of simple proportions to discover where the object stops in half the time of the other days. Q(6) determines the age at which children discover that the differences in distance traveled increase continuously as long as the speeds are conserved on the following days.

During formal operations Q(3)-(6) are successfully answered. The concept of proportions is necessary because the speeds and distances traveled are unequal. The concept of a constant increase in distance means that students have to understand some of the binary propositions, specifically:

1. the independence of distance from speed -- that the distance increases even though the speed remains constant, and
2. reciprocal implication -- that a decrease in the time of travel will cause a decrease in the distance traveled and vice versa.

So, the role of the binary propositions becomes evident in the process of conservation. Specifically, Q(5) necessitates the use of a projection into the future, and the use of hypothetical thinking to meet the possibility of having the doll catch up with the car when the car stops.

In the previous examples, instances of time and space concepts as well as specific processes of seriation and conservation have been discussed in terms of their functionings in formal thought. Many more concepts of space and time are understood at this level because of the introduction of functions like the INRC group and 16 binary propositions. Some of these will be briefly discussed in the next two sections.

Space

It has previously been mentioned that in formal thought thinking progresses due to such processes as projecting possibilities, generating hypotheses, and using deductive reasoning. These higher order forms of reasoning allow subjects to transcend the limitations of being able only to comprehend the immediate and concrete situations (Piaget, 1964, p. 16).

Although it has already been demonstrated how a spatial process is understood in formal thought, i.e., the conservation of volume, further advances in spatial concepts will be briefly mentioned to give the reader a more thorough idea of the advances at this stage.

Geometric Points.

It is not until children can view geometric points on an abstract level that the operation of continuity (one of the sub-processes of space) is realized. Once children understand that points can be extended infinitely, concepts such as unlimited subdivision and enclosure are mastered. When children are asked to draw a square that is larger than a given square, their response is that this task could go on infinitely since one could always draw one larger (Piaget, 1967, p.p. 129-49). This represents a type of deductive thinking that is characteristic of the binary proposition tautology in that it represents a principle of infinite recurrence (iteration).

This principle is demonstrated in geometric tasks involving the loci of points satisfying a specific situation. In the problem presented in finding the locus of points that lie equidistant from either (1) one point or (2) two points, a child first constructs either a series of points which are circular in the instance of the single point or a straight line in the case of two points. In formal thought, children achieve the final deductive step of realizing that these points can be generalized to represent an infinite series of circles or a line that can be extended infinitely. "This discovery of geometric loci .... is the finest example of the direct transition from induction which is empirical and intuitive to operational generalization which is deductive" (Piaget, 1964, p. 225).

Advance studies which show how children understand higher concepts of straight lines and curves are discussed in Piaget's section on curves of movement.

Representation of Curves of Movement.

In order to integrate both concepts involving the straight line and the circle, an experiment can be designed in which a child must draw the path that an ant travels in walking the length of a cylinder while the cylinder is slowly revolving.

This task involves the construction of spirals which necessitates the integration of two reference systems, the circular path of the revolving cylinder and the straight line of the ant walking on the length of the cylinder. This demands both of the binary propositions of conjunction and disjunction since completion of the tasks necessitate that children conceptualize each path individually, either the circular or rectangular path, and then combine both together, the circular <u>and</u> the rectangular path. It also involves implication since children must generalize determination of a few points (Piaget, 1964, p. 226).

There are several other topics which Piaget has documented specific formal structures for. These are listed on the following page.

Topic	Formal Structure
Duplicating a triangle (Piaget, 1964, p.p. 192-94)	Students draw lines that are outside the scope of the original drawing in order to solve a problem.
Sum of angles in a triangle (Piaget, 1964, p. 204)	Children differentiate between rectangular and triangular systems.

The judgments of similarity and the equality necessary for the understanding of the above topics require both serial and metrical quantification, both processes which are characteristic of formal thought. The construction of spatial concepts matures at this stage and determines to a great extent one's understanding of time, a topic which will now be considered.

Time

Time concepts are inherently more difficult than those of space because time is a totally abstract phenomenon.

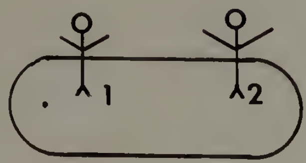
Although one can measure time by a clock, one cannot hold a second or see a minute.

Time is also irreversible. This means that children cannot reason about time directly by stopping a minute in progress and returning to the origin of that starting point. In fact, because time possesses these qualities, children come to understand time by an integration and differentiation of speed or motion with spatial concepts (distance) since these actions can be reversed and are concrete.

It is not surprising that because temporal concepts are purely abstract and must be slowly grasped indirectly, i.e., via speed and distance relationships, that great advances in the understanding of time occur during formal operations. Concepts of relativity, which compare different speeds that occur simultaneously, and concepts of acceleration (an increase in speed during a time interval) are mastered during this period. In the following section two of the concepts relating to speed and one relating to acceleration will be discussed in terms of their formal structure.

The Intuition of Speed.

The design of the experiment which is used to study children's conceptions of speeds presents a perceptual problem for the pre-formal thinking child. The experiment consists of a revolving metal rod into which two figures are attached, one very close to the point of revolution and one on the far end of the arm (see figure). Two paths are traced on the paper which lies beneath the rod. These questions



Top View

Side View

are then asked of the students:

1. Which doll went faster?
2. Which one had to hurry more?
3. Which one was more out of breath? (Piaget, 1971, p. 137)

Discussion: At first one might think that the dolls travel at the same speed since they are both attached to a rod which is traveling at a constant speed. However, what is happening conceptually is that the doll attached to the outer edge of the rod is traveling farther because of the wider diameter circle than the one closer to the point of revolution, $D_1 \quad D_2$. The fact that both dolls are attached to the same rod means that each doll completes one revolution in the same amount of time, $T_1 = T_2$. Since speed is the ratio of distance to time, $D/T = S$, the speed of the doll on the edge of the rod will have to travel at a faster speed, $S_2 \quad S_1$, since it must travel a greater distance in the same time.

Children cannot grasp this notion until they can differentiate the different paths of the dolls. Using the terminology of the binary propositions, they must recognize the independence of D_1 and D_2 and see the speeds as being entirely dependent on the distance traveled since the times are equal. They must also differentiate the different speeds from a system in which two speeds occur simultaneously (Piaget, 1971, p. 173).

It is evident in this experiment that only reasoning in abstract terms, apart from what one observes as happening, is sufficient to solve this problem. While this problem involves the differentiation of a single speed into two different speeds, students can also solve the problem by integrating or coordinating two different speeds to form one apparent speed, hence the problem of relative speeds.

Relative Speeds.

This experiment is more complex than the previous one since a variation in both distance and time occurs. The experiment consists of two belts which are parallel to one another and can move at different regulated speeds. On one belt is placed cards of eight cyclists equally divided along the belt; on the other is placed one card of a figure which represents the observer. The following questions are asked:

1. With the observer motionless and the cyclists in motion, how many cyclists will the observer see passing him in 15 seconds?
2. How many cyclists will the observer see in 16 seconds if both are traveling in the same direction?

3. How many cyclists will pass the observer in 15 seconds if the observer and cyclists travel in opposite directions (Piaget, 1971, p.p. 208-10)?

Discussion: How do adolescents come to understand this system so that they can predict the answers, given only the situation and not actually seeing the results? First, the student must concentrate on the speeds of each system separately: (1) the system where the observer is motionless, (2) the system where the observer and cyclists are moving in the same direction, and (3) the case where the observer and cyclists are moving in opposite directions, but toward each other. In system 1, the speed of the moving belt is set so that the observer sees eight cyclists moving past him in 15 seconds. This system acts as a reference when comparing other systems.

In system 2, it will take the eight cyclists more time to pass the observer since the observer is moving in the same direction, too. Since $T_2 > T_1$, $S_2 < S_1$ and the speed of the cyclists relative to the observer will appear to be slower in T_2. Likewise, in system 3 with the two objects traveling towards one another, it will take less time for the eight cyclists to pass the observer, $T_3 < T_1$. Hence, $S_3 > S_1$ and the speed of the cyclist will appear to increase relative to the observer.

Analyzing each system now allows the adolescent to return and predict the number of cyclists passed in each system. In system 1 it is a set rate of eight cyclists per 15 seconds; in system 2 it will be less since the speed of the cyclists appears to have decreased, while in system 3 it will be more than eight for just the opposite reason. It is only when the students must predict the answer that they are forced to separate the systems, since they can answer on the basis of actual observations made at the concrete level. This particular operation rests on the distinction adolescents made between one's absolute speed (when the observer is not moving) and the relative speeds encountered when both groups are moving (Piaget, 1971, p. 221). Again, the binary propositions are associated with the separation of variables, while deductive thinking functions in the understanding of relative speeds.

The discussion will now focus on the phenomenon of acceleration which consists of an increase in speed over a period of time. Specifically, it will focus on children's concepts of uniform or constant acceleration experienced by objects moving due to the effects of gravity.

Uniformly Accelerated Movement.

This experiment consists of questioning a student about the motion of a sled as it descends a uniformly sloped incline. In this experiment, flags are placed at equal distances along the hill to allow children to make measurements if they wish. Children do not totally understand the increase of speed in this experiment until they are able to ccordinate their notions of proportionality with their ideas of speed as space and time constructs. At that time, they coordinate the fact that the sled travels a greater distance in each equal time interval as it approaches the bottom of the slope (Piaget, 1971, p.p. 306-07). It should be pointed out that an exact metrical solution is not reached since this law of physics necessitates the use of a square relationship which is first understood in late adolescence.

Two Piagetian studies are very briefly mentioned to give the reader a complete picture of the temporal concepts introduced during formal thought.

Topic	Formal Structure
Relative Movements (Piaget, 1971, p.p. 114-32)	This experiment demands that students differentiate movements of a snail on a track (both of which are in motion) into two separate motions and then at a later stage recombine the motions into a coordinated whole.

Successive Movements Traveling Unequal Distances in Unequal Times (Piaget, 1971, p.p. 225-52)	Construction and comparison of proportions is needed, i.e., 4 cm. in 2 sec. is equal to 8 cm. in 4 sec.

Conclusion

Teacher's of preschool children are helped in two ways by having knowledge of formal operations. First, since they know the end point of logical thought and how it progresses from preschool to adulthood, they have a justification for what they teach in the early years. This not only gives them increased levels of confidence for teaching but allows them to project future deficiencies for children in adulthood if they do not master the early skills. A teacher knows that without competence in seriation, classification, conservation, and time and space relations, children will be completely confused by more complex phenomena they encounter later in life, and they will be unable to give even an objective account of what they see (Piaget, 1958, p. 69). Without these basic organizers to arrange their environment and to reduce the complexity, children will be hindered from becoming fully functioning adults later.

A second aid that knowledge of formal operations provides is that it gives teachers an overall scheme for the cognitive growth of the child which suggests ways of improvising and improving a child's overall competence.

For example, knowledge of seriation helps a child organize an experiment with the balance, while knowledge of time concepts enables children to organize their life and is prerequisite for their volitional competence. In addition, the role of language[8] now becomes crucial for competence in structuring abstract concepts.

Knowledge of formal operations gives some insight into an ever-present problem in education of why some people are consistently poor students in mathematics and science. Since both of these areas require increasing competence to organize and transform abstract concepts, lack of proper early training is often the reason for such deficiencies. The basic competencies that have been identified in the cognitive area can be used as a base for strengthening one's ability for logical and abstract thought. Prerequisite to these competencies is the teacher's skill in encouraging and molding individual and creative logical thought patterns in children.

With the addition of formal thought, the components of learning competence, which include integration, differentiation, generalization, and verification, are present in their most complete form. In an experiment on the separation of variables which involves a pendulum and the discovery of which of four factors influences its swing

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[8]Language used here refers to both the spoken form used in social communication and to mathematics, the language which is used for understanding the relationship among phenomenon of the physical world.

(period), the process of isolating the factors and determining their influence requires a *differentiation* of the factors. Then a combination process of coordinating all of the relevant factors into a formula or explanation represents the *integrative process*. From this a *generalization* is made to all pendulum systems, while verification occurs in the process of experimenting with each factor to find its relevancy.

Summary

Formal thought is the ultimate in flexibility of human thought. It allows the child to transcend his immediate concrete situation by a process of mental operations which can occur without having particular concrete objects present. This ability to think in abstract forms allows students to project possibilities which are inherent in a given situation and which frees one from the confusion wrought by unsuspecting situations. The formal system allows the teacher to see the completed sequence of growth and to more easily and with greater competence creatively interact with individual youngsters to help them achieve competence in their own life.

CHAPTER V

THE CURRICULUM

The intent of this chapter of the dissertation is to introduce learning experiences which promote competence at the various levels of development in preschool children. Since the sensorimotor stage is completed before this period, only brief reference will be made in the instructional objectives to this level for diagnostic purposes; the preoperational stage will be the focus of the learning experiences. For the sake of completeness and because there are always some exceptional children, these learning experiences will include some of the objectives at the concrete operational level. This selection is in no way meant to be exhaustive, since this level of development is more appropriate for elementary school children.

The chapter is organized around the processes of seriation, conservation, space,and time relations. Under each of these processes the following will be included:

1) a list of objectives designed to promote learning competence from the sensorimotor through the concrete operational stage;
2) a set of guidelines and prerequisites for the creation of learning experiences;
3) the basic learning experiences that promote developmental growth; and

4) a learning experience that promotes growth in areas other than the cognitive (i.e., volitional) and in relationship to environments other than the physical (i.e., the human environment).

Finally, a brief discussion of three of the most popular elementary school science curricula will be examined for learning experiences that might be used to promote competence in the areas of seriation, conservation, space, and time relations.

Seriation

Educational Objectives.

General. To order relationships in one's environment on the basis of differences specified by a given criterion.

Specific.

Sensorimotor Seriation (0-2 years)

1. To distinguish between loud-soft differences using an object from one's environment, e.g., a rattle.
2. To find an object which has perceptually disappeared by removing the barrier which screens the object.

Pre-Operational Seriation (3-6 years)[1]

3. To identify differences between two objects on the basis of size, length, texture, noise, or temperature.
4. To seriate 3 or 4 objects on the basis of:
    a. size (big-little)
    b. length (long-short)
    c. weight (fat-skinny, heavy-light)
    d. texture (smooth-rough)
    e. sound (loud-quiet)

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[1]Age norms are given to give teachers a general notion of when the objectives are appropriate. Once again, teachers should note that ages are only approximate and will vary with different cultures and classes.

f. odor (pungent-odorless)

g. temperature (hot-cold)

h. variation in color saturation (light-dark)

5. To seriate a 10 element series through trial and error methods.

6. To anticipate serial relationships by drawing a picture of a set of objects in one's environment which can be seriated on the basis of size, i.e., 10 sticks, each of a different size out of sequence.

<u>Concrete Operational Seriation (6-10 years)</u>

7. To seriate a series of 10 similar objects spontaneously without any trial and error and without having to depend on the perceptual configuration of the series, e.g., can arrange a series by figuring the overall pattern which emerges; for instance, a decreasing slope with a series of sticks.

8. To anticipate a series of 10 objects which differ by height and come in different colors by constructing a drawing of the objects (which are physically present in front of the child) which shows the objects seriated according to height and positioned within the series according to their respective colors.

<u>Guidelines for Writing Educational Experiences.</u>

An operation or process is something which can be "taught" by providing those experiences which encourage children to develop specific competencies. It is important to make sure that children have mastered the prerequisite processes needed to operationalize a particular process and that they have experienced the learning tasks which can provide competence in the prerequisite process. It is important then for children to gain familiarity with these phenomena, first on a preliminary level, and then on a more advanced level, but they should not be given tasks so difficult that they will build up a high degree of frustration.

<u>Prerequisites for Seriation Competence.</u>

Several sub-processes necessary for the development of seriation include: Knowledge of object permanence, attribute identification, and recognition of asymmetry. These are defined as follows:

Object Permanence - the ability to recognize the continuing existence of an object even when it is not present perceptually.

Attribute Identification - the recognition of specific properties of objects.

Asymmetry - the recognition of differences in attributes.

During the sensorimotor period, object permanence, asymmetry, and attribute identification are all important. If children are not convinced of the permanence of an object, then the whole task of seriation is impossible. If they cannot abstract attributes even unconsciously, they will not be able to recognize differences, and if they do not recognize differences (asymmetry), there would be no possibility of seriating anything.

Transitivity is also a factor in achieving fully operational seriation, as exemplified in the ordering of sticks using the method of increasing or decreasing slope lines. Transitive comparisons are made between the members of the series in order to construct the longer series containing 10 elements (see p. 80).

Prototypical Experiences.

Experience 1.

Objective: To identify the differences between objects (all of the same type) on the basis of size.

Process: Gross size discrimination.

Level: Pre-operational.

Materials: Generous amounts of play dough, painting supplies, wet sand, tinker toys, or any other construction materials.

Activity: Have child decide what he is going to make, but make sure he decides from the beginning whether it will be either large or small, or tall or short, etc.. Then after he constructs the object, the teacher questions him using objects other children have created as to whether it is bigger or smaller in comparison to his own. The objective is to help the child understand that a relation implies a comparison which is dependent on two or more objects (Weikart, et.al., 1971, p. 110).

Experience 2.

Objective: To seriate 3 or 4 objects on the basis of a difference in

a. height
b. diameter
c. height and diameter (conjunctive)
d. height or diameter (disjunctive)

Level: Pre-operational, concrete operational, 4-7 yeras.

Materials:

a. 10 yellow, wooden cylinders, equal in diameter, but varying in height from 3/8" to 2" in 1/8" increments.
b. 8 green cylinders of identical height but varying in diameter from 2" to 5/16" in varying increments.

c. 8 orange cylinders of different heights and diameters constructed so that the tallest cylinder has the largest diameter.

d. 10 purple cylinders of different heights and diameters, constructed so that the tallest block has the smallest diameter and the shortest block has the largest diameter.

Activity:

1. Select five of the smallest objects.
2. The teacher should order them in a series by height or by diameter by placing them upright on the carpet or table. Ask the child:

   How are they different?
   How are they alike?
   What do they look like?
   Which one is the daddy?
   Which one is the mommy?
   Which one is the baby?
   Where are the brothers and sisters?

3. The teacher mixes up the materials so they are not parallel to one another and asks the child to arrange the objects as before except that he must

position the objects on their sides. (Appropriate only with materials a, b, and c.)

4. If the child succeeds, mix up the objects and have them order the entire set of objects according to differences in diameter or height. If unsuccessful, the teacher should order the entire series and then remove every other object in the series until only 5 are left and then repeat step 3. This arrangement reduces the difficulty in recognizing the differences.
5. If successful in step 4, arrange the series of cylinders in reverse order on the same dimension (height or diameter) that was used in step 4, interchanging several members. See if the child can perceive the difference and correct the error.

Experience 3.

Objective: To anticipate a series by drawing a sketch of it before the actual manipulation of the objects.

Process: Anticipation through correspondence.

Level: Concrete operational.

Materials: 10 wooden rectangular blocks, 3/8" x 3/8" ranging in height from 3/8" to 3 9/16" in 3/8" intervals; pencil, paper, 4 dolls that differ in height.

Activity:

1. Ask child to order a series of 4 dolls. If child doesn't respond, ask him to order the dolls so that the shortest one is on the left and the longest on the right.
2. With sticks placed so that they are parallel to one another, but not seriated, and the dolls removed, tell the child that he/she is going to arrange the sticks in a similar fashion to that of the dolls only that he/she should draw a picture of how that arrangement will look first. The children may not manipulate or change the sticks.
3. Ask the children to order the sticks so that the longest is on the right and the shortest is on the left.
4. Reverse the order if the child completes step 3. During this change, rearrange the series by interchanging at least

2 and no more than 4 of the blocks. Observe if child can reconstruct the series.

5. Compare these results to those of previous experiences.

<u>Experience 4.</u>

Objective: To establish a correspondence between each member of two series of objects.

Process: Simple seriation with correspondence, 3-5 years.

Double seriation, 5-7 years.

Direct ordinal correspondence, 7-9 years.

Level: Pre-operational, concrete operational

Materials: 10 dolls constructed of pipe cleaners, ranging in height from 3" to 7½" varying by ½" increments; 10 sticks or wood, 3/8" x 3/8" and ranging in height from 3/8" to 3 9/16" varying every 3/8".

Activity:
1. Select 5 of the shortest dolls.
2. Order them in a series according to their height. Ask the child the following questions:
    a. How are they alike?
    b. How are they different?
    c. Which one is the daddy?
    d. Which one is the mommy?

e. Where is the baby?

f. Where are the brothers and sisters?

3. Mix up the dolls so that they are not parallel to one another and ask the child to arrange the dolls as before.
4. Mix up the dolls and ask the child to order the complete set of 10, putting the shortest on the left and the tallest on the right.
5. Tell the child that each doll has a toothbrush (stick of wood) and ask him/her to find the toothbrush that belongs to each doll so that the tallest doll gets the longest toothbrush. Begin this exercise by mixing up the series formed in step 4.
6. Once the 2 series are constructed and the appropriate stick is opposite each doll, spread the dolls out and push the sticks together. Pick put certain sticks and ask the child to find the appropriate doll.
7. Disarrange one of the series and repeat the question. Observe whether child forms direct correspondence or must recreate the series.

Experience 5.

Seriation and Attention - Attention is a major process necessary for the achievement of volitional or intentional competence. It can easily be coupled with serial tasks through non-verbal instruction.

Objective: To duplicate a seriation task that is modeled by non-verbal instruction.

Materials: 5 triangles cut from a 5" x 8" file card labeled A, B, C, D, and E. Dimensions:

A = base 8", sides 4 15/16", a - 2 7/8"

B = base 5", sides 4 3/16", 4", a - 3¼"

C = base 7 1/8", sides 4 3/4", 4 3/16", a - 2 5/8"

D = base 5", sides 4½", 5", a - 4"

E = base 7 1/8", sides 4½", a - 3 3/16"

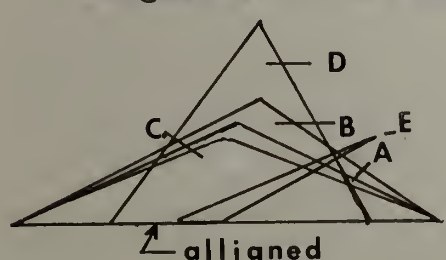
base is marked with dark line, a = altitude

Environment: 1. box of any shape to hold 5 triangles

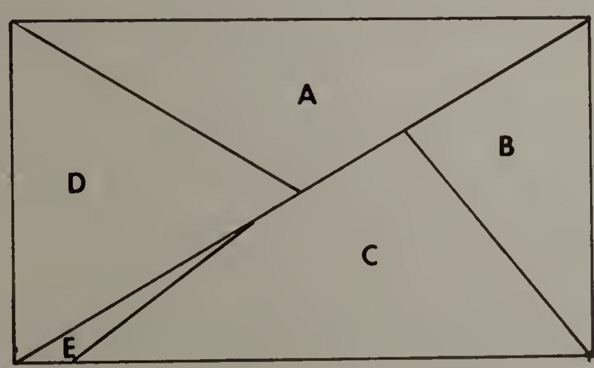
2. table, carpet, or carpeted platform

Activity:

1. Trace finger along base of triangle D and place on floor.
2. Trace finger along base of triangle B and place on floor so base of B is aligned with the base of D.



3. Repeat for A and place on top of D as in step 2.
4. Repeat with C.
5. Repeat with E.
6. Pick up E and place on carpet.
7. Pick up C and place it next to E so that the base of E and C together form a straight line.
8. Pick up triangle A and place it so that the side which is 4 15/16" touches the side of C which is 4 3/4".
9. Pick up B and place it so that it is between C and A with its base forming the third side of the rectangle.
10. Pick up D and place it between E and A so that its base forms the fourth side of the rectangle.
11. Have the child repeat the activity.



Conservation

Educational Objectives.

General. To recognize the invariance of certain qualities in physical systems which undergo particular transformations.

Specific.

Sensorimotor Conservation (0-2 years)

Object Permanence. To recognize that an object still exists even when it has disappeared from one's perceptual field.

Pre-Operational Conservation (3-6 years)

Generic Identity. To recognize the invariance of a living being across any transformation, e.g., to recognize that a cat is still a cat even when wearing a mask that symbolizes a worlf's head.

Inanimate Object Identity. To recognize the constancy of a physical substance across some transformations, e.g., to recognize that by pouring water from a large beaker into 3 smaller ones, the physical quality of the water is not changed; it is still the same water.

Order Identity. To identify the proper order of a sequence of 3 objects which disappear from view and then reappear (see p.106).

Concrete Operational Conservation (6-10 years)

Conservation. To recognize the invariance across transformations in the following physical systems.

Age of Initial Appearance in Years	Physical System
5-7	1. Number
5-7	2. Length
7	3. Substance (Mass)
7	4. Continuous Quantity (Liquids)
7	5. Discontinuous Quantity
7	6. Area
7-8	7. Order (with Transformation)
9-10	8. Weight

Guidelines for Writing Educational Experiences.

When writing educational experiences, one should remember that an operation as defined by Piaget is something which can only be "taught" by providing those experiences that facilitate a process of assimilation, accommodation, and equilibrium between a child, his environment, and his present developmental level.

In addition, other guidelines include:

1. At the intuitive or perceptual level, children are not able to deal with more than one property of an object or situation at a time.

2. Children able to conserve in one task may be unable to conserve with different materials or tasks.
3. Children tend to revert to the intuitive or perceptual level when the demands of the environment are too removed from concrete content.
4. Experiences must be active and accompanied by speech (Smart, p. 17).

Here is a cluster of studies on conservation of weight which have investigated which of three training methods were most effective in inducing conservation in 6-8 year old children. The training procedures used in these studies and performed with a series of different transformations consist of: (1) reinforced practice (R.P.), (2) addition/subtraction methods (A.S.), and (3) verbal rule instruction (V.R.I.).

Reinforced practice consists of 1 or 2 objects of equal weight being deformed, after which the question of conservation of weight is asked of the child. The objects are then weighed on a scale and with no comment the teacher proceeds to the next transformation (exercise).

The addition/subtraction method involves a deformation followed by the addition or subtraction of a piece of the object by the teacher in full view of the child. The question of conservation is asked of the child after which the results are observed on a scale.

The verbal rule instruction method also includes the deformation of one of the objects followed by the standard conservation question. If the child answers incorrectly a statement of the principle of conservation of weight is given followed by a demonstration of reversibility.

Smith (1968) reports in his study a comparison of three methods done on non-conservers and transitional conservers. With the non-conservers he found no significant difference between A.S., R.P., and the control. However, he did find that the V.R.I. method produced a highly significant difference. It should be pointed out that the balances used in these experiments were very crude and could have been a factor in consistently reinforcing a positive response. For the transitional conservers, significance was found for the R.P. and V.R.I. methods, although here again the V.R.I. method showed the greatest gain.

Smedslund (1961) studied the changes in the types of answers children give in a conservation task, using both the R.P. and A.S. methodology. He classified their answers as either symbolic or perceptual. Symbolic answers required explanations which directly or indirectly referred to previous events in the test sequence, while perceptual answers included explanations that could be directly perceived at the moment of the explanation. Smedslund found that the two methodologies, A.S. and R.P., produced no significant difference in their ability to produce an increase in the amount of symbolic answers a child would use during an experiment. However, it should be noted that the R.P. method had slightly greater effects than the A.S. sequence.

Brainerd and Allen (1971) conclude that the most effective methods of training conservation are those which incorporate reversibility phenomenon into the training method or prototypical experience. Specifically, there is a large number of studies which use the inversion-negation form of reversibility (Wallach, Wall, & Anderson, 1967), (Smith, 1968), (Gelman, 1969), and (Beilin, 1965). These studies tend to be the most successful in inducing conservation in non-conservers.

The ANISA concept of isolating relevant processes, arranging the environment of the learner, and then guiding children's interaction with that environment support Brainerd and Allen's conclusion. Specifically, experiences 2, 3, 4, and 5 employ reversibility techniques within the experience. In experience 5, an attempt is made to use the "reciprocity" form of reversibility.

Prerequisites.

Sub-processes necessary for the development of conservation include: identity, object permanence, perceptual constancy, inversion-negation, reciprocity, structuring, and synthesis, and an understanding of causality. Several of the sensorimotor processes, perceptual constancy and object permanence, seem to be especially important. "Perceptual constancy is comparable at the sensorimotor level with various ideas of conservation," (Piaget, 1966, p. 54) and "the permanence of the object. . .is not only the product of intelligence, but constitutes the very first of those fundamental ideas of conservation which we see developing within the thought process" (Piaget, 1966, p. 108). Identity, inversion-negation, and reciprocity have already been previously mentioned in the elaborate description section. Structuring and synthesis refer to a whole and its subsequent division into parts. These sub-processes refer to the ability to synthesize the parts to perceive the whole, and the ability to recognize the equivalence between the whole and its parts.[2] Finally, conservation demands that the child is able to free himself from a dependence on perceptual reasoning alone to deal with the more abstract concept of quantitative invariance.

<u>Prototypical Experiences.</u>

<u>Experience 1.</u>

Objective: To recognize using psychomotor parameters, the permanence of an object, when it has

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[2]Prerequisites like object permanence, structuring, synthesis, identity, etc., occur in conjunction with other processes as well, i.e., object permanence and seriation.

disappeared from one's view.

Process: Object permanence.

Level: Sensorimotor.

Materials: Teething ring, rattle.

Activity: Introduce object (teething ring) to child so that he begins to play with it. After a period of 3 minutes withdraw the ring so that he cannot see it. Observe his facial expressions.

Repeat with rattle, but when you withdraw rattle, shake it so the infant can hear the sound, even though it is out of sight.

Evaluation: If the infant seeks the object after it has disappeared, he has achieved a degree of object permanence. Intermediate stages are present when you observe the infant staring at the spot where the object disappeared, instead of playing with some unrelated object. Also, the infant begins to use his eyes to follow object's disappearance (Ginsburg & Opper, p.p. 42-43).

Experience 2.

Objective: To understand that when water (and like substances) undergoes a transformation regarding its shape, it is still the same water (or substance).

Process: Object identity.

Level: Pre-operational.

Materials: Water, pans (different shapes), play dough.

Activity: Pour water into one pan and let child play with it a while. Question him as to its height, amount, color, etc. Then pour water into a second pan of different size and shape. Question child as to the difference in height, appearance (e.g., round vs. square), etc. Ask him if it is still the same water.

Repeat using play dough.

Repeat using living objects (DeVries, 1969).

Experience 3.

Objective: To understand that two rows of objects contain the same number of items if there is a one-to-one correspondence between these objects, regardless of the physical appearance of the rows (ie., differences in distances between objects in a given row).

Process: Conservation of number.

Level: Concrete operational.

Materials: Button assortment, number of pennies (10).

Activity: Ask child to select 6 buttons and 6 pennies and arrange them on the table so that there are 2 rows, one of pennies and one of buttons. Ask him which set has more. Rearrange row of pennies so that they are spread out more than the row of buttons. Ask child about equivalence.

Take the buttons and put them side by side. Repeat question. If he repeats that the sets are unequal, ask him to count the elements of each set. If he says they are equal, ask him how he could prove it.

<u>Experience 4.</u>

Objective: To understand that 2 objects, initially determined to be equal in the amount of matter, maintain that equality when one of the objects undergoes a change in shape <u>because</u> that change can be reversed (inversion).

Process: Conservation of mass.

Level: Concrete operational.

Materials: Two balls, 3" in diameter, made out of play dough.

Activity:

1. Place 2 balls on the floor or table.
2. Ask child if the 2 balls contain the smae amount of play dough. If the child thinks they contain different

amounts, allow him to take away or add play dough from one ball until he claims they are equal.

3. Take one ball and roll it into a cylinder.
4. Roll the cylinder back into the original ball.
5. Ask child if the 2 balls are equal. If he agrees that they are, proceed to step 6. If he thinks they are not, return to step 2.
6. Pick up one ball and roll it into a cylinder. Repeat the question about equality of amount between the ball and cylinder.
7. Evaluate whether the child uses inversion as a reason for believing that there is no change in the amount of play dough.

<u>Experience 5.</u>

Objective: To understand that 2 objects, initially determined to be equal in the amount of matter, maintain that equality when one undergoes a change in shape <u>because</u> the changes in appearance compensate for one another (reciprocity).

Materials: Two balls, 3" in diameter, made out of play dough.

Level: Concrete operational (5-8 years).

Activity: 1. and 2. Repeat first two steps of Experience 4.

3. Take one ball and roll it into a cylinder. Extend thumb and index finger the length of the cylinder. Extend the fingers the length of the diameter.
4. Roll the cylinder back into a ball. Ask child about the amounts of play dough in the two balls. If he agrees the 2 balls are equal in amounts, go on to step 5. If he does not, return to step 1, described in Experience 4.
5. Repeat step 3.
6. Ask child to compare the amounts of play dough in the cylinder and the ball.
7. Evaluate whether child uses reciprocity as a reason for believing that there is no change.

Experience 6.

Conservation of Love - Systems of conservation apply to other potentialities besides cognitive. This learning experience introduces the use of the process of conservation to promote affective competence, and specifically involves the emotion of love. Love is a very powerful emotion, yet there can be much diversity in its expression. The behaviors which are characteristic of the love between parents and children can vary from the warm reassurance of parents during times of stress to firm guidance during periods of discipline. One might say that the quality of love is conserved in this transformation, although the outward behaviors are perceptually different. This type of conservation is of quality not quantity, since it is impossible to measure the quantity of love. In this way conservation of love is similar to identity conservation.

Objective: To understand that parental love is manifested in all types of behaviors and that a change in behavior does not mean that one's parents do not love them.

Materials: Four 5" x 8" file cards with pictures pasted on them showing a parent or parents: (1) kissing their children, (2) talking sternly to their children, (3) shouting at their children, and (4) spanking their children.

Environment:

1. Have child sitting on platform, chair, or carpeted floor.
2. Child, age 3-5 years old.

Guided Interaction/

Activity:

1. Place one of the pictures on the floor or table. Ask child to make up a story explaining the picture.
2. Repeat for each of the remaining 3 pictures.
3. Ask the child to indicate which pictures show a parent loving their child. Select the picture from 2, e, or 4 that children relate to best in terms of representing punishment. Use the appropriate picture in step 4.
4. Create a story about pictures 1 and 2, 3, or 4 as follows: "One day Otis (the child) and his parents decided to go on a picnic. They awoke early in the morning when Otis jumped on his parents' bed and his parents kissed him (picture 1). However, later in the day, Otis told his parents a lie about brushing his teeth when he really didn't, so his parents punished him (picture 2). Which picture shows that Otis' parents loved him? How could they love him here (picture 1) and not

here (picture 2, 3, or 4)? Would you want parents who didn't punish you at all?

5. If the child does not understand, tell him that parents show love in different ways depending on how they behave. It might not always be a happy occasion, but this doesn't mean that parents do not love their children (i.e., the form of the expression changes, but the love remains).

Cognitive Space

Educational Objectives.

General.

I. To draw open and closed figures showing an understanding of the relationships of: (1) proximity, (2) separation, (3) order, (4) enclosure, and (5) continuity.

II. To view figures in perspective with relationship to other figures, both with real objects and with pictures.

III. To demonstrate metric competency in concepts of length, area, and volume.

Specific.

Sensorimotor Space (0-2 years)

To discriminate between different shapes utilizing tactile and visual perception by filling a cube with objects of various shapes, which fit the respective openings in the sides of the cube. (No experiments which require drawings are possible at this stage.)

Pre-Operational Space (3-6 years)

1. To make topological discriminations when replicating pictures by differentiating open from closed figures and circular from straight lines.

2. To make ordered correspondences on the basis of color by duplicating a string of beads on a chain from a supply of beads of different sizes (topological order).
3. To duplicate a knot (topological surrounding).
4. To construct a straight line using match sticks and a plasticene table top which has the shape of a square or rectangle.
5. To make euclidean discriminations by accurately drawing rectangles, squares, and triangles.

<u>Concrete Operational Space (7-11 years)</u>

1. To construct spontaneously the reverse order of a string of beads (topological order).
2. To see as equivalent 2 knots of different tautness (topological surrounding).
3. To draw the smallest or largest representation of any figure (topological continuity).
4. To construct a straight line regardless of the orientation of that line with respect to the edges of a table (projective space).
5. To represent a straight line and circle from different perspectives through the use of drawings (projective space).
6. To construct different perspectives through a point-by-point correspondence between what is seen and what is drawn (projective space).

7. To recognize two objects as being equivalent if they were both initially the same but now one is rotated 180° (projective space, euclidean space).
8. To correctly duplicate a rhombus (projective, euclidean space).
9. To recognize similarities between triangles by establishing the equality of the interior angles and parallelity of the corresponding sides (projective, euclidean space).
10. To inductively conclude that the sum of all angles in a triangle are equal in all triangles (euclidean space).
11. To understand that 2 areas can be equivalent even if the shapes differ (euclidean space, conservation of area).
12. To recognize the permanence of length regarding the rearrangement of points which make up a line (euclidean space, conservation of length).

<u>Formal Operational Space (11-15 years)</u>

1. To recognize that subdividion is unlimited and that the synthesis of the whole is the reverse of unlimited subdivision (topological-continuity).
2. To understand mathematically the relationship between area and volume (euclidean space).
3. To understand that two volumes can be equivalent even if two objects have different shapes (euclidean space-conservation of volume).

Guidelines in Writing Prototypical Experiences.

Because concepts of space vary according to culture, it is important to understand how a particular culture conceives of space when writing prototypical experiences. Although examples of an international nature already have been cited in the justification section, examples of different spatial concepts can be found within a culture also. The adjustment of people from rural society, who move to urban centers, is primarily one of adjustment to differences in spatial and temporal concepts. If someone, who has lived on a farm and whose nearest neighbor is a mile from them, moves to a high-rise apartment, which holds from two to three thousand occupants, they would have to adjust to a different spatial arrangement which has many more objects per given amount of space than a rural environment. Add to this a wide cultural difference, i.e., the American Indian or the Chicano, and the adjustment is more difficult.

What are the educational problems in such situations? First, there are apt to be refinements in a particular culture's language. Educational studies, which were done with Eskimoes who live in wilderness areas, show a predominance of descriptive words in their language which describe spatial locations in barren environments. These Eskimoes exhibited an extraordinary ability to recognize and draw objects in their own environment from almost any perspective and orientation (Vernon, 1966). Other studies

(Jahoda, 1966; Segall, 1963) have demonstrated differences of spatial concepts in African cultures with respect to their responses to the Muller-Lyer illusion, which is the tendency to interpret three-dimensional stimuli as if it were two-dimensional. The studies conclude that the more urban a population, the more susceptible they are to the illusion. Hudson (1960, 1962) concluded that cultural rather than intellectual variables influence this illusion. In another study, emotional disposition and nutrition are cited as variables which influence a person's ability to perceive space globally (Dawson, 1967).

An ANISA teacher must be aware of these factors and compensate for cultural differences so that the basic levels of competency described in the specification can be achieved.

Prerequisites.

Viewing an object in a spatial environment requires the use of logico-mathematical operations as a base, i.e., seriation, conservation. This necessitates the reappearance of former processes for the growth of a mature conceptual awareness of spatial relations. The internalization of sub-process of order and continuity requires a competency in seriation; classification is necessary for the coordination of perspectives and the recognition of similarities of angles and triangles. Number relations is essential for metric quantification when working with length, area, and volume. Conservation is demanded for: (1) the comparisons of transformations of length, area, and volume, and (2) the transformation of ordinary manipulations between numbers into a system of measurement, required for competency of formal spatial concepts.

If perceptual variables are considered, visual experience is a limiting factor in spatial conceptualization. A study, comparing children who have congenital blindness with normal children, reveals a statistically poorer conception of spatial relationships in the blind youngsters (Hartlage, p.p. 650-651). In a different experiment which studied the effect of genetic intellectual ability, Hermelin (1961) found that shape recognition is greatly impaired in imbeciles, if visual discrimination is used to test the level of spatial awareness; however, impairment is reduced if a method of sterognosis (the use of active manipulation to explore objects) is introduced.

Prototypical Experiences.

Experience 1.

Objective: To discriminate between different geometric shapes.

Level: Sensorimotor, pre-operational.

Process: Perceptual recognition of shapes.

Materials: Large cube with openings in the shape of geometric figures located on all sides, different shaped pieces of plastic to fit the openings (may be obtained from Child Guidance Toys).

Activity: Present the materials to the child. Allow child to play and manipulate objects. If he doesn't attempt to put the objects in the box via the openings, demonstrate the task for him.

Evaluation: Observe the time period which it takes for a child to put the objects in the box. An increase in learning is indicated by an increase in speed of putting objects in cube or a decrease in the number of trials it takes to fit a particular shape in the appropriate hole. Keep in mind that some materials are easier than others.

This experiment is similar to the others using the Gesell performance box (Gesell, 1925). Other prototypical experiences are described by Meyer (1940) using normal children and by Worchel (1951) using blind children.

Experience 2.

Objective: To draw the smallest or largest representation of a given figure realizing that the shape is constant and not destroyed during the process.

Level: Pre-operational, concrete-formal operational.

Process: Topological space - continuity.

Materials: Paper, pencil, 1 rubber band.

Activity:

1. Draw a square on a sheet of paper. Ask child to draw:
   a. the largest possible square, and
   b. the smallest possible square.
2. Draw a straight line on a piece of paper; ask the child to draw ahlf the line, then half of the half, and so on. After has has drawn the shortest possible line, ask him if he can continue the task in his <u>mind</u>. Repeat, substituting a rubber band for the drawing of a straight line.
3. Ask child what the end point of the subdivision of the straight line or the seriation of the cube will be. If he says 'point' ask him whether the point has a shape. If the answer is yes and he believes it is in the shape of the figure originally subdivided, it shows that he is convinced of the continuity of the forms. If he answers negatively, it shows that he is still perception bound.

4. Ask child what will happen if all points are added together. Supplement the question by drawing points and then fitting them within the points. Repeat question.

Experience 3.

Objective: To project viewpoints from other perspectives without physically being in that position.

Level: Pre-operational, concrete and formal operational.

Process: Projective space - coordination of perspectives.

Materials: 3 cones of thin cardborad: 1 red cone (1.5 cm. height, 20.0 cm. diameter); 1 blue cone (14 cm. diameter, 7.5 cm. height); 1 yellow cone (9 cm. diameter, 5 cm. height); 1 square of green cardborad (52 cm. x 52 cm.) on which three circles are marked showing the positions of the cones; 9 cards (14 x 18 cm.) showing pictures of cones from different perspectives (Laurendeau and Pinard, p. 315); 1 man made of modeling clay or wood (3 cm. maximum height); 3 cut out triangles: 1 blue (14 cm. base, 7.5 cm. height); 1 yellow (9 cm. base, 5 cm. height); 1 red (20 cm. base, 11.5 cm. height).

Activity: Arrange cones which represent mountains so that the blue mountain is on the left and the yellow mountain on the right in front of the red mountain (Laurendeau and Pinard, p. 314), as shown below.

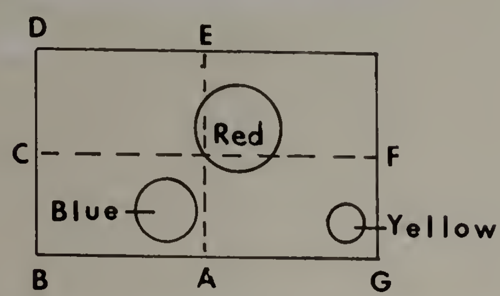


Figure showing positions of cones described in activity above. The letters are perspectives described below.

1. The child is given three paper triangles and asked to construct the kind of snapshots that would be taken at perspectives A, C, E, and F. Then, he is asked to construct a similar arrangement for perspectives B and C.
2. Use the doll and place it at various perspectives. Direct the child to select the snapshot that would be taken at that perspective from among those shown on the cards.

3. Have the child select one of the cards. Then ask him to position the doll and coordinate it with that perspective.

Evaluation: Laurendeau and Pinard have found that activity 1 is too difficult of children. For other evaluation suggestions, see Piaget (1967, p.p. 210-246) and Laurendeau and Pinard (p.p. 321-401).

<u>Experience 4.</u>

Objective: To understand that the distance of a straight line composed of several different segments is constant no matter what the orientation of the segments.

Level: Pre-operational, concrete operational (5-8 years)

Process: Euclidean space - conservation of length.

Materials: 10-16 match sticks of equal lengths.

Activity:
1. Construct two rows containing 5 match sticks apiece and placed end to end so as to form two straight lines of equal length.
2. Ask child if the two lines are equal. If he answers negatively, allow him to arrange the rows until he can agree to the equality.

3. Transform the bottom row into the following configurations:

4. After each transformation, ask child to compare the new transformation with the original straight line.

5. If he correctly understands the invariance, devise new transformations with 8 match sticks in a row that offer greater perceptual difficulty. If the child does not easily master the task, rearrange the transformation back into the straight line and begin at step 2.

<u>Experience 5.</u>

<u>Space and the Human Environment</u> - In order to stimulate children to become adaptable in terms of life style, e.g., rural as opposed to urban, and to have the flexibility needed to become a world citizen, they must familiarize themselves with other cultures. Earlier in this chapter, examples were cited of how different cultures organized space in unique ways. The following experience makes children aware

of the differences in spatial organization between rural and urban environments.

Objective: To understand the spatial differences between the environments of the city as opposed to that of the country.

Materials: Audiovisual materials in the form of pictures and movies showing scenes from the country and the city.

Environment: 6-15 children, ages 4-10 years.

Activity:

1. Show children pictures of the country scenes and elicit responses to the following questions:
   a. What objects do you see in the picture?
   b. What colors do you see?
   c. Where would you play in the picture?
   d. What would you play?
   e. Would you like to live there?
   f. Why?
2. Repeat with pictures of the city.
3. Repeat activity with movies representing the differences.
4. Repeat taking a field trip to the environment that children are not familiar with.

5. Ask children to draw a picture of each environment.
6. Discuss with children each environment in terms of the amount of space that is occupied by buildings, people, cars, and other objects.
7. Ask children how other children in each environment must feel about their own home neighborhood.
8. Summarize each environment point out the differences in occupied space in each environment.

Cognitive Time

Educational Objectives.

General. To order (1) a sequence of two events occurring at different speeds, (2) to comprehend the equality of durations which occur within the same time interval, and (3) to seriate durations between two events.

Specific.

Sensorimotor Time (0-2 years)

1. To respond to the final event of a sequence through psychomotor movements, i.e., reaching with the hands to take a bottle. (Conditioning experiments might be used here.)
2. To distinguish between different time intervals in a feeding schedule with a psychomotor action.
3. To Psychomotorally repeat rhythmic sequences, i.e., fast, slow, 4/4 time, 3/4 time.

Pre-Operational Time (3-6 years)

1. To increase one's vocabulary in the use of words of past, present, and future.
2. To order durations of two events traveling at the same speed but covering different distances.
3. To correctly order a sequence of two events which are independent of one another, i.e.,
   a. Two cars traveling at different velocities on two tracks.

b. The order of the birth and age of your favorite playmates.

c. The order of birth and the age of two trees planted at different times.

4. To correctly order a sequence of two events which are interrelated to one another, i.e., the flow of liquids between two containers.

5. To recognize the equality of durations taking place at synchronous time intervals, regardless of the interference of perceptual and spatial cues, i.e.,

   a. The duration of two periods of time in which a liquid flows from one container to another.

   b. The difference in ages between you and two playmates who were born in the same year.

6. To order the length of durations within a single event at a constant motion, i.e., the flow of liquid out of a container where the liquid is stopped at equal time intervals.

7. To demonstrate that velocity is inversely proportional to time; that is, the faster an object or event moves, the less time it takes.

8. To understand the duration of a year.

Concrete Operational Time (7-11 years)

1. To order on the basis of the length of a time interval the durations of two events occurring at equal times.
2. To measure time in terms of a clock and to coordinate this with concepts of succession and duration.

Guidelines for Writing Educational Experiences.

It is important to realize that while the child should be competent in the coordination of processes of succession, simultaneity, and duration, he should also be developing his competency of measurement for time intervals. Orme suggests that a child's concept of time arises from inner experiences and rhythmic needs with adults. To develop this concept, it is the author's experience that at the age of 5 the clock should be introduced and practice should be provided so that a child can recognize the different subdivisions, i.e., hour, second. Opportunities should be introduced, beginning at,6-7 for children to estimate time intervals. A pendulum might be provided as an instrument for measuring time. Children's concepts of an hour are not developed until around 8 (Orme, 1969), and his sense of a year develops at 9 (Bradley, 1948). Furthermore, there is at least one study on time that suggests differences of time estimation are present between men and women (Matsuda, 1968).

Also, rhythm is a very good way of providing experiences of time in infants (Fraisse, 1963).

Prerequisites.

Several other processes are involved in cognitive time. In succession, the process of seriation and serial correspondence (necessary for co-seriation) is necessary, only here it is on the basis of a sense of time. Succession and duration also demands that a child's ability to classify be fairly well developed, particularly his understanding of class inclusion. For example, the child must grasp that if event B follows event A, and event C follows event B, then the duration of A - C is longer than A - B or B - C. Cognitive time also relies on a system of measurement, which is defined as the synthesis of the systems of displacement and partition (Piaget, 1971b, p. 297), and is introduced at the operational level (Piaget, 1971c, p.p. 70-75).

In addition, there is a conservation process involved in several of the temporal concepts. Children must understand that:

(1) all clocks are equal in terms of the time it takes for a minute or an hour to pass;

(2) each day is equal to every other day no matter what one's experiences were, be they ecstatic or depressing; and

(3) two or more continuous events are equal in time when the beginning and end points coincide, regardless of the distance covered or the speed traveled.

A major consideration in developing prototypical experiences for populations internationally is that time to a large extent is culturally determined. For instance, the Truk tribe in the Southwest Pacific show an inability to grasp the simultaneity of two events, if spatially they are separated by a distance. In the Tiv culture of Nigeria, succession of time is almost non-existent; this culture views time as if it occurred in a capsule; that is, a series of durations which are regulated for a specific daily event (Hall, 1959, p.p. 26-27). Other examples include the Iranian culture, where the future isn't viewed as reality, or the Arab culture which makes no distinction between waiting a long time and a very long time (the sense of duration is dulled) (Hall, 1959, p.p. 29, 139).

<u>Prototypical Experiences.</u>

<u>Experience 1.</u>

Objective: To discriminate between different temporal rhythms.

Level: Sensorimotor (0-2 years)

Materials: None

Activity: 1. Gain the infant's attention by holding up your hand.

2. Slap your hand on the floor or the crib.

3. Repeat until infant imitates your gesture.

4. Slap your hand twice in succession, counting from one to three before commencing the second slap.

5. Repeat until infant imitates.

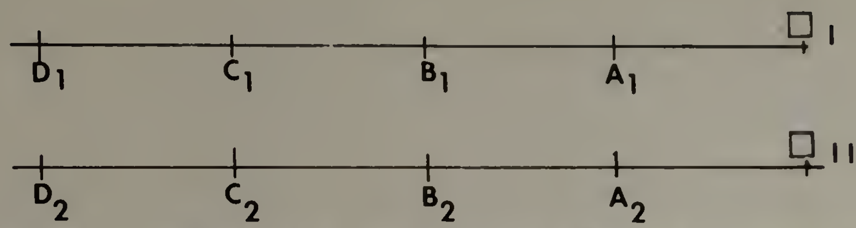
6. Slap your hand twice in succession c counting from one to eight before commencing the second slap.

7. Repeat and evaluate whether the infant has recognized the difference in the duration between the slaps. If this exercise is successful, diminish the separation between durations from 5 seconds to three seconds.

<u>Experience 2. Cognitive Time with Two Independent Events</u>

Level: Pre-operational - concrete operational

Materials: Two electric trains, cars, or other moving vehicles that can be varied in velocity, two tracks, markers as shown.



Activity: There are two tracks of equal lengths with two vehicles, I and II, placed at the same location on their respective tracks. Simultaneously, the experimenter allows I to cover the distance A_1D_1, where it stops, while II covers the distance A_2B_2; II then continues to travel between B_2 and C_2 where it stops.

Questions to child:

1. Which car stopped first, I or II (succession)?
2. Did it take longer to travel distance A_1D_1 or A_2C_2 (duration)?

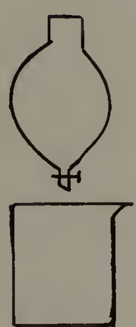
The vehicles are now placed at the beginning, are started and stopped simultaneously, and the velocity of the vehicles is altered so that II reaches B_2 (assume I to reach C_1 during this time).

3. Which car stopped first, I or II?

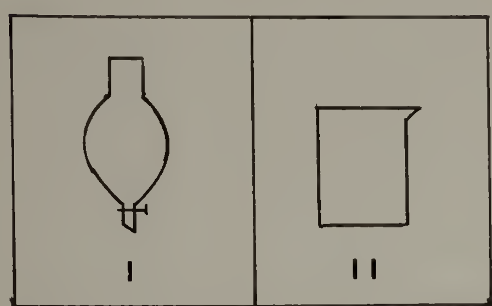
Experience 3. Cognitive Time with Two Interrelated Events

Level: Pre-operational - concrete operational

Materials: Ring stand, ring, a 250 ml. separatory funnel or other suitable glass apparatus, which has an opening on top and a stop-cock or other mechanism for allowing liquid to be removed from bottom (Figure A), a 250 ml. glass beaker or appropriate container, 10 pre-drawn paper cards/student (see Figure B), marking pencil, 500 ml. water, dye with food coloring.



A



B

Activity: Add water to the separatory funnel, I. Slowly empty the water into a glass beaker, II. At various intervals the experimenter stops the flow and the child marks the level of liquids on a set of drawings (Figure B) both for figures I and II.

This is continued for 6 or 7 intervals, so that we now have 6 or 7 drawings with the levels of I and II marked respectively I_1, I_2, I_3, I_4, I_5, and I_6 equal to the corresponding levels II_1, II_2, II_3, II_4, II_5, and II_6. The drawings are first shuffled and the child is asked to put them in order on the basis of which ones he made first and to follow that order until all have been placed correctly. Nest the sheet is cut in two and the drawings of I are separated from those of II, are shuffled and the child is asked to seriate the drawings. Next, the child is asked a series of questions.

1. Was water here, e.g., I_2 before or after it was here, e.g., I_4?
2. When the water was here, E.g., I_3, where was the water in the other flask?
3. Find the drawing you made at the same time as I_3.

<u>Determination of Intervals and Evaluation of Durations</u>

1. Does water take the same time to go from $I_1 - I_2$ as it does from $II_1 - II_2$?

2. Which takes longer: for water to drop from $I_1 - I_3$, $I_1 - I_2$, or $II_1 - II_2$?
3. Does water take the same time to rise from $II_1 - II_2$ as it takes from $II_2 - II_3$, etc.? (Piaget, 1971b, p.p. 5-11)

For further experiences, see Weikart, 1971, p.p. 135-145.

Experience 4.

Objective: To understand that living things that are born at different times remain separated by that duration throughout life.

Level: Pre-operational, Concrete operational (5-8 years)

Materials: 11 pictures showing a sequence of growth of an orange (6 pictures) and a lemon tree (5 pictures). These pictures are constructed so that the younger the tree, the fewer the fruits that are pictured on its branches. The body of the tree becomes proportionately larger as the tree grows.

Activity: 1. Explain to the child that the frawings of the orange tree are of the same tree, only the pictures were taken with a camera once a year.

2. Ask the child to arrange the pictures of the orange tree according to their age.
3. Repeat the sequence for the lemon tree adding that the lemon tree was planted (1 year old) when the orange tree was 2 years old.
4. Ask the child to arrange the lemon trees in a similar sequence to that of the orange trees only they must pair together the photographs that were taken at the same time, i.e., card O_2 and L_1 are placed together since the lemon tree was planted (1 year old to the child) when the orange tree was 2 years old.
5. With the two series formed, children are asked the following questions about each of the corresponding pairs:
   a. Which tree is older during a specific year?
   b. How many years older is it?

Experience 5. Time and Volitional Competence

Introduction - In order to follow one's intentions to closure, children must be able to form goals along a realistic time dimension. In order to establish a feel for temporal events, certain techniques can be used to make children aware of temporal duration and sequences over very short periods of time.

Objective: To understand durations of from 0-60 seconds in connection with some event that children want to occur.

Materials: None

Activity:

1. Ask child what he would like to do at that moment.
2. When the task is established, tell him that he will have to wait for 10-60 seconds.
3. Ask him to count up to that number from zero.
4. Then tell him to proceed with what he planned to do.

Comment: As children grow older, one may increase the time limit in terms of minutes if the teacher simply multiplies the number of minutes by 60. If children cannot count up to 100 or even 60, they can count up to 10 or 10 six times, to achieve the same result.

Experience 6. Time and Volition

Objective: To carry out some pre-set goal within a weeks time.

Materials: A calendar in which days might be noted, money or some means of currency to buy a reward.

Activity:
1. Ask child to think of some toy that he wants that costs less than $1.00.
2. Divide that amount by seven.
3. Give that amount every day, having the child make a mark on the calendar on the day he received the money.
4. At the end of a week have the child purchase the toy.

Current Elementary Science Programs and the ANISA Model

In constructing such preschool science curricula, it is wise to review present sicence programs to discover if some of the ideas can be incorporated to promote learning competence in the areas identified by the ANISA model. Since ANISA has a philosophy and theory of development, curriculum, and pedagogy, it can utilize ideas from other programs, modify those ideas so that they are consistent with the ANISA philosophy, and present such concepts in a unified approach so as to facilitate the growth of processes such as seriation and conservation and enrich the conceptual aspects of the ANISA curriculum as well.

Accordingly, three of the most popular science programs for elementary school, ESS, AAS, and SCIS, will be reviewed in terms of their philosophy of teaching and content structure. Afterwards, recommendations will be made for incorporating their contents into the ANISA science programs.

Elementary Science Study (ESS). The Elementary Science Study curriculum, which was initially founded in 1960, consists of a collection of some 60 units which are loosely organized to provide physical and biological objects which children can study and which stimulate them to ask questions (Rogers and Voekner, 1970, p.p. 37-38). The units were not designed around a particular learning theory, but rather were constructed to fit a discovery approach[3] to science investigations. Because of this the materials which make up the ESS units have the following characteristics:

1. Materials must stimulate children to raise questions and perform experiments which are not teacher directed.
2. The materials should allow children to come to their own conclusions from the results of these experiments.
3. Children should be stimulated by the material so that they will discuss the events which occur in a unit with other children (Duckworth, 1964, p. 242).

The ESS units can be grouped according to the number of students that each unit can accommodate at one time and according to how the materials are packaged. For instance, the unit "Batteries and Bulbs" can be introduced to an entire class at one time, and a packaged unit includes all the equipment that a teacher would need to perform the experiments. On the other hand, the unit "Mealworms," which is also designed for an entire class, contains

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[3]Bruner defines discovery as ". . .all forms of obtaining knowledge for oneself by the use of one's own mind" (Bruner, 1961, p. 22). Essentially, it is a learning strategy of self-investigation that requires a high degree of self-motivation.

only a teacher's guide and a list of equipment which can be purchased at local supply houses. Finally, there are units like "Geo Blocks" which can be offered for individual or small group instruction and which usually come pre-packaged.

How are such units used with an ANISA curriculum? First, each unit is studied to find the relevant cognitive process. Then specific learning experiences can be devised to strengthen that process. For instance, with the unit on "Growing Seeds," children can draw pictures at various stages of development and order these pictures according to a sequence of growth emphasizing the process of time. Two seeds can be planted at different times to give children experience in making comparisons between their differences in age. Many such experiences can be devised to promote competence not only in understanding temporal relationships, but also in understanding the content, i.e., the evolution of plants from seeds.

Almost all the ESS units can be used to promote ANISA cognitive processes through a variety of contents. Some of the kits are appropriate for children as early as kindergarten and can be used with modification for children at earlier ages. A list is given below:

Name of Unit	Process Enhanced
Spinning Tables	Time
Life of Beans and Peas	Time, Seriation

Name of Unit	Process Enhanced
Primary Balancing	Conservation, Seriation
Growing Seeds	Time
Light and Shadows	Projective Space
Butterflies	Time
Pattern Blocks	Space, Seriation
Geo Blocks	Space
Tangrams	Seriation, Conservation, Space
Eggs and Tadpoles	Time
Attribute Games and Problems	Seriation, Conservation

The final result of such use of the ESS materials transforms this program which has great flexibility and no internal structure between the units into a unified whole. This is the tremendous advantage in utilizing a model like ANISA.

Science Curriculum Improvement Study (SCIS). The SCIS science curriculum is organized around content and is also developmentally based to foster the growth of scientific literacy in children from the pre-operational to the formal operational stage of growth (Karplus, 1964, p.p. 295-99). With this emphasis on development SCIS has developed major concepts to be introduced at each grade level, both in the physical and biological areas. This discussion will be limited to those concepts which are introduced at the first level (kindergarten or first grade), namely,"Material Objects" and "Organisms."

With the "Organisms" concept, children gain experience with growing plants and understanding the life cycles which occur in an aquarium (SCIS, 1970a). This type of growth phenomena can be used to enhance the process of cognitive time because teachers can structure activities which require children to sequence events or make comparisons of time intervals. Also, ecological conservation is demonstrated during this unit, however, this is too advanced a concept for preschoolers because of the level that is presented in the text.

The use of the "Materials Objects" concept provides additional material for enhancing cognitive processes (SCIS, 1970b). Below is a list of how various units within "Material Objects" can strengthen the processes described in this dissertation.

Unit	Processes Enhanced
Grandma's Button Box	Space, Seriation
Objects Grab-Bag Game	Space, Seriation
Sorting Woods and Metals	Seriation of weight, Space
Sorting Rocks	Space, Seriation
Sorting Shells	Space, Seriation
Observing and Mixing Liquids	Conservation of Amount
Observing Gases	Conservation of Amount
Serial Ordering and Comparison of Objects	Seriation, Space

Unit	Processes Enhanced
Rock Candy and Sugar Cubes	Conservation
Solid and Liquid Water	Conservation of Amount
Floating and Non-Floating Objects	Seriation
Experimenting with Air and Water	Conservation

Specifically, "Material Objects" includes a collection of woods and metals that are cut in exactly the same shape, but vary noticeably in weight. This provides excellent experience in seriating weights without the use of a balance.

Materials from the SCIS program can provide much enrichment in the ANISA classroom. The ANISA model, on the other hand, provides much more extensive experiences in strengthening those processes which SCIS gives scant attention to. For instance, there is one chapter or unit on seriation, yet only a few of the many objects included in the "Material Objects" package are used. Seriation is only introduced during that one unit, when it should be a recurring process used during the entire semester.

American Association for the Advancement of Science. The AAAS science program is designed to develop student skills in using scientific processes. The curriculum is divided into 15 processes and the materials are provided to teach these processes. For instance, in the primary grades, the following processes are stressed at different developmental levels: (1) observation, (2) classification, (3) measurement, (4) communication, (5) inference, (6) prediction, (7) recognition, (8) space/time relations, and (9) number relations. These processes are integrated to produce a hierarchy of processes that provide sequential activity within a grade level (Libermore, 1964, p.p. 271-72).

The AAAS curriculum is the closest to the ANISA model in terms of structure, since it emphasizes process. Part B of that curriculum will be reviewed to demonstrate how it might be used to enhance the processes developed in this dissertation. Part B is designed for first grade and it should be noted that there is a Part A which is written at the kindergarten level.

In the chart below, appropriate units of the AAAS material are noted under each ANISA process and the specific activity is noted at the far right.

ANISA Process	AAAS Unit	Specific Activity
Conservation	Communicating 3	Conservation of Mass, length, area
Conservation	Observing 6	Conservation of size when color changes
Conservation	Observing 9	Conservation of size when order changes

ANISA Process	AAAS Unit	Specific Activity
Seriation	Measuring 3	Seriation of volume
Seriation	Communicating 5	Order growth sequence of plants
Seriation	Measuring 5	Seriation of weight
Space	Measuring 6	Spatial order with area
Space	Space/Time Relations 9	Projective space, two-dimensional projections of three-dimensional objects
Time	Observing 13	Growth of a mold
Time	Communicating 4	Events of Colliding Bodies
Time	Measuring 7	Time changes in the growth of seeds
Time	Space/Time Relations 11	Discriminating between different time intervals

The advantage of using the ANISA model with the AAAS science program is that ANISA provides continuity and is a diagnostic tool for students who transfer to schools which do not use the AAAS materials. Such a framework as ANISA can provide a highly structured curriculum like AAAS with added flexibility and transfer across school systems.

Summary. The curriculum section of this dissertation provides the teacher with an idea of how a theoretical model such as ANISA can be translated into practical learning experiences. The great flexibility of ANISA across environments has also been demonstrated in learning experiences like the conservation of love, and the temporal sequence of intentions. Finally, the use of other curricula to teach and strengthen ANISA's concept of learning competence has been demonstrated, and the added advantage that such curricula gain from such utilization has been noted.

CHAPTER VI

EVALUATION AND CONCLUSIONS

Evaluating a developmental model such as ANISA presents new problems which traditional paper and pencil type tests fail to solve. Kamii has pointed out that traditional achievement tests have evolved in a psychometric tradition in which a test question is structured so that there is only one correct answer to each question. These tests are designed without regard to the child's process of thinking, since previous to Piaget's work, there was no theoretical body of knowledge available which described the development of logical thought (Kamii, 1971, p. 330).

The availability of such a theoretical body has initiated new perspectives in the evaluation of children. Kohlberg and Mayer (1972) have detailed the underlying assumptions that a developmental model makes, and this gives the teacher several solutions for classroom evaluation. First, development level operations such as seriation and conservation are cognitive processes and must be evaluated on a competence[1] basis rather than a performance basis. Developmental tests measure the level of thought process and not only the difficulty or correctness of the product.

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[1]Cognitive competence refers to a level of functioning.

The concept of difficulty is explained from the developmental point-of-view by the existence of stages.[2] A higher stage is more advanced and develops because a lower stage is inadequate or only partially successful for solving problems. In this sense the higher stage is the more complex, and the aim of development is "the eventual adult attainment of this highest stage." Moreover, developmentalists assume that children have a natural tendency to move toward this higher stage under normal conditions of stimulation (Kohlberg and Mayer, 1972, p.p. 483-86).

The structure of the stage provides one method of evaluation, that of recording children's behavior and determining what subcomponents of the specific process have been mastered. This can be compared with normative data[3] to determine whether children are developing at the same rate as the general population, keeping in mind that tremendous individual differences mean that children will reach different stages at different ages. This evaluation can be used in conjunction with time studies to record a child's development over a period of time.

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[2]Kohlberg defines a stage as a progression from a less adequate to more adequate psychological state.

[3]There is very little normative data available on cognitive developmental tests at present. Several major studies have been undertaken to generate such information (Pinard and Laurendeau, 1964) and (Tuddenham, 1971).

Another characteristic of developmental processes is that the behavior change incurred at a new level is resistant to extinction or irreversible. Resistance to extinction implies that once a child reaches a specific level within a process, he does not regress to a lower level, but his behavior is fixed at that level. If it can be reversed, then children are not at the assumed level of competence. For example, in the conservation of weight, once children become convinced that a change in the shape of material does not influence its weight, they are classified as conservers. Experiments can be performed in which some material is removed without the child's knowledge. If he retains his belief in the face of conflicting results, he would have exhibited resistance to extinction.

This characteristic presents teachers with another clue for evaluating such phenomenon since test procedures can be devised to nullify the newly manifested behavior. If children are susceptible to such changes, then the original behavior is not an internalized process and does not represent a new level of attainment.

Accordingly, this final chapter will briefly illustrate how formative evaluation methods discussed by Kamii can be utilized in recording children's behavior. Then, the use of extinction experiments to determine whether children have really internalized a process will be discussed. In cases where actual extinction is difficult, i.e., seriation, space, and time, experiments that provide some cognitive strain by forcing children to use a process to evaluate a new and novel problem will be introduced. Finally, there is a section that briefly discusses some considerations that are helpful in evaluating each specific process.

In the final section of this chapter, suggestions for further research and limitations in the use of this curriculum will be presented. Several considerations for the training of teachers will be mentioned in this discussion.

Formative Evaluation Methods

Kamii uses the term "formative evaluation" to refer to the diagnostic progress tests which are given once every two or three weeks to determine the child's developmental level. She has proposed the use of a chart which lists the various stages of each operation vertically and has space horizontally for the number of objects used, the description of the objects, and the date the tests were administered (Kamii, 1971, p.p. 332-33). The author has proposed a modified chart shown on the following page, which lists the actual tasks in the vertical column. At the bottom on the chart is the key which explains the symbols used in the chart. For instance, if the child is at the global anticipation stage with respect to seriation of eight, the instructor would mark a G in the box opposite

Evaluation Chart for Seriation Tasks

Name of Child: ______________________________

Number of Objects	4	7	24		
Description of Objects	cyl.	cyl.	4x6		
Specific Task / Date	4/7	5/4	6/9		
Seriation of Height					
Seriation of Diameter	G				
Seriation of Height and Diameter (tallest is widest)					
Seriation of Height and Diameter (tallest is narrowest)					
Seriation of Weight					
Seriation of Shade (color)					
Seriation of Texture	N				
Serial Correspondence Task		ds			
Anticipation Drawings: Without Color					
With Color					
Multiple Seriation			N		

Description of Reasoning Key:

p - perceptual

o - operational

G - global

N - no seriation

ds - double seriation

sc - simple seriation with correspondence

dc - direct correspondence

the appropriate task. With serial correspondence, different methods which are used to solve a particular task can be noted. If a child solves his correspondence task by using the method of double seriation, the notation ds is placed in the appropriate box.

With the use of such a chart, accurate records can be kept to inform the teacher of the exact task performed. For example, with multiple seriation the exact size of the matrix should be noted since the difficulty of the task depends upon the size. A matrix 3 x 5 is easier to seriate than a matrix 8 x 10. Furthermore, if there are special difficulties or a child makes surprising progress, these observations can be footnoted and written in the comment section below the key chart (not shown in the diagram).

Such a chart provides teachers with useful records when analyzing their own preparation for lessons. It also provides a useful guide in parent/teacher conferences, giving teachers an idea of the gaps which exist in children's experiences that might be overcome through parental influence.

Evaluation and Extinction Techniques

Extinction experiments were originally devised by Smedslund (1961b) in an attempt to evaluate whether teaching conservation of weight through direct reinforcement techniques had the lasting effect that is characteristic of an internalized operation. In these experiments, clay was removed inconspicuously and the child was questioned about his beliefs in conservation.

Smedslund (1961c) added to this experiment by removing the clay in full view of the child while deforming one of the objects in an attempt to study children's actions in situations of cognitive conflict. However, these experiments were performed to determine the effect of negative influences with the lack of external reinforcement on non-conservers.

These initial experiments are useful in producing suggestions for such experiments with seriation, conservation, space, and time. Such experiments can be subdivided into those that apply to conservation and those that concern seriation, space, and time since the general techniques for the latter three are similar.

Conservation. The general strategy for devising extinction experiments that apply to conservation is to destroy the concept by inconspicuously removing an object or an amount of substance producing the effect that there is a change in the quantity of some characteristic with a change in shape. Such an experiment should be given only after a child has shown evidence through his verbal answers that he might be at the highest level of concrete operations. The removal then takes place after the final explanation is given through a repetition of the experiment. In the case of the conservation of weight with two plasticene or clay balls, removal of the clay should be introduced when the experiment is repeated and the final transformation is made. Careful notes should be taken of the child's reasoning, and his use of reasoning with the processes of inversion, identity, and reciprocity should be particularly noted. If he has mastered the process, he will eventually infer than an amount of material was removed despite the fact that they did not observe it.

<u>Seriation, Space, and Time.</u> Extinction experiments involving these processes require the teacher to devise an arrangement of materials that necessitate the use of the process to be evaluated. The task of the student is to evaluate the arrangement, and if it is incorrect, the student must restructure the materials using this process. In seriation, the teacher can devise a series of incorrectly sequenced elements as shown below. To properly evaluate the

level of competence, teachers should notice whether children can spontaneously rearrange the sticks or whether they must destroy the original series and recreate a new one. The former behavior would indicate a higher level of competence.

Similar experiments can be created for space and time. In the task where children must create a straight line on a table, an initial pattern is introduced and the child is asked to evaluate it. Likewise, with temporal events the symbols that indicate the events, whether that is a series of pictures representing the growth of a tree or a series of pictures showing different levels of water in a beaker, can be ordered in a false sequence and children's behavior can be observed as they attempt to evaluate the arrangement.

Generally, extinction experiments provide children with situations where they must make evaluations of arrangements other than their own or they must reason why a system functions contrary to their expectations.

Other Considerations in Evaluating Seriation, Conservation, Space, and Time

In the original development of each process, the author cited several considerations and suggestions for evaluating these processes. These are noted in the following pages.

Seriation. Most of the seriation activities are diagnostic in that they establish the level of seriation a child operates on if he cannot do the task within a short span of time. Probably the best diagnostic test would be to simply give the child a set of 10 elements differing on some dimension and direct him to order them. By observing his performance, his operating level will become apparent.

For instance, if he can only order two or three elements of the whole, he is in Stage I; if he orders all 10 but constantly shifts the sticks around, he is performing at a trial and error level and is at Stage II.

Another method of evaluating a child's performance is by the quality of the answers he gives to certain questions. If the answers show that he is looking at the whole structure in anticipation of a total organizational mechanism, then he is at the concrete operational level of competence. For example, if a child seriates 10 sticks by telling his teacher that what he looks at is the slope or diagonal formed as he places the sticks together, then this would tell the teacher the child is performing operational seriation.

However, caution must be used in evaluating children's verbal responses, since children do not necessarily use words in the same way as adults. Furthermore, there is a stage of growth when a child is inconsistent in his use of words and concepts (Flavell, p.p. 205, 209). In many cases, rephrasing and questioning children about concepts using several different lines of questioning will reveal these inconsistencies. Thorough questioning will also reveal whether a child is answering in a way in which he feels the experimenter expects him to.

Conservation. As demonstrated by the prototypical experiences, this method or criteria for evaluating the stage of growth a child is in differs depending on whether he is at the sensorimotor level or concrete operational level. In the former, psychomotor movements are the means for evaluation, while in later childhood, verbal reasoning dominates.

In conservation, as in seriation, the quality of the child's answer will allow the teacher to diagnose weaknesses. If in the conservation of continuous quantity, a child fails to conserve, an experimenter can probe through questions to see if the child has concepts of identity, reversibility, or synthesis in his cognitive repertoire. If the child doesn't, experiments could be designed to strengthen these sub-processes. For instance, one beaker of water could be used to perform a number of transformations and the identity question constantly asked so that a child gains experience in these matters. Measurement might also be used to enhance learning. For instance, in the previous example, actually measuring the amount of liquid would help a child grasp the process of identity faster.

Finally, the amount of time it takes for a child to answer is very indicative of whether he has achieved totally operational conservation. If he hesitates, is inconsistent with his answers, or appears to be unsure of himself, all of these clues are indications of his lack of a true grasp of conservation.

Cognitive Space. In reference to the Piagetian tests regarding the evaluation of spatial competence, Laurendeau and Pinard (1970) have used extensive and rigorous measurements using Piagetian formats, and they discuss the strong and weak points of these tests. Generally, Piaget's developmental scheme is verified,[4] although their age norms differ with specific populations. Further, there is a great vertical decalage[5] depending on the materials used. In addition, Dodwell (1963) concluded that Piaget's theory of stages can be blurred by variables like children's special interests, special training, and the amount of previous formal instruction (Hudson, 1960; 1962).

With regard to Piaget's format and the interpretation of what developmental stage a child is in with respect to spatial concepts, Laurendeau and Pinard report the following difficulties:

1. There is a decalage effect between figures within the same category, i.e., all topological figures.

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[4]This is also confirmed by Dodwell (1963).

[5]Children can be at different levels of spatial competence with different types of materials simultaneously. For instance, they may demonstrate greater competence with spatial continuity if they are asked to find subdivisions of squares of cubes than if they would if the materials were circles of spheres.

2. Because abstract shapes, which are used to evaluate euclidean space, are inherently more difficult than the simple one used to evaluate topological space, Piaget's conclusions as to the prior development of topological space is weakened.
3. Some figures can be used at more than one level, i.e., evaluation of both topological and euclidean space.

It would be well to use this book as a guide to any of the spatial tests, since techniques for refinement and the solution for overcoming some of the above problems are given.

Finally, Lorell (1962) suggests that the great contribution of Piaget's studies in geometry (Piaget, 1964) is that he has shown that children can acquire a certain "verbal facade" or perform some action by rote without having the operational structure to internalize their actions. Teachers should be aware of these multiple levels. An example of this is the child who is very competent at measuring length with a ruler, but may not understand the conservation of lengths, which is fundamental to the concept of measurement itself.

Cognitive Time. Several established facts should be kept in mind as one attempts to evaluate children's concepts of time:

1. "Time concepts develop independently of school instruction".
2. The logic in a child's thought regarding the future is less well established than his thinking concerning the past (Friedman, 1944, p.p. 337-42).

Such information will help the teacher when attempting to evaluate a child's reasoning and in controlling factors within the child's environment. Furthermore, our concept of temporal intervals is largely dependent on our state of mind, i.e., whether we are bored or enthusiastic (Lovell, 1960). Also, the involvement of muscle activity leads to longer estimates of duration (Goldstone, 1958).

Evaluation of time requires the use of language and a person's time vacabulary is again culture dependent. To the Navajo Indian, calendar months are descriptive of the life of the family (Sorokin, 1937); in Konkomba, Northern Ghana, the days of the week are reflected in markets held each period of the cycle, while the Andaman Islanders mark different parts of the year by scents (Jahoda, 1963).

In terms of evaluating the prototypical experiences, Kamii suggests a scoring system based on the number of elements a child can coordinate, beginning with two and then progressing to three (Kamii, 1971). Other tests to be given to evaluate a child's conception of clock time are described in periodical journals (Ames, 1946; Elkine, 1928; Lovell, 1960). In addition, Piaget has developed tasks centering around natural phenomena, i.e., trees and the number of fruits it yields, which prove to be valuable for analyzing the child's idea of his environment and how it responds to time (Piaget, 1971a, p.p. 237-40; 244-45).

Limitations in Using the Curriculum

There are two major limitations in utilizing the curriculum developed in this dissertation. The first concerns the feasibility of using the curriculum in all classrooms. Since the curriculum is structured to develop individual as well as social competence, classrooms that use this curriculum must be individualized to the extent that staff personnel are available to keep records of the individual progress of each child and to stimulate each to perform at the maximum of his potential in that environment. Without the availability of a support staff to insure such growth, the curriculum is merely an idealized conceptualization.

The second major limitation is that the curriculum assumes an extremely capable, well-trained, and knowledgeable teaching staff. It is important that teachers, or at least a master teacher if the staff is differentiated, have internalized the basic theory encompassed in this dissertation. This is important for stimulating the growth of those processes mentioned in this dissertation, both in planned as well as spontaneous activities. It is also important that teachers project the competence they hope to stimulate in their students.

Suggestions for Further Research

Many opportunities exist for further research within the area of this dissertation. First, with respect to the curriculum, the processes of number relations and classification must be more firmly tied to those of seriation, conservation, space, and time. Other processes need to be explored in terms of their feasibility in the model, particularly reasoning processes such as analysis, synthesis, interpolation, and extrapolation. The feasibility of the use of these processes for preschool children can only be determined with future research. Furthermore, with non-Piagetian processes, a format would have to be devised and tested and then implemented to get the data on children in the same way Piaget did.

The prototypical experiences need to be tested and will become refined with actual use in the classroom. However, more learning experiences which use cognitive processes to improve competence in the moral and unknown environments need to be conceptualized. Finally, the entire method of studying processes at the pre-operational and concrete operational stages needs to be expanded to the formal operational level of thought. It is at this level that our research is very scanty, particularly with respect to

Piaget's conceptualization of adolescents. It is also at this level where most adults fail to achieve their full maturity. By carefully isolating each process, teachers may possibly be able to teach the processes included within the 16 binary propositions by controlled exposure to first, physical phenomena, and then to environments other than the material environment. Hopefully, this would give adults greater control over their future in terms of material, moral, and spiritual competence. Idealistically, the end product of such competence could generate world-wide unity and the elusive quest for world peace.

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