

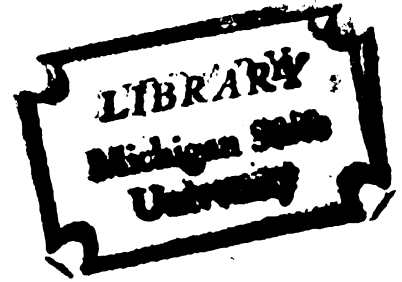
AN APPLICATION OF PIAGET'S THEORY OF SPACE
AND GEOMETRY TO LEARNING ORTHOGRAPHIC
PROJECTION CONCEPTS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

JAMES S. LEVANDE

1972



This is to certify that the
thesis entitled
AN APPLICATION OF PIAGET'S THEORY OF SPACE
AND GEOMETRY TO LEARNING ORTHOGRAPHIC
PROJECTION CONCEPTS

presented by
James S. Levande

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Secondary Education and
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Major professor

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ABSTRACT

AN APPLICATION OF PIAGET'S THEORY OF SPACE AND GEOMETRY TO LEARNING ORTHOGRAPHIC PROJECTION CONCEPTS

By

James S. Levande

The purpose of the study was to apply Piaget's theory to the learning of orthographic projection concepts in a middle school industrial arts program. A series of games was used to present the concepts in a systematic and sequential manner. The investigation focused on examining the facilitation of learning and the stimulation of the sensory-motor and infralogical systems.

The hypotheses tested concerned: (1) the effects of treatment, classroom unit, and sex upon the stimulation of the sensory-motor and infralogical systems, (2) the effects of treatment, classroom unit, and sex upon the facilitation of learning, and (3) the correlation relationship between reading performance and performance on measures of space relations and orthographic visualization.

The industrial arts program of the East Lansing, Michigan, middle schools was the setting for the investigation. The sample was drawn from the beginning industrial

arts classes in the two schools and consisted of 163 students, 95 boys and 68 girls.

The design involved an experimental and a control treatment of four classrooms each. Assignment to treatment was done randomly in each school and provided two experimental and two control groups per school. The experimental group received the presentation of the concepts through the playing of the games. The control group did not receive the presentation of the concepts in the form of the games or in any other manner. Within the experimental group four testing schedules were built around the presentation of three concept groups: (1) points-lines, (2) lines-planes, and (3) planes-forms.

Implementation of the treatments and data collection procedures were completed over an eleven week period during Fall, 1971. The tests used to provide the dependent variable were the Space Relations test and the Visualization Test. The Gates-MacGinitie Reading Tests, Survey - E was used to provide the data in the reading performance area.

Data analysis consisted of univariate and multivariate analysis of variance of gain scores on the pre-test and post-test instruments and an analysis of the correlations between gain scores and reading test scores.

The results of the analysis yielded the following major conclusions:

1. The factor of treatment had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.

2. The factor of group had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.
3. The factor of sex had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.
4. The factor of group had no effect on facilitation through the systematic and sequential programming of the concepts as based on the heirarchy of task complexity in the puzzles and games.
5. The factor of sex had no effect on the facilitation through the systematic and sequential programming of the concepts as based on the heirarchy of task complexity in the puzzles and games.
6. Reading performance is significantly correlated to performance on the measures of space relations and orthographic visualization.

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By

James S. ^{ANCE} Levande

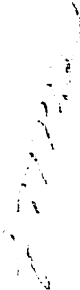
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Submitted to
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CHAPTER I

FORMULATION AND DEFINITION OF THE PROBLEM

Introduction

Industrial arts curriculum in the middle and junior high school concerns itself, in part, with providing instruction in pictorial communication. This pictorial communication is: (1) highly related to the development of problem-solving skills and (2) based on projective and Euclidian geometry.

A review of abstracts published by the American Industrial Arts Association¹ and the Dissertation Abstracts² provides little information about research that investigates instruction or learning in the area of pictorial communication.

Theory and knowledge about the perception and cognition of space and geometry, pictorial representation, and learning in these areas is limited. A review of

¹American Industrial Arts Association, "AID-- Abstracts of Interesting Dissertations," The Journal of Industrial Arts Education.

²Dissertation Abstracts (Ann Arbor, University Microfilms).

available research indicates that no application of the theories or the knowledge have been attempted in the area of industrial arts instruction.

Need

The preceeding points suggest that a comprehensive and exhaustive exploration of the relationships between the theories and knowledge and industrial arts instruction needs to be made. This study will attempt to meet a portion of this need by examining the application of a cognitive developmental theory of learning to the instruction of concepts related to understanding orthographic projection in one type of school environment. It is hoped that information provided by this examination will be useful to the field in the formulation and implementation of instructional techniques and materials.

Purpose

In an attempt to place some focus on learning and instruction of pictorial communication, percept and concept, and learning in industrial arts programs this investigation will examine the application of one theory of space and geometrical cognition to learning and instruction of pictorial communication in a selected middle school industrial arts program.

The conceptual theory of Jean Piaget will be applied to the area outlined above. The developmental stages of this theory are directly concerned with

projective and Euclidian geometry. Learners entering the middle school are only beginning to handle these geometries in their concept of space according to the theory.

Because of the common geometrical base of the theory and pictorial communication it seems appropriate to make an application in industrial arts instruction. The term for this pictorial communication is orthographic projection. This form of communication is used to implement problem-solving in the technical world and is taught to help the learner in solving problems of a similar nature in industrial arts. The ability to use two dimensional representations as guides for recognition of objects and conversely the ability to recognize objects represented in two dimensions is a basic part of both the technical world and industrial arts instruction.

Limitations

In describing the purpose of this study one major limit was placed on what will occur, that is, the investigation will apply just one theory, that of Piaget. The study is further limited in its scope because of the constraints placed upon it by demographic and procedural factors. The location of the middle school industrial arts program in which the study is made; the nature of the learner population and sample; instrumentation; and the selection of the concepts to be studied all place limits upon the investigation and the applicability of the conclusions to be drawn from the analysis.

Hypotheses

Research based on the theory of Piaget's constructs suggests that learning can be stimulated and facilitated. On this basis the question of applying the theory to learning and instruction of orthographic projection can be investigated.

The question can be formalized in the following hypotheses:

Competency in the perception and cognition of the orthographic projection of objects is dependent upon the stimulation of the sensory-motor and infralogical development systems of Piaget's theory.

The perception and cognition of the orthographic projection of objects is facilitated through a systematic and sequential program of concepts based on a hierarchy of task complexity.

The rationale formulating the above questions is based upon applications of Piaget's work. Ojemann and Pritchett³ indicate that guided and planned construction of the tasks are needed for facilitating learning when the learner uses sensory-motor as well as infralogical and logical systems. Fowler⁴ also indicates that systematic and sequential task ordering is important to facilitation in working with learners.

³Ralph H. Ojemann and Karen Pritchett, "Piaget and the Role of Guided Experiences in Human Development," Perceptual and Motor Skills, VII (1963), 927-940.

⁴W. Fowler, "Dimensions and Directions in the Development of Affecto-Cognitive Systems," Human Development, IX (1966), 18-29.

Assumptions

The assumptions upon which the application of the theory is to be based cover the Piagetian theory, the relationship of the theory to the orthographic method, and the applicability of the theory to the problem of instruction in industrial arts.

Piaget's theory is concerned with the concept of objects in space and their relationship to the geometrical realm. The knowledge of objects in space is based on actions performed on objects and this action is said to be able to transcend the physical limit of the object creating operational schemas in the learner. Formalization of the operational level is possible and the learner can function with the concepts in an abstract and deductive manner. The order of the psychological development of the operational schemas follows the same order as formal geometrical construction: topological, projective, Euclidian. The operational schemas involved in the development of space concepts are parallel to the operational schemas in the development of logical thought.

It is necessary to assume that the geometrical constructs used in the orthographic method are identical to the constructs of the learner's psychological development of space concepts. The application of the theory to the learning and instruction of orthographic projection is not possible without this supposition.

Underlying the above points is the basic belief that Piaget's theory and research is relevant to instruction and learning in industrial arts programs.

Theory

In a comprehensive review and critique of Piaget's work Flavell⁵ has this to say about the application of the theory to learning and instruction.

(The) theory has a good deal to say about the nature of the cognizing organism and the process by which unknown externals become known internals. It might be that this part of his (Piaget's) system could tell us something about the most favorable conditions for learning and hence, the way in which we should go about teaching.⁶

If the application of the theory is to be undertaken as Flavell suggests then the researches of Piaget and his colleagues Inhelder and Szeminska serve as a basis for the constructs in the area of space and geometry concepts. It seems essential to apply this theory under a more strict regime than that which Piaget used because of the criticisms leveled against the sampling and methodology of the original Piagetian work. Flavell⁷ presents a summarization of these criticisms in his review of the theory.

⁵John H. Flavell, The Developmental Psychology of Jean Piaget (Princeton, N.J.: D. Van Nostrand Co., Inc., 1963).

⁶Ibid., p. 366.

⁷Ibid., pp. /405-446.

French and Vierck⁸ state in their comprehensive and definitive work on engineering graphics that orthographic projection follows the line of classic construction in geometry: topological, projective, Euclidian. They go on to develop the concepts of point, line, area, and volume is using orthographic projection in the same order that Piaget states in his theory about the learner's psychological development.

Definition

The following definitions will be used in this study. All of these definitions, with the exception of the one for orthographic projection, were drawn from Piaget's writing. The terms were then confirmed in the extensive reviews of Piaget's work by Flavell⁹ and Holloway.¹⁰ In the case of the mathematical terms confirmation was based on Newman's¹¹ and Holloway's¹² work.

Concrete operations: Cognitive actions used in the acquisition of a well-structured and coherent framework within which to represent and operate upon the concrete perceivable world of things and events.

⁸Thomas E. French and Charles J. Vierck, Graphic Science (New York: McGraw-Hill Book Co., Inc., 1958).

⁹Flavell, Psychology of Jean Piaget.

¹⁰G. E. T. Holloway, An Introduction to the Child's Conception of Space (New York: Humanities Press, 1967).

¹¹James R. Newman, The World of Mathematics (New York: Simon and Schuster, 1956).

¹²Holloway, Child's Conception of Space.

Euclidian geometry: A geometry dealing with equality of lengths, angles, areas, and volumes.

Infralogical: Cognitive actions bearing on position and distance relationships and part-whole relationships apropos of concrete spatiotemporal objects and configurations.

Logical operations: Cognitive actions used to classify, seriate, and set into multiplicative correspondence. They bear on sets of discrete, discontinuous objects. Their operation is independent of spatialtemporal proximity, or lack of it, of the objects they deal with. They do not require any actual modification of their objects, neither alteration of their structure nor modification in the sense of changing their spatial or temporal location.

Orthographic projection: The method of representing the exact shape of an object in two or more views on planes generally at right angles to each other by extending perpendiculars from the object to the planes.¹³

Projective geometry: A geometry concerned with non-metrical propositions. No parallelism exists; every pair of coplanar lines is a pair of intersecting lines in this geometry. The properties which are invarient under projection deal with the colinearity of points, with concurrence of lines, with cross-ratios, and with the

¹³French and Vierck, Graphic Science, p. 78.

fundamental roles of point and line as exhibited by the principles of duality.

Schema: A cognitive structure which has reference to a class of similar action sequences, these sequences of necessity being strong, bonded totalities in which the constituent behavioral elements are tightly interrelated. Operational schemas can be defined in terms of observable behavior in the face of certain tasks.

Topology: The doctrine of those properties of a figure or object unaffected by any deformation without tearing or joining. A geometry based on these doctrines.

Procedure

The procedural organization for the investigation will follow the pattern of steps below. The beginning industrial arts classes in the middle schools selected for the study will be sampled. The sample will then be divided into two groups, one an experimental group, the other a control group. The experimental group will be divided into four treatment groups for the purpose of assessing concept attainment at points in time during the investigation. All the sampling and assignment of treatments to groups will be on a randomized basis. Instrumentation will consist of two space and visualization tests and a battery of reading tests; these instruments will provide the dependent variable for the analysis. The analysis will be through the use of a univariate and a multivariate analysis of gain scores on the space-visualization

tests and correlational analysis of the relationship between all the test scores.

Overview

The purpose and direction of the study are outlined in the following chapters. Chapter II contains a presentation of philosophical literature and experimental research relevant to the questions raised in this chapter. A description of the study's sample, experimental treatments, tests and measurements, the hypotheses to be tested, and the design to test and analyze the results of the research are presented in Chapter III. The data, interpretation of the results, and statements of significance in relation to the formulated hypotheses are presented in Chapter IV. Conclusions and implications for further research will be presented in Chapter V.

CHAPTER II

RELEVANT RESEARCH AND LITERATURE

The following review and citations are provided for the purpose of establishing a philosophical rationale and to outline the theory and its application in an educational setting. These statements are intended to relate the literature and research to the problem area and the questions stated in Chapter I.

A Persistent View of Cognition

"Why do precisely these objects which we behold make a world?"¹ Thoreau's question exemplifies that which philosophers and in their turn psychologists have asked since men began to debate the relationship of percept and concept. For ease in presenting their arguments the debaters have split the two and discuss each separately creating an apparent dichotomy. Arnheim² traces this dichotomy to the early Greek philosophers and their separation of perception from cognition; thus giving rise

¹Henry David Thoreau, Walden (New York: W. W. Norton, 1961), p. 244.

²Rudolf Arnheim, Visual Thinking (London: Faber and Faber, 1969), p. 1.

to present day emphasis on words and numbers in our educational system. In arguing for a unified or integrated view of percept and concept Arnheim suggests that only because perception gathers types of things, that is, concepts, can perceptual material be used for thought. And, inversely, that unless the stuff of the senses remains present the mind has nothing to think with.

Arnheim's arguments are a reflection of the Kantian statement that percepts without concepts are blind and that concepts without percepts are empty. Immanuel Kant did not accept either empiricism or rationalism in total; he attempted to reconcile or integrate these two schools of philosophical thought.

O. W. Miller³ reviews the writings of the Greek thinkers and other philosophers and traces the conflict of percept-concept to Kant's arguments concerning Ding an sich or "Thing-in-itself." Miller's description of the process by which the outside world is perceived and then conceptualizes is based on a mind functioning by the continual input of new perceptions and the subsequent assimilation of those perceptions.

. . . the ultimate "Thing-in-itself" is the cognizing mind of the individual, as he creates the "known" world out of the "raw stuff" of something which is finally absorbed and assimilated by the mind; and then by it projected beyond as the world which is now more satisfactory to its "creator" than any "raw stuff" world could possibly be.

³Oscar W. Miller, The Kantian Thing-in-Itself or The Creative Mind (New York: Philosophical Library, 1956).

And so does man, by the power of his own inherent creative capacity, become the builder of the world in the midst of which he lives. A world was here when or before he began to think; but his world was not here until he created it out of the stuff of his own being.⁴

Arnheim describes the process of perceiving and cognizing as visual thinking.⁵ A term which includes both perception and cognition involved in a continuous interaction. He states, "No thought processes seem to exist that cannot be found to operate, at least in principle, in perception."⁶ The process of visual thinking can be seen to operate in the same manner as Miller describes the process of Kant's "Thing-in-itself." The application of this unity of perception and thought is culminated, according to Arnheim, in the educational world and it contains implications for all teachers.

Wegener⁷ supports Arnheim's views in his review of the Kantian philosophy's implications for education. Considering the importance of Kant's statement on percept and concept he says that educators should be cognizant of the implications of epistemology, or the study of theories of knowledge. Those in the teaching profession must consider the arguments both for and against empiricism and rationalism

⁴Ibid., p. 133.

⁵Arnheim, Visual Thinking, p. 13.

⁶Ibid., p. 14.

⁷Frank C. Wegener, "Perception and Conception in Education," in Theory of Knowledge and Problems of Education, ed. by Donald Vandenberg (Urbana: University of Illinois Press, 1969), p. 238.

and not accept either blindly. The practical implication would mean that every aspect of an instructional unit should be viewed in light of the relationships between percept and concept.

In following the arguments of reconciling percept and concept we see education indicated as the place where these views must be integrated and applied. The educator is asked to look at both views and not to accept one or the other blindly. If education is to accomplish this task then a systematic review of learning theory is evident. This study attempts to review and apply one such theory. The theory is unique in that it not only conforms to Kant's percept-concept arguments, but it also incorporates Arnheim's ideas concerning visual thinking. The theory is that of Jean Piaget.

Flavell⁸ in describing Piaget's theory reviews the relationship to the Kantian view as follows:

He (Piaget) emphatically rejects the notion that the subject is in simple and direct contact with the "real" external world, either at the beginning of development or at any time thereafter. Rather, it is his epistemological position that the subject-object relationship is a subtle and complex affair which itself shows important developmental changes.⁹

It is the central conclusion of the Piagetian theory that the apprehension of reality is ever and always as much assimilatory construction by the subject as it is an

⁸Flavell, Psychology of Jean Piaget.

⁹Ibid., p. 69.

accommodation of the subject. A process which requires the interaction of perception and conceptualization.

Arnheim's concern for the application of this Kantian unity of percept and concept to the individual's re-creation of things seen in the form of pictures and sculpture provides a basis by which one can review Piaget's thoughts on how the learner approaches the concepts of space and geometry. Both Piaget and Arnheim agree on the nature of the un-separability of percept and concept. The individual grows through a series of stages requiring the use of percepts to develop concepts which in turn foster new perceptions structured on the attained concepts.

Piaget's Theory

Piaget's theory is considered a stage theory in that the learner's cognitive development centers on fixed sequences. Cognitive processes are the reorganization of psychological structures resulting from organism-environment interactions. This reorganization involves assimilation and accommodation through an order of stages. Assimilation and accommodation are processes in the acts of intelligence; coming into balance and equilibrium they constitute an intellectual adaptation. Flavell¹⁰ describes adaptation and organization (reorganization) as two sides of the same coin, adaptation presupposing an underlying

¹⁰Ibid.

coherence, on the one side, and organizations resulting through adaptations, on the other side.

Flavell then goes on to define assimilation:

Assimilation here refers to the fact that every cognitive encounter with an environmental object necessarily involves some kind of cognitive structuring (or restructuring) of that object in accord with the nature of the organism's existing intellectual organization.¹¹

Every act of intelligence, however rudimentary and concrete, presupposes an interpretation of something in external reality, that is, an assimilation of that something to some kind of meaning system in the subject's cognitive organization.¹²

In regard to accommodation Flavell explains this with respect to the subject's encounter with reality.

Reality can never be infinitely malleable, even for the most autistic of cognizers, and certainly no intellectual development can occur unless the organism in some sense adjusts his intellectual receptors to the shapes reality presents him. The essence of accommodation is precisely this process of adapting oneself to the variegated requirements or demands which the world of objects imposes upon one.¹³

Both of these processes, assimilation and accommodation, are simultaneous and indissociable as they operate in a living organism.

In regard to this association mentioned above Piaget says:

. . . From the beginning assimilation and accommodation are indissociable from each other. Accommodation of mental structures to reality implies the existence of assimilatory schemata apart from which any structure would be impossible. Inversely, the formation of schemata

¹¹Ibid., p. 48.

¹²Ibid.

¹³Ibid.

through assimilation entails the utilization of external realities to which the former must accomodate, however crudely . . .¹⁴

Assimilation can never be pure because by incorporating new elements into its earlier schemata the intelligence constantly modifies the latter in order to adjust them to new elements. Conversely, things are never known by themselves, since this work of accomodation is only possible as a function of the inverse process of assimilation.¹⁵

As the subject grows this process of assimilation and accommodation progresses through several fixed sequences or stages. These stages of cognitive development are sensory-motor, pre-operational, concrete, and formal. They proceed from infancy to maturity. The sensory-motor period is associated with infancy, usually from 0 to 2 years of age. The pre-operational period extends from 2 years through 7 years of age. Concrete operations corresponds to the ages of 7 through 11 years with the formal period going from 11 years through adolescence. These age ranges are not considered definitive in that there is some variance about the time at which individuals will go from one stage to another stage. Flavell¹⁶ and Fowler¹⁷ cite studies supporting both the existence and order of

¹⁴Ibid., p. 49, quoting Jean Piaget, The Construction of Reality in the Child (New York: Basic Books, 1954), pp. 352-354.

¹⁵Ibid., p. 49, quoting Jean Piaget, The Origins of Intelligence in Children (New York: International University Press, 1952), pp. 6-7.

¹⁶Ibid., pp. 357-402.

¹⁷Fowler, "Affecto-Cognitive Systems," pp. 18-29.

the stages of cognitive development as Piaget has defined them.

Concepts of Space and Geometry

The learner's cognitive development of space and geometry progresses through each of the stages described above. The stage of concrete operations is characterized by the ability of the learner to go through a series of logical and infralogical operations. Flavell¹⁸ states that these infralogical operations apply to the physical world of spatiotemporal wholes and parts, spatiotemporal positions and displacements, and the like. Sigel¹⁹ indicates that this stage of concept development starts to occur in children at about nine or ten years of age.

Piaget²⁰ categorizes the learning of the spatiotemporal, physical world, interactions as following the order of geometrical constructs in the world of mathematics: topological, projective, Euclidian. He goes further and breaks down the learning of projective and

¹⁸Flavell, Psychology of Jean Piaget.

¹⁹Irving E. Sigel, "The Attainment of Concepts," in Review of Child Development Research, ed. by Martin L. Hoffman and Lois W. Hoffman, I (New York: Russell Sage Foundation, 1964).

²⁰Jean Piaget and Barbel Inhelder, The Child's Conception of Space, trans. by F. J. Langdon and J. L. Lunzer (London: Routledge and Kegan Paul, 1956); Jean Piaget, Barbel Inhelder, and Alina Szeminska, The Child's Conception of Geometry, trans. by E. A. Lunzer (New York: Basic Books, Inc., 1960).

Euclidian concepts into the following order: point, line, area, and volume.

Holloway²¹ in his introduction to Piaget's works on space perception and conceptualization explains that the child's first perceptions and rudimentary notions of spatial relationships are based on the branch of mathematics known as topology. He states that:

. . . mathematically speaking, this represents a late and advanced level of theory, it rests on very early modes of perception from which the small child can most readily form his first elementary spatial representations.²²

Later in this same work he speaks of the child's further development.

With projective and euclidian space we encounter new and different problems, that of locating objects and their configurations relative to one another, in accordance with general perspective systems or according to co-ordinate axes.²³

He describes the processes as starting with elementary sensory-motor and perceptual activity, evolving into intuitive representations, then concrete operations, and eventually abstract or hypothetico-deductive (logical) operations.

According to Flavell the cognitive action during the concrete stage of operations concerns, in the area of infralogical development, the dealing with wholes, parts,

²¹G. E. T. Holloway, An Introduction to the Child's Conception of Space (New York: Humanities Press, 1967).

²²Ibid., p. 3.

²³Ibid., p. 27.

positions, and displacements of objects in a manner that establishes a picture of concept of space for the learner. This space is made up of a network of these wholes, parts, positions, and displacements. Flavell's review of the studies exploring Piaget's theory of space and geometrical conceptualization substantiates the order and sequence of this stage and the other stages of development.

The stage of concrete operations is characterized by the ability of the child to go through a series of groupings of logical operations. These are:

1. Primary addition of classes.
2. Secondary addition of classes.
3. Bi-univocal multiplication of classes.
4. Co-univocal multiplication of classes.
5. Addition of asymmetrical relations.
6. Addition of symmetrical relations.
7. Bi-univocal multiplication of relations.
8. Co-univocal multiplication of relations.²⁴

Infralogical groupings are the homologues of the logical groupings. The infralogical counterpart of simple classification can be used as an example: A single object is composed of parts just as a class is composed of class objects; one can perform the direct operation of combining parts into wholes and the inverse operation of dissociating the whole into the parts again. These infralogical groupings characterize the cognitive structure of the child when

²⁴Flavell, Psychology of Jean Piaget, pp. 173-187.

his operations apply to the physical world of spatio-temporal wholes and parts, spatiotemporal positions and displacements of the positions, and the like.²⁵

The learner is seen to approach space and geometry through the infralogical groupings. The classifications and relationships are explored in one-dimensional (length-distance), two-dimensional (area), and finally three-dimensional (volume) aspects.

Other research not directly associated with Piaget's work but in the area of perception gives evidence that the theory has an application to the subject of space and geometrical conceptualization. Arnheim in the fourth chapter of his book Art and Visual Perception describes the growth of perception as growing from the simple to the complex. He bases his contentions on a review of psychological research, philosophical statements, and two and three dimensional art works of the past and present. In speaking to educators he states:

Visual education must be based on the premise that every picture is a statement. The picture does not present the object itself but a set of propositions about the object; or if you prefer, it presents the object as a set of propositions.²⁶

In the case of Piaget's theory the propositions are points, lines, areas, and volumes.

²⁵Ibid., pp. 327-341.

²⁶Rudolph Arnheim, Art and Visual Perception (Berkeley: University of California Press, 1965), p. 148.

This view of the simple to the complex is not contemporary. Pestalozzi, in his ABC of Anschauung, proposes much the same idea. He placed these elements of Anschauung before the ABC of letters. He states in How Gertrud Teaches her Children:

I must point out that the ABC of Anschauung is the essential and only true means of teaching to judge the shape of all things correctly. Even so, this principle is totally neglected, up to now, to the extent of being unknown; whereas hundreds of such means are available for the teaching of numbers and language. This lack of instrumental means for the study of visual form should not be viewed as a mere gap in the education of human knowledge. It is a gap in the very foundation of all knowledge at the point to which the learning of numbers and language must be definitely subordinated. My ABC of Anschauung is designed to remedy this fundamental deficiency of instruction; it will insure the basis on which the other means of instruction must be founded.²⁷

Bennett²⁸ in reviewing Pestalozzi's work relates these concepts to the establishment of drawing instruction and its techniques which were adapted in the United States in the latter part of the nineteenth century.

Orthographic Projection

French and Vierck²⁹ describe orthographic projection as a method of describing shapes of objects using

²⁷Johann Pestalozzi, Wie Gertud ihre Kinder lehrt und Ausgewählte Schriften zur Methode ("How Gertrud Teaches Her Children and Selected Writings on the Method") (Paderborn: Ferdinand Schöningh, 1961), p. 137.

²⁸Charles A. Bennett, History of Manual and Industrial Education up to 1870 (Peoria, Ill.: Charles A. Bennett Co., Inc., 1926), p. 122.

²⁹French and Vierck, Graphic Science.

perpendicular lines of projection and planes at right angles to one another. The right angle planes are usually three in number and they are called the frontal, horizontal, and profile planes. The names of these planes indicate where they are located in relation to the object being described. The general convention in the United States is to represent these planes as passing above, in front, and to the right of the object. The views of the front, top, and right side are projected on these planes.

The basic dimensions dealt with in this form of projection are space dimensions as opposed to the actual size dimensions of the object. Space dimensions are height, width, and depth and are based on distance between parallel planes; planes which are parallel to the planes of projection.

The method includes point, line, and area. Points being singular positions in space. Lines are surface edges, intersections and limits. Areas are concerned with adjacency and relationships with lines, corners, and edges. All are combined to define a volume or position occupied in space.

French and Vierck go on to say that the ability to interpret the shape of an object from its orthographic views is based on the recognition and application of the descriptive method. They also outline the fact that the concepts point, line, area, and volume are necessary for correct interpretation.

Space and Geometry Concepts and Orthographic Projection

The infralogical groupings offer a system upon which to organize the structure of the orthographic method for the learner. The groupings are ordered in such a way that the learner establishes a picture of space as a kind of all enveloping container made up of a network of sites and sub-spaces. Starting with points and lines (one dimension) and progressing through areas (two dimensions) and volume (three dimensions) the learner reaches a conceptualization of space and objects in space. These same concepts are those needed for the use of orthographic representation.

Orthographic projection establishes an object as a site or subspace within the spatial network by imposing on the spatial container arbitrary planes of projection. Points, lines, areas, and volumes are described as further subsets of the site or subspace by use of space dimensions which relate the parts of the object to each other and the object to the planes of projection.

Previous Research and Methods

Fowler³⁰ in his research on Piaget's theory has explored the area of stimulating learners on a form and level which is appropriate to the sensory-motor and infralogical operations of the learners. He goes on to indicate that systematic and sequential programming of the concepts to be learned should follow a hierarchy of task complexity.

³⁰Fowler, "Affecto-Cognitive Systems."

This sequential programming according to his research facilitates learning of the concepts. The basis for the organizing and sequencing begins with a selection and prior analysis of a defined reality structure or subject area. Emphasis is placed upon selecting, initially isolating, and simplifying central concepts and elements which are presented alternately in and out of context. The stimulation tactics center on the employment of model discrimination-generalization and problem-solving tasks.

Ojemann and Pritchett³¹ in a specific application of Piaget's theory to the instruction of the concept of specific gravity indicated that planned learning programs can significantly affect the development of a concept. The planned learning experience was based on an analysis of the learning task and a sequential presentation.

Basis for the Present Investigation

According to the findings and constructs of the above theory and research it seems reasonable to organize the learner's behavior to allow for a systematic and sequential interaction with the concepts. The interaction should be in and out of context. The sensory-motor and infralogical activity should be organized to stimulate and facilitate the learning of the spatial and geometric concepts and the orthographic method.

³¹Ojemann and Pritchett, "Guided Experiences."

At the present time industrial arts instruction attempts to get the learner to interact and exercise behaviors in the use of orthographic projection through the actual making of drawings using the rules and theory of the system. Little regard has been given to the incorporation of this instruction into more familiar things which are in the learner's personal domain. Nor, has it been examined in the light of a specific theory of cognition such as Piaget's.

The problem then is to get the learner to interact with the system of orthographic projection, incorporate the behaviors involved in the learner's personal domain, and provide for the exercise of these behaviors under a variety of contexts. Twelker³² suggests that games and simulations provide a format that will allow for this interaction, involvement, and activity. He also suggests that games and simulations provide a base for using theories and models of learning in structuring interaction with the information to be taught. Osmond³³ reviews the entire scope of using games and simulations in the educational field. She points out in this review that games are not new in the field but that emphasis is only now being placed on their relationship to sound educational theory.

³²Paul A. Twelker, "Designing Simulation Systems," Educational Technology (October, 1969), 64-70.

³³Marie W. Osmond, "The Method of Simulation Games in Family Life Education," Experimental Publication System 9 (December, 1970), Ms. No. 346-45.

A review of industrial arts literature reveals only one game pertaining to the instruction of orthographic projection. This game, "Visualize--An Educational Game,"³⁴ was based on a fifty-two card deck which contained thirteen sets of four cards each. Each set was made up of a top, front, side, and isometric view of a particular object; the thirteen sets represented thirteen objects. The rules provided for a solitaire or multiple player format. The game was used as a supplement to instruction and was not used as a primary tool in teaching the concepts of orthographic projection. The basic concern of the game's author was to help the student in the industrial arts laboratory to visualize mental pictures of the objects from orthographic drawings and in the drafting room to visualize orthographic views from pictures or objects. Some success seems to have been achieved in using the game but no evidence is offered to substantiate the claim. Nor, was there any description of the use of an educational or psychological theory that the game might have been developed upon.

Orthographic Projection, Piaget's
Theory, and Games and Simulation

Piaget's theory offers a basis for the instruction of learners in the system of orthographic projection in a manner which utilizes their ability to interact with spatial and geometrical concepts. The projective and Euclidian

³⁴D. E. Kellogg, "Visualize--An Educational Game," Industrial Arts and Vocational Education, XXIV (Aug., 1935), 246-248.

geometries used in the theory and in the orthographic system are identical. And, in turn, the orthographic system is an area which industrial arts is concerned with in attempting to teach technical visual communication. Games and simulations can provide the vehicle by which the learner can be taken through the Piagetian structure and taught the orthographic system.

The infralogical groupings offer a structure upon which a series of games and simulations might be constructed. These groupings give an indication as to how to provide for: the exercise of behaviors under various contexts; interaction with the projection system; and a place to start in the learner's domain of ability.

Addition and multiplication of object-parts and relationships can be structured around the object-parts in orthographic projection. Points, lines, planes, and volumes can be used in a sequential order in the instructional approach; each step in the sequence containing the parts of the step that is to follow. Games and simulations can be developed so that each step can deal with behaviors in using two and three-dimensional interchange. Terms, definitions, attributes, concepts, and principles of the orthographic projection system can be introduced throughout the sequence providing for interaction with each. The learner can then, through games based on the theory and system, start at his own operational level and in his own personal domain of behavior.

Flavell speaks of the application of Piagetian theory to planning curricula on the basis of grade placement and the methods by which the child ought to be taught at any level. These two points give further foundation for an attempt at objectively exploring the application of the theory to instruction and methods in the industrial arts classroom and laboratory.

The Games and Simulations

The games revolve around the two- and three-dimensional manipulation and representation of points, lines, areas or planes, and volume or form. These are the objects and parts of the orthographic system. The games sequence the object-parts of the system and introduce orthographic projection in a logical manner. A manner that parallels the development of spatial and geometric concepts in the Piagetian theory. A description of the game rules can be found in the Appendix.

Design for Research

The organization of the concepts and the means for incorporating them into a researchable experimental design are based on the techniques presented by Campbell and Stanley.³⁵ Their model for the use of non-equivalent control groups served as a foundation upon which the classrooms in the study are arranged and assigned to

³⁵Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally Co., 1963).

experimental and control status. The Campbell and Stanley approach accounts for factors which exert an influence on internal and external validity in problems of the type described in this study.

Summary

The above review and citations were presented to elaborate on the philosophy, theory and curricular content and to tie these three areas together to form the rationale for a study of instruction in an industrial arts program.

The philosophical review provided a basis for utilizing Kant's position on percept and concept in the content and methods of education. The argument of rationalism versus empiricism was traced to the present state of instruction with respect to these two philosophical views. A theory of learning based on the above philosophical views, the theory of Jean Piaget, was described. Piaget's theory was also related to an area of industrial arts instruction, orthographic projection. The relationship of the Piagetian theory and the orthographic system provided a foundation to prepare instructional materials to teach the concepts of the system. A series of games and simulations based on the Piagetian theory and orthographic projection was proposed as a method by which the theory could be applied to the instructional area of interest. These games would allow the theory to be tested on the

basis of previous research models which indicated that a systematic and sequential interaction with the concepts could stimulate and facilitate learning.

CHAPTER III

THE DESIGN

Introduction

The measurement of the learner's ability in the areas of percept and concept of objects in space must be based on providing some means by which to organize for stimulation of the sensory-motor and infralogical systems and the facilitation of learning the concepts. An experimental design using a systematic and sequential presentation of the orthographic and spatial concepts can provide the means to investigate this topic. The information in this chapter describes and details the organization of such an experimental design.

Overview of the Study

The study took place in the industrial arts program of the middle schools in East Lansing, Michigan. The two schools offer a general industrial arts program for all students in the seventh and eighth grades. Each school employs one industrial arts teacher. The beginning course concentrates upon problem-solving approaches and is concerned with the study of woods, plastics, graphic arts,

drawing and communication, metals, and industrial organization to produce products in quantity through mass production techniques. The students are encouraged to start with their own ideas, to communicate their ideas, to plan their activities, to conduct appropriate preliminary experimentation, to do the actual construction, and to complete an objective evaluation of their work.

Four classroom groups of the beginning industrial arts course in each school were directly involved in the research. These naturally occurring classroom units provided the place where the orthographic and spatial concepts would be presented. Two classroom units in each school were randomly selected to be part of the experimental group while the remaining classroom units served as a control group. The specific treatments were then randomly assigned within the experimental group.

The experimental group, four classrooms, two in each school, all received the presentation of the geometric concepts through the playing of the games described in the Appendix. The teacher's role with each of these classroom units was to present the games at the appropriate times and to act as a referee in disputes that might arise due to pupil interaction in playing the games. At no time did the teachers present any other instructional material related to geometric or orthographic projection concepts to these classes. The games were the exclusive vehicle for the presentation of the concepts.

The treatments within the experimental group consisted of four testing schedules. These schedules were built around the presentation of three specific concept groupings: (1) points-lines, (2) lines-planes, and (3) planes-forms. A separate class was tested before and after the playing of the games that dealt with a single concept grouping; this served to bracket the presentation of the three concept groupings on each of three distinct classes. The fourth classroom was tested before and after playing all the games dealing with all the concept groupings.

The control group, two classes in each school, did not receive the presentation of the geometric or orthographic projection concepts in the form of the games or in any other manner. The teachers, by design, provided no instruction to students relating to these concepts.

Each of the classes in both the control and experimental groups were given instruction in all other areas of the industrial arts program. An attempt was made to provide each class with the same type of activities and instructional materials. The only difference in their instruction was the use of the games in the four classes which made up the experimental group.

The total time involved for the study ran from the beginning of school in September to just prior to Thanksgiving. On specified days during this time period the tests were administered and the games introduced and played.

At the conclusion of the experimental period the test performance data and other data pertaining to the study were tabulated, processed, and analyzed. A detailed description of the sample, measures, experimental design, testable hypotheses, and analysis of data are discussed below.

Sample

The sample subjects were drawn from the total enrollment of students in Industrial Arts - I classes of the East Lansing, Michigan, middle schools during the fall semester of the 1971-72 school year. All the students were without previous industrial arts instruction in their backgrounds. The age range for this group of subjects was from 140 to 174 months with a mean age of 150.7 months and a standard deviation of 6.86 months. The total number of subjects encompassed in the study was 163. Attrition due to student absence and incomplete supplementary data reduced the number who provided a complete set of data to 151. The remaining 12 provided partial data which was used in those parts of the analysis where it would provide information. All the subjects were assigned to their groups through the normal enrollment and registration process for the middle schools. Both sexes were included in the population and sample; boys numbered 95 and girls numbered 68. The two East Lansing middle schools have a total enrollment of 1151 students. The "Statement of Philosophy" of the school system describes the cultural

setting of the school-community as, "one which is growing in number, is relatively mobile, and relatively homogeneous racially. The socio-economic range in the community is broad, but extremes are few. The economic base for school support is relatively favorable, and our citizens generally support the value of public school education."¹ The socio-economic, religious, and racial nature of the community has been summarized in the following manner: "East Lansing is a middle class community, predominantly Protestant, with less than one per cent Negro students in the schools."² The community's population is 47,540 but it neighbors the state's capital, Lansing, which has a population of 131,546. East Lansing is also the location of a state university which enrolls approximately 40,000 students. The middle schools in which the sample was drawn reflect in their student bodies the varied economic levels, home environments and life styles of this total community.

Experimental Design

In order that controls could be placed on answering the questions raised concerning the hypotheses stated in Chapter I, the following experimental design was used in the study.

¹East Lansing Public Schools, East Lansing, Michigan, "Statement of Philosophy" (East Lansing, 1967), p. 1. (Mimeographed.)

²John W. Vaughn, "Implications of Physical and Intellectual Growth Characteristics, Interests, and Cultural Forces for the Improvement of the Middle School Program" (unpublished Ph.D. dissertation, Michigan State University, 1969), p. 87.

Two treatments were determined to be needed to assess the factor of stimulation of the sensory-motor and infralogical systems of the Piagetian theory. One treatment to be directly concerned with stimulation procedures and another to serve as a control measure. They can be defined as follows:

- T_1 : Stimulation of the sensory-motor and infralogical systems by direct interaction with an ordered presentation of the orthographic projection concepts.
- T_2 : A control group receiving no presentation of the orthographic projection concepts.

The eight available classroom groups for the study were placed into the treatment groups by the process of random selection and assignment. The four groups within the stimulation treatment were then randomly assigned to one of four test schedules which were designed to assess the facilitation of learning in the presentation of the concepts. The four test schedule groups in the stimulation group were then randomly assigned to the two teachers who participated in the study. Each teacher, one in each middle school, then worked with two groups in the stimulation and testing treatment and two groups in the control treatment. This procedure also served as a means by which the games (Appendix), used for the purpose of introducing the concepts in a systematic and sequential manner, could be evaluated. The test schedule consisted of what could be termed a series of treatments within the larger treatment group. They were as follows:

- t₁: Testing before and after the use of the games dealing with the concepts of points and lines.
- t₂: Testing before and after the use of the game dealing with the concepts of lines and planes.
- t₃: Testing before and after the use of the game dealing with the concepts of planes and forms.
- t₄: Testing before and after the use of all the games dealing with all the concepts.

The organization of the treatments described above and the test schedule within treatment one is displayed in Figure 3.1. The assignment of the groups conforms to a non-equivalent control group design outlined by Campbell and Stanley.³ The groups are naturally occurring collectives, classrooms. Campbell and Stanley indicate that sources of external and internal validity in this design are strong for this type of investigation when the proper assumptions and controls are met.

Instrumentation

Observations in the above design were accomplished with the use of two standardized tests: The Spatial Relations sub-test of the Differential Aptitude Test⁴ and

³Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally and Co., 1963), pp. 47-50.

⁴George K. Bennett, Harold G. Seashore, and Alexander G. Wesman, Differential Aptitude Tests (New York: Psychological Corp., 1959).

Week

	1	2	3	4	5	6	7	8	9	10	11
Group 1	0 ₁	0 ₂	X ₁		0 ₃	X ₂			X ₃		0 ₁
Group 2	0 ₁		X ₁		0 ₃	X ₂		0 ₂	X ₃		0 ₁
Group 3	0 ₁		X ₁			X ₂		0 ₂	X ₃	0 ₃	0 ₁
Group 4	0 ₁	0 ₂	X ₁			X ₂			X ₃	0 ₃	0 ₁
Group 5	0 ₁	0 ₂								0 ₃	0 ₁
Group 6	0 ₁	0 ₂								0 ₃	0 ₁
Group 7	0 ₁	0 ₂								0 ₃	0 ₁
Group 8	0 ₁	0 ₂								0 ₃	0 ₁

0₁ = Observation on Space Relations Test.
(Split-half forms of this test were used.)

0₂ = Observation on Visualization Test, Form A.

0₃ = Observation on Visualization Test, Form B.

X₁ = Games dealing with the concepts of points and lines.

X₂ = Game dealing with the concepts of lines and planes.

X₃ = Game dealing with the concepts of planes and forms.

Figure 3.1.--Non-Equivalent Control Group Design for the Study of Percept and Concept in Relation to Piaget's Theory and Orthographic Projection.

the Visualization Test⁵ of three dimensional orthographic shape. The gain in score on these tests served as the dependent variable in the design of the study. An observation on the reading ability of each subject was taken on the Gates-MacGinitie Reading Tests - Survey E;⁶ these observations were provided through the school's regular testing program and were not part of this investigation's assessments.

Space Relations

All the subjects were pre-tested and post-tested on a split form of the Space Relations sub-test of the Differential Aptitude Test. Pilot testing of the split form was carried out on a comparable group of subjects from the population during the year prior to this investigation. The test forms were based on a division of the items into odd or even numbers; this division resulted in two, thirty item, forms of the test. One form contained all the even numbered items and the other form contained all the odd numbered items. These forms provided a power test with a time limit of twelve and one-half minutes with the number of correct choices being the subject's score. The pilot test data analysis indicated that there was no significant difference in performance

⁵E. C. Biewald, Visualization Test (Peoria, Ill.: Charles A. Bennett Co., Inc., 1971).

⁶Arthur I. Gates and Walter MacGinitie, Gates-MacGinitie Reading Tests (New York: Teachers College Press, 1965).

on either of the two forms. The results showed a mean of 12.71 and a variance of 182.13 for the even numbered items and a mean of 13.04 and a variance of 190.74 for the odd numbered items.

The subjects were randomly assigned to take either the odd numbered form or the even numbered form for the pre-test. For the post-test the subjects were given the form of the test that they did not take as the pre-test measure. This was accomplished by distributing equal numbers of both forms during pre-testing and then assigning each subject the form alternate to their pre-test form during the post-testing.

Visualization Test

The subjects were also tested on the Visualization Test of three dimensional orthographic shape. The two equivalent forms, Form A and Form B, allowed for pre-testing and post-testing of the subjects without the necessity of repeating the use of either form for any one group or subject.

This test consisted of forty items arranged in order of difficulty with a time limit of twenty-five minutes. The basic test items were made up of orthographic projections of three dimensional shapes with one of the three orthographic views missing. The subject was to select the missing view from among five choices provided for each test item. The number of correct choices provided the subject's score.

Reading Tests

The Gates-MacGinitie Reading Tests - Survey E scores for the subjects were obtained from the middle school's regular testing program. These scores were gathered because recent research indicated that there may be some association of reading ability and space visualization. Symmes and Rapoport,⁷ in research for the National Institute of Health, indicated that a child's talent for visualization of objects in three dimensional space may be related to the child's reading difficulty.

The reading scores consisted of three parts, speed and accuracy, vocabulary, and comprehension. The speed and accuracy test was a power test to determine the student's ability to read and comprehend thirty-six short paragraphs in four minutes. The vocabulary test sampled the student's reading vocabulary on a fifty-item test of words. The comprehension test assessed the student's ability to read prose passages; it contained twenty-one passages.

A test of correlation between the reading scores and the Space Relations and Visualization Test was determined as a method by which a relationship could be examined and if there was such a relationship the reading scores were then to become a factor in the analysis of the space and visualization observations.

⁷Jean Symmes and Judith L. Rapoport, "Today's Poor Reader May be Tomorrow's Architect," Report on Education Research (August 18, 1971), p. 10.

Procedure and Setting

All instruction and testing for both the treatment and control groups took place in the industrial arts laboratory-classrooms in the two middle schools. Other industrial arts instruction and activities were pursued by all the groups during the investigation period. These activities consisted of safety instruction, demonstrations on tool and machine use, materials identification and use, instruction on industrial organization and functions, and the problem-solving approach to constructing personal project ideas.

The presentation of the concepts through the use of the game or games, the above activities, and the testing of all groups took place over an eleven week period. During this period each group met four times per week for fifty-five minutes at each meeting.

Testing on the Space Relations test occurred in the class period prior to the introduction of the treatments and after the last period on which the games were used. The Visualization Test administration occurred on a schedule that provided for the tests to be given before and after the appropriate concepts were introduced through the game or games.

The two teachers introduced the games, demonstrated the artifacts, explained the rules of play, and acted as referees in the playing of the games. The game or games dealing with each particular concept were played for eleven

class periods. The teachers also administered the tests as the various concepts were being introduced throughout the entire investigation period. The introduction of the concepts and the testing occurred in the following sequence:

- | | | |
|---------|--------|---|
| Period | 1: | Test on <u>Space Relations</u> for all groups. |
| Period | 4: | Test on Form A, <u>Visualization Test</u> for Groups 1, 4, 5, 6, 7, and 8. |
| Periods | 5-15: | Introduction and use of games on the concepts of points and lines for Groups 1, 2, 3, and 4. |
| Period | 16: | Test on Form B, <u>Visualization Test</u> for Groups 1 and 2. |
| Periods | 17-27: | Introduction and use of the game on the concepts of lines and planes for Groups 1, 2, 3, and 4. |
| Period | 28: | Test on Form A, <u>Visualization Test</u> for Groups 2 and 3. |
| Periods | 29-39: | Introduction and use of the game on the concepts of planes and forms for Groups 1, 2, 3, and 4. |
| Period | 40: | Test on Form B, <u>Visualization Test</u> for Groups 3, 4, 5, 6, 7, and 8. |
| Period | 43: | Test on <u>Space Relations</u> for all groups. |

The above schedule started in the first week of classes during September and finished on the Monday before Thanksgiving in November.

Statistical Hypotheses to be Tested

The following hypotheses were based on the general hypotheses stated in Chapter I. The statements below were designed to inquire about the general hypotheses in a

specific manner. These hypotheses have been stated in the null form. The instrument used for data collection and the form in which the data were analyzed have been specified for each hypothesis.

Reading Correlation

1. There is no significant correlation between scores on the Gates-MacGinitie Reading Tests - Survey E and the scores on the Space Relations test or the Visualization Test.

Stimulation of the Sensory-Motor and Infralogical Systems

1. Stimulation of the sensory-motor and infralogical systems as measured by gain scores on the Space Relations test does not vary according to treatment.
2. Stimulation of the sensory-motor and infralogical systems as measured by gain scores on the Space Relations test does not vary according to sex.
3. Stimulation of the sensory-motor and infralogical systems as measured by gain scores on the Space Relations test does not vary according to group.

Facilitation Through the Programming of Concepts

1. Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Visualization Test does not vary according to group.
2. Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Visualization Test does not vary according to sex.

3. Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Space Relations test does not vary according to group.
4. Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Space Relations test does not vary according to sex.

Analysis of Data

The program used for the analysis of the relationship between reading scores and the scores on the Space Relations test and the Visualization Test employed the use of a statistical test for linear correlation between variables. This test does not assume a causal relationship between variables but only provides a measure of relationship between variables.

The general program used for the analysis of gain scores was a multivariate analysis of variance. Multivariate analysis of variance is a statistical procedure designed to eliminate making comparisons between groups that exist in a set and are known to interact with one another. In this analysis the data are treated at one time and a general null hypothesis of no differences among the means of the various groups is tested. The assumptions to be met in multivariate analysis require that the observations be independently drawn from normal treatment populations having the same variance, and with error components independent across all pairs of observations. The assumptions connected with normal distribution and

independence were met in terms of the investigation's design by considering the group means as the basic observation and testing the treatment effects against variations in these means⁸ and the random assignment of treatments to groups. Independence was established by considering each group as an experimental unit. Tests for equality of variances are extremely sensitive to any departure from normality in the population, and contemporary opinion holds that the analysis of variance can and should be carried on without a preliminary test of variances.⁹

The specific computer program employed in this study was developed by and named for Jeremy D. Finn.¹⁰ The program was designed so that it allows for the analysis of more than one dependent variable at the same time. The dependent variables in this investigation were the gain scores derived from the pre-post Space Relations scores and the pre-post Visualization Test scores. The factors in the analysis were treatment, group, and sex.

Summary

This chapter contained a description of the sample and its characteristics. The experimental design along

⁸Campbell and Stanley, Experimental and Quasi-Experimental Designs for Research, p. 23.

⁹William L. Hayes, Statistics (New York: Holt, Rinehart and Winston, Inc., 1963), p. 381.

¹⁰Jeremy D. Finn, Multivariate: Fortran Program for Univariate and Multivariate Analysis of Variance and Covariance (Buffalo: Department of Educational Psychology, State University of New York at Buffalo, 1967).

with a description of the treatments was presented. The instruments used for data collection were explained and attention was given to the procedure and setting of the investigation. The hypotheses were stated in the null form and the methods used to analyze the data were presented and discussed. Chapter IV will include the results and discussion of this analysis.

CHAPTER IV

ANALYSIS OF RESULTS

The data on the stimulation and facilitation of learning orthographic projection is presented below in tabular order. Included in this data are the correlation coefficients, means, variances, and other information related to the hypotheses of this study.

The analysis will follow the outline presented in Chapter III.

1. The significance of reading performance as a correlate of performance on tests of space relations and orthographic visualization.
2. The stimulation of the sensory-motor and infralogical systems as measured on a space relations test with respect to the factors of treatment, sex and group.
3. The facilitation of learning the concepts as measured on the space relations and orthographic visualization tests with respect to group and sex.

A discussion of the findings will follow the presentation of the results.

Reading Performance

The scores from the Gates-MacGinitie Reading Tests - Survey E, the Space Relations test, and the Visualization

Test were analyzed with a test which was based on the linear relationship between the variables in question. Table 4.1 presents the data in the form of a correlation matrix between the various scores on the instruments used in the study. The coefficients presented are Pearson product-moment r 's. At the 0.05 level of probability, with greater than 100 degrees of freedom, five of the eight coefficients of interest were assessed to be significant. These significant r 's, the correlations between the gain scores on the space and visualization tests and the reading test scores, were 0.24 and 0.29. It has been shown¹ that the square of the correlation coefficient between two independent variables accounts for the proportion of the variance due to linear regression. This squared coefficient is the relative reduction in variance accomplished by the use of the linear prediction rule. The proportions for the significant r 's are presented in Table 4.2. On the basis of the small proportions of variance due to a linear relationship the hypothesis of no significant correlation between the Gates-MacGinitie Reading Test - Survey E, the Space Relations test, and the Visualization Test was not rejected. The reading scores were not used as a covariate in the analysis of the data because of this decision.

¹Hayes, Statistics, p. 512.

TABLE 4.1.--Correlation Coefficients for the Relationships Between the Gates-MacGinitie Reading Tests - Survey E, Space Relations Test, and Visualization Test.

	<u>Visualization Test Scores</u>			<u>Space Relations Test Scores</u>		
	Pre-Test N = 156	Post-Test N = 157	Gain N = 152	Pre-Test N = 155	Post-Test N = 159	Gain N = 153
Gates-MacGinitie Reading Tests						
Survey - E						
Scores						
Vocabulary	.29*	.44*	.18	.24*	.33*	.17
Comprehension	.20*	.40*	.24*	.41*	.44*	.14
Speed	.11	.32*	.24*	.25*	.38*	.24*
Accuracy	.01	.22*	.24*	.17	.31*	.29*

* = r significant at .05 with the degrees of freedom being greater than 100.

TABLE 4.2.--Significant Correlation Coefficients and Proportions of Variance Due to Linear Regression.

Source	r	Proportion
Comprehension - Visualization Gain Score	0.24	0.06
Speed - Visualization Gain Score	0.24	0.06
Accuracy - Visualization Gain Score	0.24	0.06
Speed - Space Relations Gain Score	0.24	0.06
Accuracy - Space Relations Gain Score	0.29	0.08

Stimulation of the Sensory-Motor
and Infralogical Systems

The analysis of variance of the Space Relations test score provided the data to test the hypotheses concerned with the stimulation of the sensory-motor and infralogical systems of the learning theory in question. In the analysis of the data 76 individuals were in the treatment unit and 75 individuals in the control unit. The input variable was the gain score on the Space Relations test. The factors in the design were: (1) treatment (two levels), (2) sex (two levels), and (3) group (four levels). The number of cells in the analysis of variance matrix was sixteen. The cell means, the variance, and the standard deviation are presented in Table 4.3. The weighted means for treatment and sex, and treatment and group are presented in Tables 4.4 and 4.5 respectively. The univariate analysis

TABLE 4.3.--Means, Variance, and Standard Deviation of the
Space Relations Test Gain Scores in the Testing
 for Stimulation of the Sensory-Motor and
 Infralogical Systems.

	Factor			Variable
	N	Sex	Group ¹	<u>Space Relations</u> Gain Score Means
Treatment	11	M	1	1.45
	12	F	1	1.92
	10	M	2	2.80
	4	F	2	3.25
	10	M	3	3.70
	9	F	3	3.22
	10	M	4	0.60
	10	F	4	4.00
Control	16	M	5	2.88
	5	F	5	3.60
	12	M	6	1.00
	8	F	6	1.13
	9	M	7	3.67
	7	F	7	- 0.86
	10	M	8	- 0.30
	8	F	8	0.63
Variance of Variable				18.00
Standard Deviation of Variable				4.24

¹Group designates the classroom unit.

TABLE 4.4.--Cell Means for the Space Relations Test Gain Scores Across Sex in the Testing for Stimulation of the Sensory-Motor and Infralogical Systems.

	Male	Female	Combined
Treatment - 1			
Experimental	2.12	3.00	2.53
Treatment - 2			
Control	1.92	0.94	1.53

TABLE 4.5.--Cell Means for the Space Relations Test Gain Scores Across Group In the Testing for Stimulation of the Sensory-Motor and Infra-logical Systems.

	Group 1	Group 2	Group 3	Group 4	Combined
Treatment - 1					
Experimental	1.70	2.93	3.47	2.30	2.53
Treatment - 2					
Control	3.05	1.05	1.69	0.28	1.53

of the factors in this portion of the study is summarized in Table 4.6 which presents the sources of variance, degrees of freedom, mean squares, calculated F-ratios with their probability levels, and the tabled values of F-ratios at the 0.05 level of probability for treatment, group, sex and interaction.

Treatment Differences

The null hypothesis concerning the treatment effect was:

Stimulation of the sensory-motor and infra-logical systems as measured by gain scores on the Space Relations test does not vary according to treatment.

A univariate analysis comparing the mean gain scores on the Space Relations test for the experimental and control treatments across group and sex, with 1 and 135 degrees of freedom, yielded an F - ratio of 2.50 with a probability of 0.12. The tabled F - ratio, with 1 and an infinite number of degrees of freedom and a probability of 0.05, is 3.84. On the basis of these findings the null hypothesis was not rejected.

Sex Differences

The null hypothesis concerning differences due to sex was:

Stimulation of the sensory-motor and infra-logical systems as measured by gain scores on the Space Relations test does not vary according to sex.

TABLE 4.6.--Summary Table for the Analysis of Variance on the Space Relations Test Gain
Scores for Treatment, Sex, Group, and Interaction in the Testing for Stimula-
tion of the Sensory-Motor and Infralogical Systems.

Source	df	Mean Square Between	Calculated F	Tabled F df = 1 / 00, p = .05
Grand Mean	1 / 135	620.11	34.44	0.0001
Treatment	1 / 135	44.99	2.50	0.12
Group	3 / 135	13.63	0.76	0.52
Sex	1 / 135	0.73	0.04	0.84
Group x Sex	3 / 135	36.68	2.04	0.11
Treatment x Sex	1 / 135	15.27	0.85	0.36
Treatment x Group	3 / 135	25.61	1.42	0.24
Treatment x Group x Sex	3 / 135	7.48	0.42	0.74

A univariate analysis comparing the mean gain scores on the Space Relations test for the experimental and control treatments across group and treatment, with 3 and 135 degrees of freedom, yielded an F - ratio of 0.04 with a probability of 0.84. The tabled F - ratio, with 3 and an infinite number of degrees of freedom and a probability of 0.05, is 2.60. On the basis of these findings the null hypothesis was not rejected.

Group Differences

The null hypothesis concerning the differences due to group was:

Stimulation of the sensory-motor and infra-logical systems as measured by gain scores on the Space Relations test does not vary according to group.

A univariate analysis comparing the mean gain scores on the Space Relations test for the experimental and control treatments across treatment and sex, with 3 and 135 degrees of freedom, yielded an F - ratio of 0.76 with a probability of 0.52. The tabled F - ratio, with 3 and an infinite number of degrees of freedom and a probability of 0.05, is 2.60. On the basis of these findings the null hypothesis was not rejected.

Interaction Effects

A univariate analysis of the interaction between group and sex; treatment and sex; treatment and group; and treatment, group and sex was made to determine if such interactions did exist in the data. Table 4.6 presents

the sources of variance, degrees of freedom, mean squares, calculated F - ratios with their levels of probability, and the tabled values of F - ratios at the 0.05 level of probability. On the basis of these findings the null hypothesis:

There are no interaction effects between the factors in the analysis of gain scores on the Space Relations test with respect to stimulation of the sensory-motor and infra-logical systems.

was not rejected.

Facilitation Through the Systematic and Sequential Programming of Concepts

The analysis of variance on the Visualization Test and the Space Relations test scores provided the data to test the hypotheses concerned with facilitation of learning through the systematic and sequential programming of concepts. The input variables were the gain scores on the Visualization Test and the Space Relations test. In the analysis of the data 86 individuals provided scores. The factors in the design were: (1) group (four levels) and (2) sex (two levels). The number of cells in the analysis of variance matrix was eight. The cell means, the variances, and the standard deviations are presented in Table 4.7. The weighted means across group and sex for the gain scores on the Visualization Test and the Space Relations test are presented in Table 4.8. The univariate analysis of the factors in this portion of the study is summarized in Table 4.9 which presents the sources of variance, degrees

TABLE 4.7.--Cell Means, Variances, and Standard Deviations of the Space Relations Test and Visualization Test Gain Scores in the Testing for Facilitation Through the Systematic and Sequential Programming of Concepts.

Cell	N	Factor		Input Variables	
		Group	Sex	Visualization Test Gain Scores	Space Relations Gain Scores
1	11	1	M	- 0.09	1.45
2	12	1	F	2.08	1.92
3	12	2	M	3.75	2.33
4	5	2	F	0.40	2.60
5	12	3	M	2.67	3.75
6	12	3	F	3.42	2.92
7	11	4	M	2.64	0.82
8	11	4	F	1.82	3.64
Variance of Input Variables				16.24	17.47
Standard Deviations of Input Variables				4.03	4.18

TABLE 4.8.--Cell Means for the Visualization Test and the Space Relations Test Gain Scores Across Sex and Group in the Testing for Facilitation Through the Systematic and Sequential Programming of Concepts.

Source	N	Visualization Test	Space Relations Test
Males	46	2.33	2.13
Females	40	2.44	2.80
Group 1	23	0.065	1.74
Group 2	17	2.76	2.41
Group 3	24	3.04	3.34
Group 4	22	2.23	2.23

of freedom, mean squares, calculated F - ratios with their probability levels, and the tabled values of F - ratios at the 0.05 level of probability.

Group Difference

The first null hypothesis concerning group effects was:

Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Visualization Test does not vary according to group.

A univariate analysis comparing the mean gain scores on the Visualization Test of the four groups across sex, with 3 and 78 degrees of freedom, yielded an F - ratio of 1.09 with a probability of 0.36. The tabled F - ratio, with 3 and 80 degrees of freedom and a probability of 0.05, is 2.72. The F - ratio for the multivariate test of

TABLE 4.9.--Summary Table for the Analysis of Variance on the Space Relations Test and Visualization Test Gain Scores for Group, Sex, and Interaction in the Testing for Facilitation Through the Systematic and Sequential Programming of Concepts.

Source	Test	df	Mean Square Between	Calculated F	p	df = 1 / 80, p = .05 Tabled F
Grand Mean	Visualization	1 / 78	433.13	26.66	0.0001	3.96
Grand Mean	Space Relations	1 / 78	507.92	29.07	0.0001	3.96
Group	Visualization	3 / 78	17.68	1.09	0.36	2.72
Group	Space Relations	3 / 78	10.97	0.63	0.60	2.72
Sex	Visualization	1 / 78	0.02	0.0013	0.97	3.96
Sex	Space Relations	1 / 78	9.56	0.55	0.46	3.96
Group x Sex	Visualization	3 / 78	24.59	1.51	0.21	2.72
Group x Sex	Space Relations	3 / 78	13.25	0.75	0.52	2.72

equality of mean vectors was 0.28 with 6 and 154 degrees of freedom and a probability of less than 0.64. On the basis of these findings the null hypothesis was not rejected.

The second null hypothesis concerning group effects was:

Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Space Relations test does not vary according to group.

A univariate analysis comparing the mean gain scores on the Space Relations test for the four groups across sex, with 3 and 78 degrees of freedom, yielded an F - ratio of 0.63 with a probability of 0.60. The tabled F - ratio, with 3 and 80 degrees of freedom and a probability of 0.05, is 2.72. The F - ratio for the multivariate test of equality of mean vectors was 0.28 with 6 and 154 degrees of freedom and a probability of less than 0.64. On the basis of these findings the null hypothesis was not rejected.

Sex Differences

The first null hypothesis concerning differences due to sex was:

Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Visualization Test does not vary according to sex.

A univariate analysis comparing the mean gain scores on the Visualization Test for sex across groups,

with 1 and 78 degrees of freedom, yielded an F - ratio of 0.0013 with a probability of 0.97. The tabled F - ratio, with 1 and 80 degrees of freedom and a probability of 0.05, is 3.96. The F - ratio for the multivariate test of equality of mean vectors was 0.28 with 2 and 77 degrees of freedom and a probability of less than 0.76. On the basis of these findings the null hypothesis was not rejected.

The second null hypothesis concerning differences due to sex was:

Facilitation through the systematic and sequential programming of concepts as measured by gain scores on the Space Relations test does not vary according to sex.

A univariate analysis comparing the mean gain scores on the Space Relations test for sex across groups, with 1 and 78 degrees of freedom, yielded an F - ratio of 0.55 with a probability of 0.46. The tabled F - ratio, with 1 and 80 degrees of freedom and a probability of 0.05, is 3.96. The F - ratio for the multivariate test of equality of mean vectors was 0.28 with 2 and 77 degrees of freedom and a probability of less than 0.76. On the basis of these findings the null hypothesis was not rejected.

Interaction Effects

A univariate analysis of the interaction between group and sex was made to determine if such an interaction did exist in the data. Included in Table 4.9 is the source

of variance, degrees of freedom, mean square, calculated F - ratio with its level of probability, and the tabled F - ratio at the 0.05 level of probability. The F - ratio for the multivariate test of equality of mean vectors was 1.25 with 6 and 154 degrees of freedom and a probability of less than 0.29. On the basis of these findings the null hypothesis:

There is no interaction effect between the factors in the analysis of gain scores on the Visualization Test or the Space Relations test with respect to facilitation through the systematic and sequential programming of concepts.

was not rejected.

Summary of Tested Hypotheses

Stated below are the hypotheses of interest in each of the areas considered in the study. A rejection statement follows each specific hypothesis.

Stimulation

- | | |
|---------------------------------|--------------|
| 1. No effects due to treatment. | Not Rejected |
| 2. No effects due to group. | Not Rejected |
| 3. No effects due to sex. | Not Rejected |
| 4. No interaction effects. | Not Rejected |

Facilitation

- | | |
|-----------------------------|--------------|
| 1. No effects due to group. | Not Rejected |
| 2. No effects due to sex. | Not Rejected |
| 3. No interaction effects. | Not Rejected |

Discussion of Analysis

Reading Performance

The significance of the data on reading performance as a correlate of performance on tests of space relations and orthographic projection suggests that some relationship does exist between these factors. The analysis of this relationship, with respect to the amount of variance it accounted for in the linear relationship, yielded data which indicated that the proportion of this variance was 0.08 or less. This latter analysis suggested the omission of the reading performance scores as a covariate in the multivariate and univariate analysis of the gain scores in testing the stated hypotheses. The remaining analysis was then performed without the use of the reading test scores.

Stimulation

The non-rejection of the hypotheses on the basis of the Space Relations test gain scores suggests that the stimulation of the sensory-motor and infralogical systems did not occur under the conditions controlled for in the study. The factor of no difference between performance by either sex suggests that the treatment acted equally for both boys and girls. No differences between groups suggests that teacher and school environment had no influence on the treatments in the design.

Facilitation

The non-rejection of the hypotheses on the basis of the analysis of the Space Relations test and the Visualization Test gain scores suggests that the systematic and sequential presentation of the concepts did have some effect on the facilitation of learning. Each of the four groups were measured at different times during the experimental period: the first group before and after the presentation of the first set of concepts; the second group before and after the presentation of the second set of concepts; the third group before and after the third set of concepts; and the fourth group before and after the presentation of all three sets of concepts. The lack of a significant difference between groups suggests that no one set of concept presentations had more effect than any other set or the sets in total. This lack of a significant difference between groups suggests that the teacher and the school environment did not influence the performance of the learners. The lack of a significant difference between the sexes suggests that both boys and girls interacted with the concepts and their presentation in the same way.

Summary

The findings of this study indicate that the stimulation of the sensory-motor and infralogical systems did not occur due to the experimental treatment. Also, the findings indicate that facilitation occurred through the

systematic and sequential presentation of the concepts. The factor of reading performance was analyzed as having a small significant linear relationship with the performance on the spatial and orthographic projection tests; this relationship was not considered strong enough to be of a significant influence on the ability to deal with the concepts being presented and tested for in the experimental groups. The factors of sex and group were shown to be of no significance in the study indicating that both boys and girls performed equally in this area and that the presentation of the concepts was not influenced by the teacher or the school environment.

In the stimulation of the sensory-motor and infra-logical systems, as measured by the Space Relations test gain scores, a large arithmetic difference (2.06) in means between the girls in the control group and the girls in the treatment group was evident as opposed to a small arithmetic difference (0.20) between the boys in both groups. This difference was not significant even though the figures may suggest a trend in favor of the girls' increased performance. The variance about these means were large and overlapped indicating that there was no clustering about the means; if the variances had been small a statistically significant difference would have been obtained.

A summary of the entire study, conclusions, discussion, and implications will be presented in Chapter V.

CHAPTER V

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Summary of the Study

This study, in an attempt to place some focus on the learning and instruction of pictorial communication in industrial arts, applied Jean Piaget's conceptual theory of space and geometry to the instruction of orthographic projection. The purpose of the study was to examine the teaching of the concepts of point, line, plane and form as they appeared in three-view orthographic drawing through the use of a series of puzzles and games.

Previous research had shown that the learner's sensory-motor and infralogical systems, as defined by the Piagetian theory, needed to be stimulated and that a systematic and sequential program of tasks could facilitate the cognition of the concepts being taught. The following hypotheses were formulated in order to investigate the process of learning and the application of the theory:

Competency in the perception and cognition of the orthographic projection of objects is dependent upon the stimulation of the sensory-motor and infralogical development systems of Piaget's theory.

The perception and cognition of the orthographic projection of objects is facilitated through a systematic and sequential program of concepts based on a hierarchy of task complexity.

It was assumed in the formulation of the above hypotheses that:

The constructs of the theory of space and geometry are identical to the constructs of the learner's psychological development.

The geometrical constructs used in the orthographic method are identical to the constructs of the learner's psychological development of space concepts.

A review of the learning theory and the orthographic projective system indicated that both dealt with the presentation and use of the concepts of point, line, plane and form. And further, that both the theory and the projection system followed the line of classic construction in geometry: topological, projective, Euclidian.

A review of the literature in the areas of philosophy, theory, and curricular content provided the rationale for the study. Immanuel Kant's position of utilizing the interaction of percept and concept in the content and methods of education formed the philosophical basis for the study. Piaget's theory, essentially Kantian in nature, provided a psychological view upon which to operationalize the philosophical base. The relationship between the theory and the method of orthographic projection was examined and furnished a foundation upon which to prepare materials to teach the concepts. The use of puzzles and games was examined with respect to their

providing a means by which the theory could be applied to the instruction of the concepts in question. Research had shown that puzzles and games were a valid method of presentation. It was also shown that the games would allow for the theory to be tested on the basis of previous research models which indicated that a systematic and sequential interaction with the concepts could stimulate and facilitate learning.

The industrial arts program of the East Lansing, Michigan, middle schools was the setting for the research. The sample was drawn from the Industrial Arts - I classes in the two schools and consisted of 163 students, 95 boys and 68 girls. The design involved two groups, one experimental and the other a control treatment. They were defined as follows:

Stimulation of the sensory-motor and infralogical systems by direct interaction with an ordered presentation of the orthographic projection concepts.

A control group receiving no presentation of the orthographic projection concepts.

Within the experimental group four testing treatments were used to assess facilitation through the systematic and sequential presentation of the concepts. The tests used to provide the measures for the dependent variables were the Space Relations test and the Visualization Test. The specific variable used was the gain score on each instrument. A third measure, the Gates-MacGinitie Reading Tests, Survey - E, was used to provide data on the

relationship between reading performance and performance on the spatial and visualization tests.

Conclusions

As a result of the analysis of the data in testing for the hypotheses specific to the factors in the study the following conclusions were made:

1. The factor of treatment had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.
2. The factor of group had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.
3. The factor of sex had no effect on the stimulation of the sensory-motor and infralogical systems with respect to the perception and cognition of the orthographic projection of objects.
4. The factor of group had no effect on facilitation through the systematic and sequential programming of the concepts as based on the hierarchy of task complexity in the puzzles and games.
5. The factor of sex had no effect on the facilitation through the systematic and sequential programming of the concepts as based on the hierarchy of task complexity in the puzzles and games.
6. Reading performance is significantly correlated to performance on the measures of space relations and orthographic visualization.

Discussion

The study indicates that the stimulation of the sensory-motor and infralogical systems did not occur under

the conditions and treatments in the design. The analysis indicated that the teacher and the teaching environment did not influence performance in regard to the stimulation of the systems. The results also showed that there were no sex related differences in the setting or the design.

The Piagetian theory is stage specific and these results suggest that the subjects in the population and sample were not at the point where the systems in question could be stimulated or that the systems were already stimulated. Piaget does give some indication of age levels at which the learner changes from one stage (system) to the next but he does not see age levels as specific in the growth process. Age as a factor was not included in the design because of the homogeneity of the variable in the population and sample. There have been suggestions by researchers that the cultural setting may influence the point in time when a child goes from one stage to the next. The nature of the American culture and that of the French-Swiss atmosphere upon which the theory was first researched could be indicative of some difference between the ages posited by Piaget and the ages at which American children reach specific stages. This cultural factor and the homogeneity of age in the sample could be conflicting and need to be considered in the area of stimulation of the systems and the change from stage to stage.

The facilitation of learning the concepts through the puzzles and games seemed to progress at a rate which

was constant for each of the separate presentations of the concept sequences. The data suggests that there was no influence due to the factors of group or sex in this area. The indication of no group differences also suggests that the teacher or the teaching environment did not have an effect on the learning of the concepts. As in the area of stimulation the factor of age was not included in the design. The same conflicting cultural settings as discussed above may also be a factor in the area of facilitation.

The non-significance of the factor of group, which included both teacher and teaching environment, in the experimental and control treatments in the areas of stimulation and facilitation suggests that the materials used are not influenced by these factors. Research in the area of teacher effectiveness and teaching methods often indicates that these two factors tend to confound the results of any study which includes them. It is suggested by these results that the materials can be used in a variety of learning environments and by a diversity of teaching personalities.

The significant correlational relationship between reading test performance and the performance on the spatial and visualization tests suggests that consideration be given to the reading abilities of students in the instruction of orthographic projection. A causal relationship between these factors would lend strength to this suggestion.

The data does suggest that the factor should not be discounted until the causal relationship is established or discounted in further research.

Implications of the Study

The empirical results in this study imply that the use of materials such as puzzles and games may have just as much effect on the development of the concepts as do other methods of presentation. This suggests that the use of these materials be considered as a tool in the instruction of orthographic projection in industrial arts programs.

Sex, teacher, and teaching environment, as non-significant factors in the learning of the concepts, implies that materials such as those used in the study can be applied in reaching instructional goals pertaining to the learning of concepts in the area of orthographic projection without these factors influencing the attainment of the instructional objectives.

Implications for Research

The conclusions and implications of this study provide a foundation for further hypothesizing with regard to a number of factors in teaching orthographic projection concepts on the basis of the Piagetian theory and the use of puzzles and games as a means to implement instruction. The theory and the materials used in this study are one means by which an empirical method, or way of looking at the phenomena, can be employed in gathering evidence

related to instruction in the industrial arts-lab-classroom. Age, sex, teacher, and teaching environments are all factors that need to be considered in the development of continued research.

The range of ages in further studies needs to be expanded. According to the Piagetian view the infralogical system of the learner starts its development at about age seven and the formal system of abstraction reaches into adolescence. Populations and samples would need to include a range of ages starting at seven years and ending at about sixteen or seventeen years.

In this study no direct teacher interaction with the materials was used. The use of the materials supplemented by the teacher presentation of the concepts deserve consideration in future research design. The same holds true for the teaching environment. Here too consideration needs to be given to the setting in which the materials are used.

Comparative study of the current methods used in teaching the concepts and the methods used in this research needs to be examined across the factors controlled for and those of age, teacher supplementation, and teaching environment.

Reading ability as a contributing factor in the learning of the concepts needs to be examined. The correlational relationship between the reading test performance and the ability to deal with the printed word needs to be

included as a variable in further studies. The establishment of a causal relationship between these variables, or the discounting of such a relationship, would seem to be of some importance in further theorizing in this area.

The length of the time period used in this study covered eleven weeks of scheduled presentations and testing. Further research should consider this factor.

Shortening the period of time used to present the concepts may provide different information of the effect of these materials on the stimulation and facilitation theory as well as upon the other factors considered in the study.

The time factor was also used to help control for the problem of test sophistication while presenting the total set of concept groupings. In further research consideration should be given to the separation of the concepts into single groups; on this basis each single concept group would be dealt with as was the total grouping in this investigation.

Sex related differences were not indicated as being significant in the stimulation of the sensory-motor and infralogical systems. This factor, as mentioned above, should be considered further. The Piagetian theory does not focus on the differences in how the sexes develop cognitively. Research based on other theories suggests that learning patterns may be associated with sex and/or sex role identification. Appropriate designs to test hypotheses in this area could provide information about this topic.

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APPENDIX

ORTHOGRAPHIC PROJECTION GAMES

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Orthographic
Projection
Games

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ORTHOGRAPHIC PROJECTION GAMES

Introduction

The Orthographic Projection Games were an outgrowth of games designed as part of a doctoral seminar on instructional simulation during winter term, 1970, at Michigan State University. The purpose of the original games was to incorporate a learning theory into a game or simulation which would meet a specific instructional objective. The instructional objective in this case was in the area of teaching industrial arts students about the concepts involved in technical or mechanical drawing.

Games--Definition and Development

In the design of instructional games three factors are considered to be essential: competition, pay-off, and arbitrary rules. These factors, both individually and collectively, contribute to the player's motivation. The degree to which the factors of the game accommodate real-life emotional needs of the player determines the amount of his or her involvement. The competition in a game can be against persons and/or criteria; a combination of both provides for the employment of the individual's ability

and chance. The concept of sinning, pay-off, is also hinged on the individual's ability and chance; if chance is not present in a game, players, because they lack certain skills, will become frustrated and give up on the game. The statement of arbitrary rules, in contrast to natural dynamics, provides for the inclusion of chance and a foundation upon which competition can exist. When the factors are not considered in relationship to player skill and need the game will be rejected.

Twelker in an article¹ on simulation systems provides a model for viewing how a game operates and the steps to develop games for instructional purposes.

This model upon which games can be viewed calls for a definition and statement of the manageable aspects of reality in a given situation. The relationship of these aspects is then determined and an experience in the form of a game is built around the relationship. Rules, props, constraints, and other techniques are used to get the players to interact with the definable, manageable, aspects in an experience which provides an opportunity to learn about the given situation.

The steps used in developing a game fall into three phases: determination of what is to be taught; determination of how it might be taught; and validation of the resultant teaching system.

¹Twelker, "Designing Simulation Systems," pp. 64-70.

In determining what to teach the developer begins by defining an instructional problem. From this one proceeds to describing the educational system in which the problem exists. Relating the problem to the system is the next step; in some cases this may require a re-definition or restructuring of the problem. Once the relationship of the problem and the educational system is established behavioral objectives are specified as a means to make explicit the outcomes desired in the solution to the problem. Criterion measures are also established at the same time so that an assessment about learning can be made after some specified activity has taken place. The first phase is essentially that which most teachers go through in providing for the instructional needs of their students. The next two phases provide a departure from the more traditional methods employed in instruction.

Attention on how certain behaviors might be taught, the second phase, focuses on the determination of an appropriate type of game or simulation which will bring about the desired behavior. Specifications for the game are developed after the type of activity and interactions needed for the behavioral changes are ascertained. This requires the isolation of the concepts, or aspects of reality, with which the player-learner must interact in order to demonstrate the behavior criterion set down in the first phase of development.

The third phase provides for the development and testing of the proposed game. A prototype game is developed and a limited tryout is performed to gather information about the functioning of the game in an educational setting which fits the description of the setting defined in phase one. Feedback from the tryout is then incorporated into the design; rules and chance probabilities are adjusted and artifacts redesigned so as to insure that the stated objectives are being met. From the modification then comes a game which is ready to be tested in the field. Field testing serves as a means to try the game to see how it holds up under the conditions for which it was designed. Data collection at this point then provides a basis for further adjustments and an indication of whether the desired objectives have been attained when the game is being used on a full scale basis.

Orthographic Projection Games Development

The instructional problem for which the Orthographic Projection Games were developed was that of teaching eleven, twelve, and thirteen year old students the concepts related to working with technical or mechanical drawings in industrial arts classes. The educational setting for this problem was in middle or junior high school industrial arts programs. In most cases, students in these programs were required to learn not only the concepts involved but also the motor skills necessary to actually make a mechanical drawing. Research had shown that those motor skills needed

for making drawings were only beginning to be developed for this age group. It was determined that an alternative method, divorcing the motor performance from the cognitive aspects of learning, might facilitate learning the concepts.

Instructional objectives for the problem were then stated. They were two, one the converse of the other:

1. Given a three-dimensional form the learner will be able to recognize a two-dimensional representation, as is presented in an orthographic projection, of that given form.
2. Given a two-dimensional representation, as presented in an orthographic projection, of a given form the learner will be able to recognize that given form in three dimensions.

The nature of the learners involved with these objectives indicated that some form of play or game activity might be an appropriate method of motivating an interaction with the concepts in reaching the desired behavior. A learning theory, that of Jean Piaget, was selected as a model for setting up a relationship between the various aspects of the realities of orthographic projection. Piaget's theory dealt with the concepts of points, lines, planes, and forms in a specific hierarchy of learning; orthographic projection concerned itself with the description of these same concepts in a specific manner. The organization of the concepts along the lines of the psychological theory and the provision for the interaction of these concepts with the

orthographic system was determined to be a proper basis for the development of a series of games.

A series of puzzles, both two and three-dimensional, and card games were the result of the problem statement and analysis. The first and second games in the series were in the form of three-dimensional tic-tac-toe. Games four and five were pencil and paper versions of the first and second games. Game five was the first card game and it introduced the concept of the orthographic planes of projection; these projection planes dealt with the arrangements of the points and lines in the three dimensional puzzle of game one. All of the first five games concentrated on the concepts of points and lines.

The two remaining games, both card games, dealt with the concepts of lines-planes and planes-forms respectively. Game six concentrated on using the orthographic format to depict a square and circle in various positions in space. Game seven focused on depicting the solid forms of the sphere, cube, pyramid, prism, cylinder, and cone in the orthographic manner. Both games included either flat planar shapes cut from cardboard (game six) or the solid objects (game seven) so that the players might handle and manipulate the objects during play.

The puzzles and card games were then tested on a small number of middle school students who played the games in small groups. Close observation was kept on the difficulties that arose in this play. A small group of adults

was also involved in playing with the puzzles and card games. The observations from the student use and the criticisms of the adults resulted in a change of rules, number of cards in a deck, and game format. After incorporating the changes into the games another test was run on a larger group of middle school students who played the games as part of their regular industrial arts program. This resulted in a few minor changes in scoring the card games. With this second trial the games were considered developed well enough to test their ability to conform to the Piagetian learning model and to stand alone as a means of instruction.

Summary

Outlined above was a definition, model and steps for the development of instructional games. A description of the development of the Orthographic Projection Games which followed that outlined definition, model and steps was then presented. In the remaining pages are included the rules of play, pictures and diagrams of the puzzles and games.

GAME 1PLAYERS

TWO

ARTIFACTS

A 5x5x5 MATRIX MADE OF PLASTIC AND COLORED MARKERS (CHIPS, MARBLES, OR BEADS).

OBJECT OF PLAY

TO MAKE A STRAIGHT LINE COMPOSED OF FIVE MARKERS ON THE GAME MATRIX. VERTICAL, HORIZONTAL, AND DIAGONAL LINES ARE ALL POSSIBLE.

THE PLAY

EACH PLAYER PLACES MARKERS IN THE MATRIX. TURNS ALTERNATE. THE FIRST PLAYER TO GET FIVE MARKERS IN A STRAIGHT LINE WINS.

GAME 2PLAYERS

TWO

ARTIFACTS

A BOARD WITH TWENTY-FIVE PEGS ARRANGED IN
A SQUARE, FIVE PEGS BY FIVE PEGS. 125
BEADS, SIXTY-THREE LIGHT IN COLOR AND
SIXTY-TWO DARK IN COLOR.

OBJECT OF PLAY

TO MAKE STRAIGHT LINES COMPOSED OF FIVE
BEADS, OF THE SAME COLOR ON A PEG OR PEGS.
VERTICAL, HORIZONTAL, AND DIAGONAL LINES
ARE POSSIBLE.

THE PLAY

EACH PLAYER PLACES HIS BEADS ON THE PEGS.
TURNS ALTERNATE. PLAY STARTS WITH THE
PLAYER HAVING THE LIGHT COLORED BEADS.
THE PLAYER TO GET FIVE BEADS IN A STRAIGHT
LINE WINS. IN A SERIES OF GAMES THE WINNER
OF THE PREVIOUS GAME ALWAYS TAKES AND
STARTS WITH THE LIGHT COLORED BEADS.

GAME 3

<u>PLAYERS</u>	TWO
<u>ARTIFACTS</u>	PENCILS AND PRINTED MATRIX SHEETS
<u>OBJECT OF PLAY</u>	TO MAKE A STRAIGHT LINE OF FIVE MARKS (X's OR O's) ON THE MATRIX. THE MARKS MUST BE PLACED SO AS TO CONFORM TO A STRAIGHT LINE OF MARKERS ON THE MATRIX USED IN <u>GAME 1</u> . THE <u>GAME 1</u> ARTIFACTS SHOULD BE AVAILABLE FOR THE PURPOSE OF VERIFICATION OF THE LINES.
<u>THE PLAY</u>	EACH PLAYER MARKS (X's OR O's) IN THE MATRIX. TURNS ALTERNATE. THE FIRST PLAYER TO GET FIVE MARKS (X's OR O's) IN A STRAIGHT LINE WINS.

GAME 4

<u>PLAYERS</u>	TWO
<u>ARTIFACTS</u>	PENCILS AND THE PRINTED MATRIX SHEETS USED IN <u>GAME 3</u> .
<u>OBJECT OF PLAY</u>	TO MAKE A STRAIGHT LINE OF FIVE MARKS (X's OR O's) ON THE MATRIX. THE MARKS MUST CONFORM TO A STRAIGHT LINE OF BEADS ON THE PEGBOARD USED IN <u>GAME 2</u> . THE BOARD AND BEADS SHOULD BE AVAILABLE FOR THE PURPOSE OF VERIFICATION.
<u>THE PLAY</u>	PLAY MUST FOLLOW THE SAME APPROACH USED FOR THE STACKING OF BEADS IN <u>GAME 2</u> . PLAY STARTS ON THE BOTTOM LEVEL OF THE MATRIX AND WORKS UP. A MARK CAN BE PLACED IN ANY LEVEL OF THE MATRIX WHEN THE CORRESPONDING SPACE IN THE LEVEL IMMEDI- ATELY BELOW ALREADY CONTAINS A MARK.

GAME 5PLAYERS

TWO TO FOUR

CARDS

ONE PACK OF 45 CARDS. THE DECK IS DIVIDED INTO THREE SUITS, 15 CARDS TO THE SUIT. EACH SUIT CORRESPONDS TO ONE OF THE PROJECTION PLANES IN ORTHOGRAPHIC PROJECTION. A 5 x 5 MATRIX IS PRINTED ON THE FACE OF THE CARD. A ROW OF FIVE DOTS OR POINTS IS PLACED IN VARIOUS POSITIONS WITHIN THE MATRIX. THREE CARDS IN EACH SUIT ARE WILD CARDS FOR THAT SUIT. THESE WILD CARDS CAN BE USED TO REPRESENT ANY ONE POINT ON THE MATRIX OR A SERIES OF FIVE POINTS IN A STRAIGHT LINE ON THE MATRIX WHEN VIEWED FROM THAT PLANE.

DEALING

CARDS ARE DEALT ONE AT A TIME, TO THE LEFT, BEGINNING WITH THE PLAYER ON THE DEALER'S LEFT. EACH PLAYER RECEIVES SIX CARDS, THE REST OF THE PACK IS PLACED FACE DOWN TO FORM THE STOCK. THE TOP CARD IN THE STOCK IS TURNED UP AND STARTS THE DISCARD PILE.

IN TWO-HAND PLAY THE WINNER OF EACH HAND DEALS NEXT. WITH MORE THAN TWO PLAYERS THE DEAL ROTATES IN TURN TO THE LEFT.

GAME 5--continuedOBJECT OF PLAY

THE OBJECT IS TO FORM THE HAND INTO SETS. A SET IS A GROUP OF THREE CARDS, ONE FROM EACH SUIT. THE THREE CARDS IN THE SET MUST FORM AN ORTHOGRAPHIC REPRESENTATION OF A LINE CONTAINING FIVE DOTS WHEN THEY ARE PLACED ON THE TABLE. A MATRIX FROM GAME 1 CAN BE USED TO VERIFY THE SET IF THERE IS ANY DOUBT TO THE VALIDITY OF THE SET. IT SHOULD BE NOTED THAT THE MELDED SET MUST BE PLACED ON THE TABLE IN THE PROPER ORTHOGRAPHIC ARRANGEMENT, TOP ABOVE THE FRONT AND THE SIDE TO THE RIGHT OF THE FRONT.

THE PLAY

EACH PLAYER IN TURN MUST DRAW ONE CARD, EITHER FROM THE TOP OF THE DISCARD PILE OR THE TOP OF THE STOCK. HE MAY THEN MELD OR LAY DOWN ANY SET HE HOLDS. IF HE HAS MORE THAN ONE SET HE MAY MELD ALL IN THE SAME TURN. A PLAYER NEED NOT MELD WHEN ABLE, BUT MAY KEEP A SET IN HIS HAND. TO COMPLETE A TURN THE PLAYER MUST DISCARD ONE CARD, FACE UP, ON THE DISCARD PILE. THE FIRST PLAYER TO GET RID OF ALL HIS CARDS BY MELDING WINS THE DEAL AND PLAY ENDS. A PLAYER GOES OUT BY MELDING ALL BUT ONE CARD. THIS CARD IS PLACED ON THE DISCARD PILE.

GAME 5--continuedSCORING

EACH OTHER PLAYER PAYS THE WINNER THE COUNT
OF ALL CARDS LEFT IN HIS HAND. A WILD
CARD COUNTS THREE POINTS, A VERTICAL OR
HORIZONTAL CARD COUNTS TWO POINTS AND A
DIAGONAL CARD COUNTS ONE POINT IN SCORING.
A GAME IS FIFTY POINTS.

GAME 6PLAYERS

TWO TO FOUR

CARDS

ONE PACK OF 42 CARDS. THE DECK IS DIVIDED INTO THREE SUITS, SIXTEEN CARDS TO THE SUIT. EACH SUIT CORRESPONDS TO ONE OF THE PROJECTION PLANES IN ORTHOGRAPHIC PROJECTION. ON THE FACE OF EACH CARD IS PRINTED ONE OF THESE SIX FIGURES OF LINES: CIRCLE, SQUARE, 45° ELLIPSE, 1: 1.414 RECTANGLE, STRAIGHT LINE, 45° DIAGONAL LINE.

DEALING

CARDS ARE DEALT ONE AT A TIME, TO THE LEFT, BEGINNING WITH THE PLAYER ON THE DEALER'S LEFT. EACH PLAYER RECEIVES SIX CARDS. THE REST OF THE PACK IS PLACED FACE DOWN TO FORM THE STOCK. THE TOP CARD IN THE STOCK IS TURNED UP AND STARTS THE DISCARD PILE.

IN TWO HAND PLAY THE WINNER OF EACH HAND DEALS NEXT. WITH MORE THAN TWO PLAYERS THE DEAL ROTATES IN TURN TO THE LEFT.

OBJECT OF PLAY

THE OBJECT IS TO FORM THE HAND INTO SETS. A SET IS A GROUP OF THREE CARDS, ONE FROM EACH SUIT. THE THREE CARDS IN THE SET MUST FORM AN ORTHOGRAPHIC REPRESENTATION OF A PLANE SHAPE (CIRCLE OR SQUARE), THE CARDS MUST BE MELED IN THE PROPER ORTHOGRAPHIC ARRANGEMENT. THE SHAPES THAT CAN BE FORMED ARE EITHER A CIRCLE OR A SQUARE. THESE TWO

GAME 6--continued

SHAPES, CUT FROM HEAVY PAPER OR MADE OF PLASTIC, SHOULD BE AVAILABLE TO THE PLAYERS FOR VERIFICATION OF MELDED SETS.

THE PLAY

EACH PLAYER IN TURN MUST DRAW ONE CARD, EITHER FROM THE TOP OF THE DISCARD PILE OR THE TOP OF THE STOCK. HE MAY THEN MELD OR LAY DOWN ANY SET HE HOLDS. IF HE HAS MORE THAN ONE SET HE MAY MELD ALL IN THE SAME TURN. A PLAYER NEED NOT MELD WHEN ABLE, BUT MAY HOLD A SET IN HIS HAND. TO COMPLETE A TURN THE PLAYER MUST DISCARD ONE CARD, FACE UP, ON THE DISCARD PILE.

THE FIRST PLAYER TO GET RID OF ALL HIS CARDS BY MELDING WINS THE DEAL AND PLAY ENDS. A PLAYER GOES OUT BY MELDING ALL BUT ONE CARD; THIS CARD IS PLACED ON THE DISCARD PILE.

SCORING

EACH OTHER PLAYER PAYS THE WINNER THE COUNT OF ALL OTHER CARDS IN HIS HAND. CIRCLES AND SQUARES COUNT ONE POINT. ALL OTHER CARDS COUNT TWO POINTS. A GAME IS 100 POINTS.

GAME 7PLAYERS

TWO TO FOUR

CARDS

ONE PACK OF 45 CARDS. ON THE FACE OF EACH CARD IS PRINTED ONE OF FIVE SHAPES: CIRCLE, SQUARE, ISOSCELES TRIANGLE, A SQUARE WITH TWO DIAGONALS, A SQUARE WITH A PERPENDICULAR BISECTOR.

DEALING

CARDS ARE DEALT ONE AT A TIME, TO THE LEFT, BEGINNING WITH THE PLAYER ON THE DEALER'S LEFT. EACH PLAYER RECEIVES SIX CARDS. THE REST OF THE PACK IS PLACED FACE DOWN TO FORM THE STOCK. THE TOP CARD OF THE STOCK IS TURNED UP AND STARTS THE DISCARD PILE.

IN TWO HAND PLAY THE WINNER OF EACH HAND DEALS NEXT. WITH MORE THAN TWO PLAYERS THE DEAL ROTATES IN TURN TO THE LEFT.

OBJECT OF PLAY

THE OBJECT IS TO FORM THE HAND INTO SETS. A SET IS A GROUP OF THREE CARDS. THE THREE CARDS IN THE SET MUST FORM AN ORTHOGRAPHIC REPRESENTATION OF A SOLID. THE CARDS MUST BE MELDED IN THE PROPER ORTHOGRAPHIC ARRANGEMENT. THE SOLIDS FORMED CAN BE ANY OF THE FOLLOWING: SPHERE, CUBE, CYLINDER, PYRAMID, TRIANGULAR PRISM, CONE. A SET OF THESE SOLIDS SHOULD BE AVAILABLE FOR PLAYERS TO VERIFY VIEWS PRESENTED IN THE MELDED SETS.

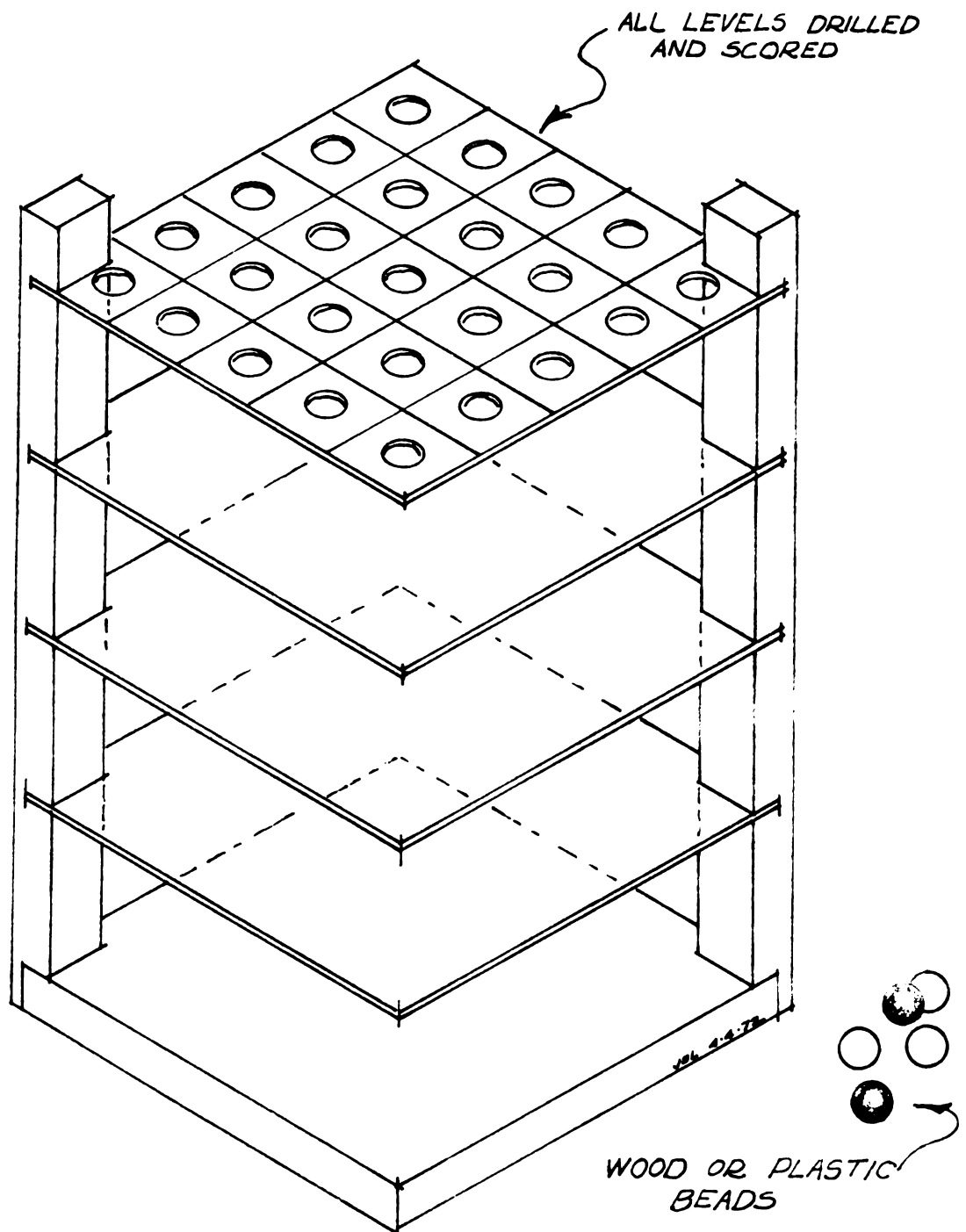
GAME 7--continuedTHE PLAY

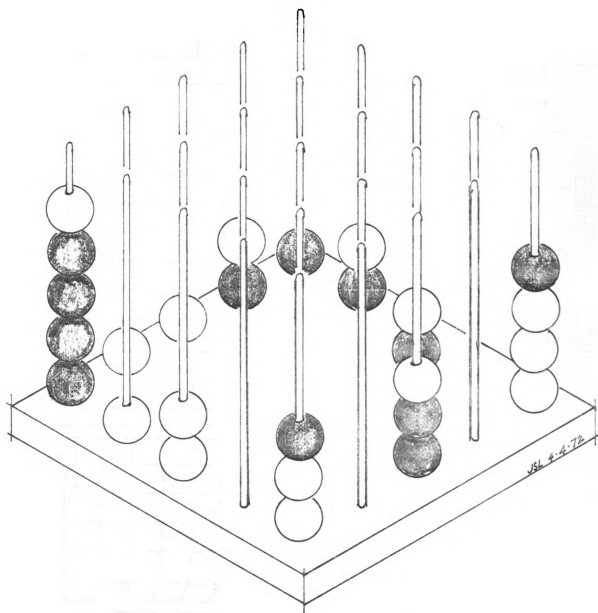
EACH PLAYER IN TURN MUST DRAW ONE CARD, EITHER FROM THE TOP OF THE DISCARD PILE OR THE TOP OF THE STOCK. HE MAY THEN MELD OR LAY DOWN ANY SET HE HOLDS. IF HE HAS MORE THAN ONE SET HE MAY MELD ALL IN THE SAME TURN. A PLAYER NEED NOT MELD WHEN ABLE, BUT MAY KEEP A SET IN HIS HAND. TO COMPLETE A TURN THE PLAYER MUST DISCARD ONE CARD, FACE UP, ON THE DISCARD PILE.

THE FIRST PLAYER TO GET RID OF ALL HIS CARDS BY MELDING WINS THE DEAL AND PLAY ENDS. A PLAYER GOES OUT BY MELDING ALL BUT ONE CARD; THIS CARD IS PLACED ON THE DISCARD PILE.

SCORING

EACH PLAYER PAYS THE WINNER THE COUNT OF ALL THE CARDS LEFT IN HIS HAND. A CARD CONTAINING A CIRCLE COUNTS THREE POINTS, A SQUARE FOUR POINTS, AN ISOSCELES TRIANGLE FIVE POINTS, A SQUARE WITH DIAGONALS ONE POINT, A SQUARE WITH A BISECTOR TWO POINTS. A GAME IS 100 POINTS FOR FOUR PLAYERS, 75 POINTS FOR THREE PLAYERS, AND 50 POINTS FOR TWO PLAYERS.

GAME -1

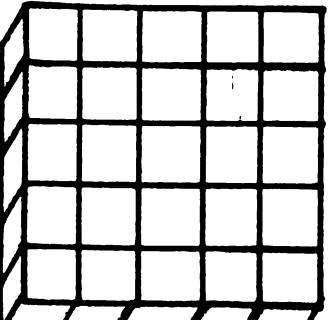
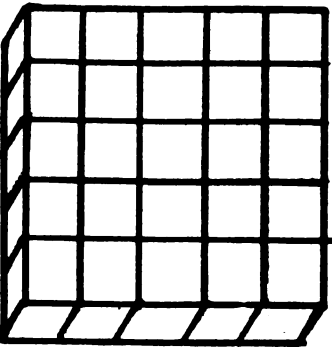
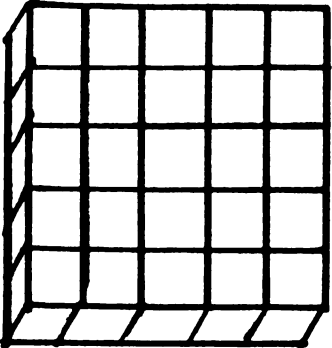
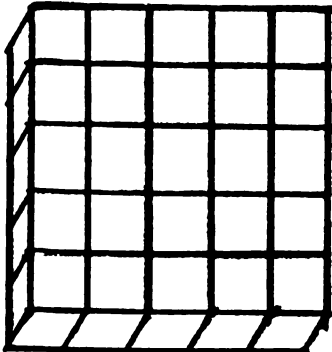
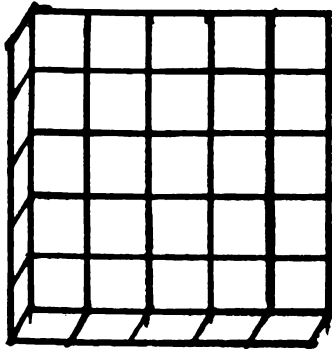
GAME - 2

CHECK ONE: GAME - 3GAME - 4

PLAYERS NAMES: 1. _____

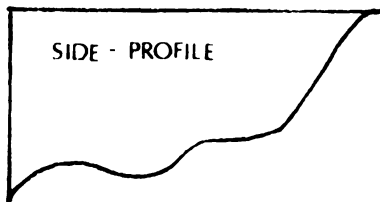
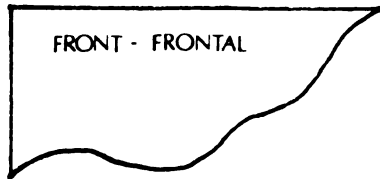
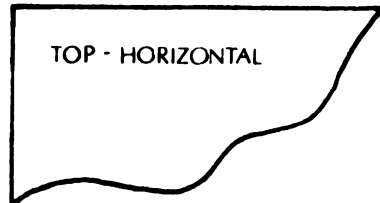
2. _____

SECTION: _____



GAME - 5

card faces



Fifteen cards in each
suit, 3 wild cards,
one each of all other
cards.

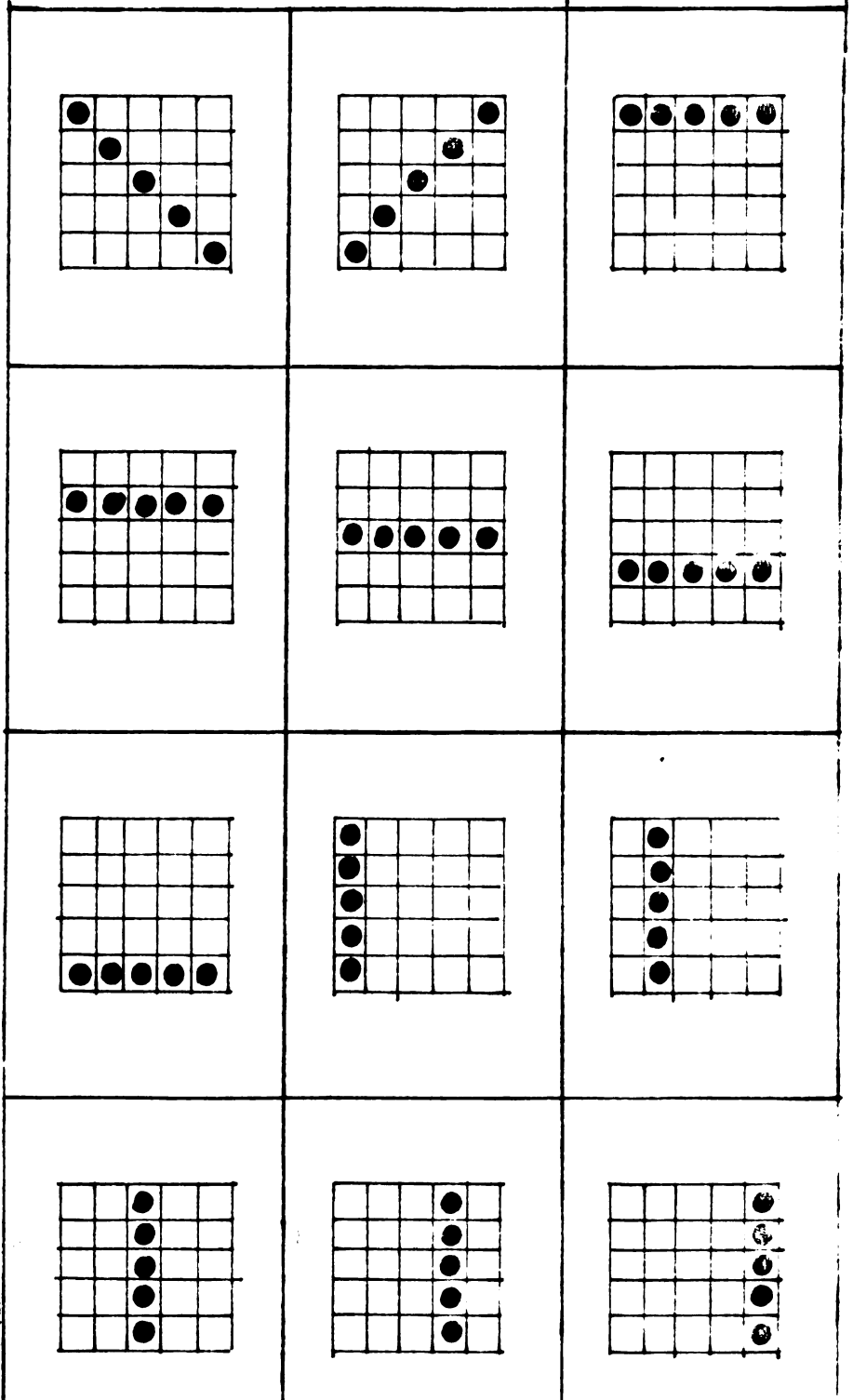
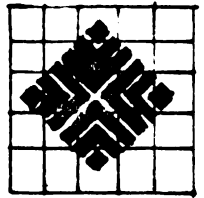
Each suit is printed
in a different color:

Top = Red

Front = Green

Side = Blue

Side - Profile



GAME - 6**card faces**

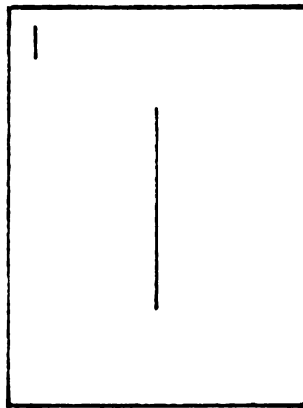
Each suit is printed in a
different color:

Top = Red

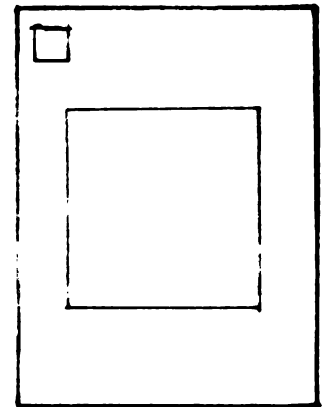
Side = Blue

Front = Green

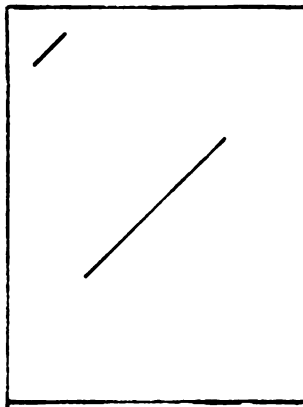
3 Red
3 Green
3 Blue



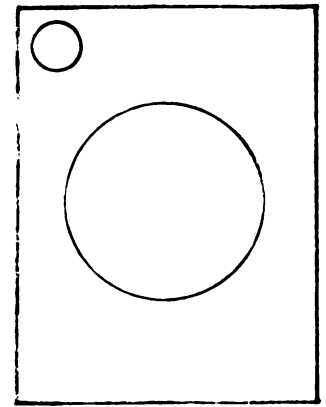
2 Red
2 Green
2 Blue



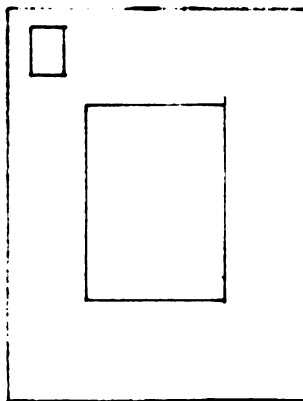
3 Red



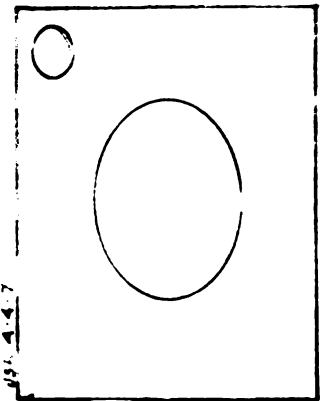
2 Red
2 Green
2 Blue



3 Red
3 Green
3 Blue



3 Red
3 Green
3 Blue

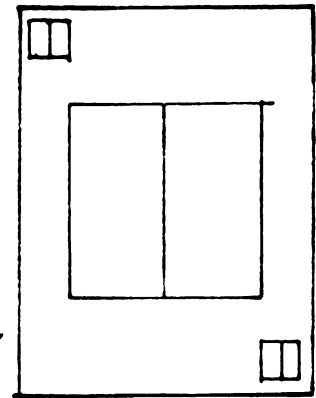


GAME - 7

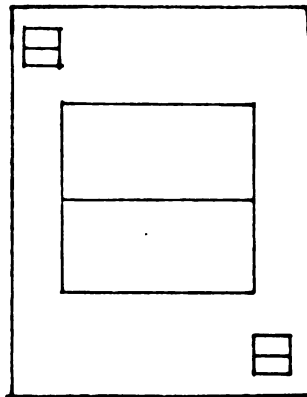
card faces

The cards in this deck are printed in black ink. There is no color code to denote suits. A card can be used for any view, top, front or side.

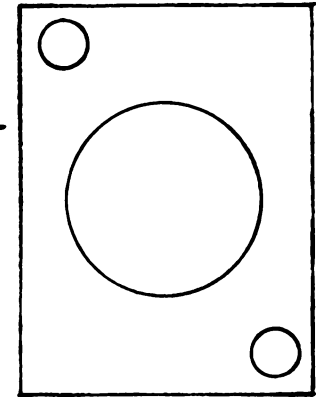
3 Cards →



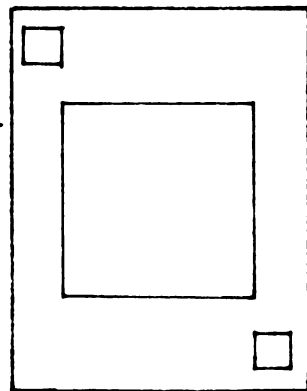
3 Cards →



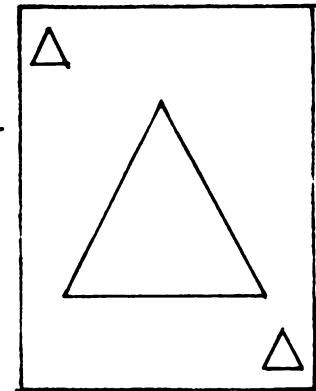
9 Cards →



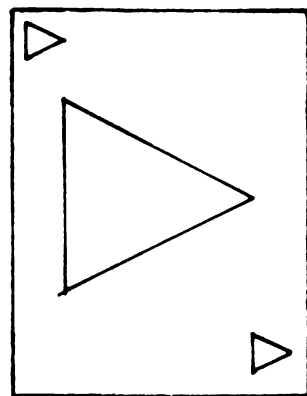
15 Cards →



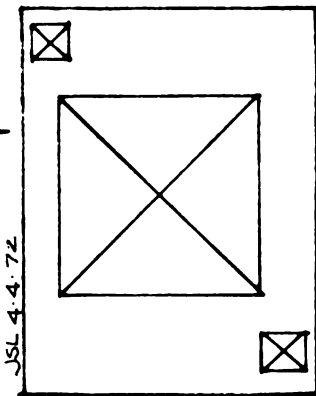
6 Cards →



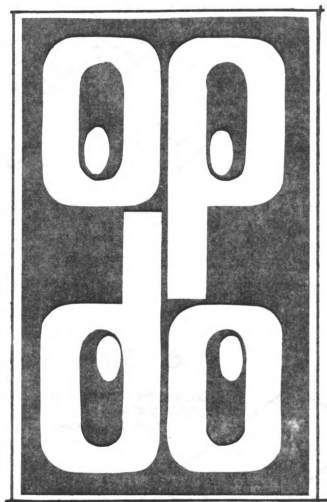
6 Cards →



3 Cards →



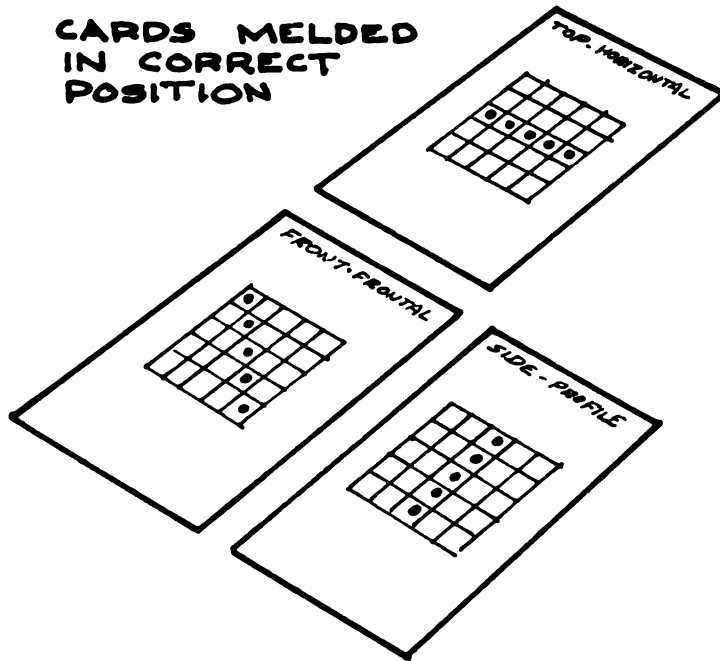
GAMES 5,6 & 7 **card back**



USL 1-4-72

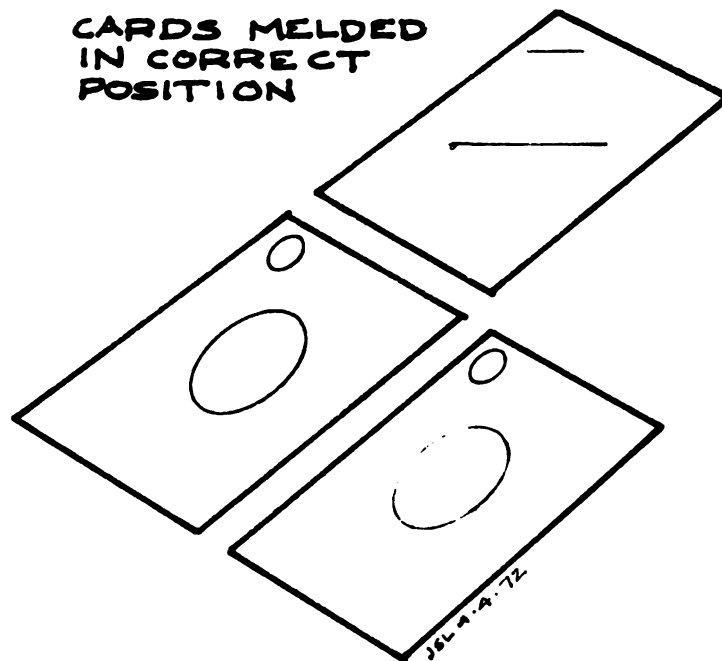
GAME - 5

CARDS MELDED
IN CORRECT
POSITION

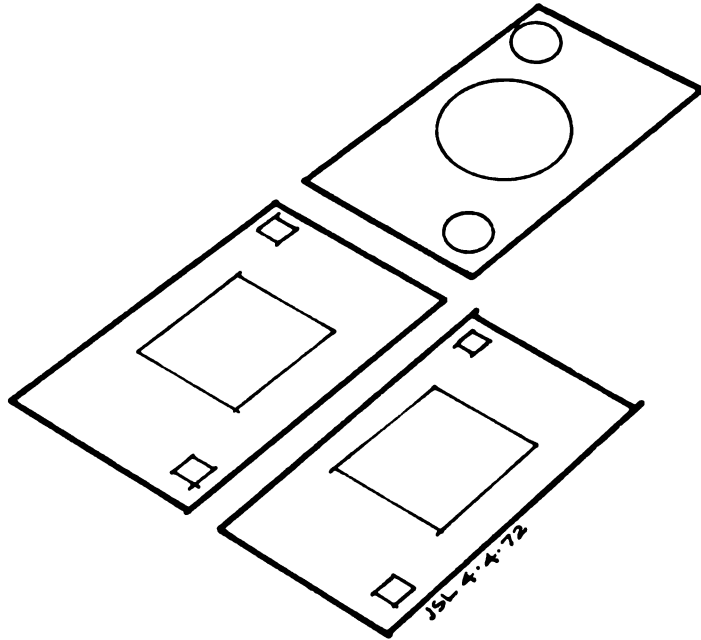


GAME - 6

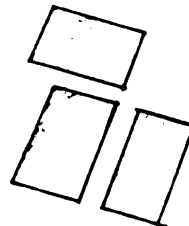
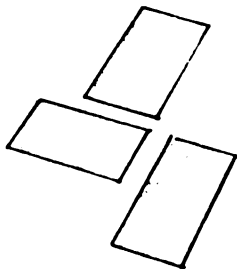
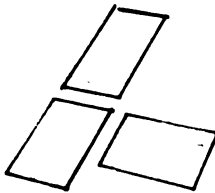
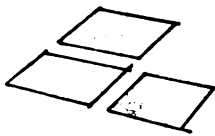
CARDS MELDED
IN CORRECT
POSITION



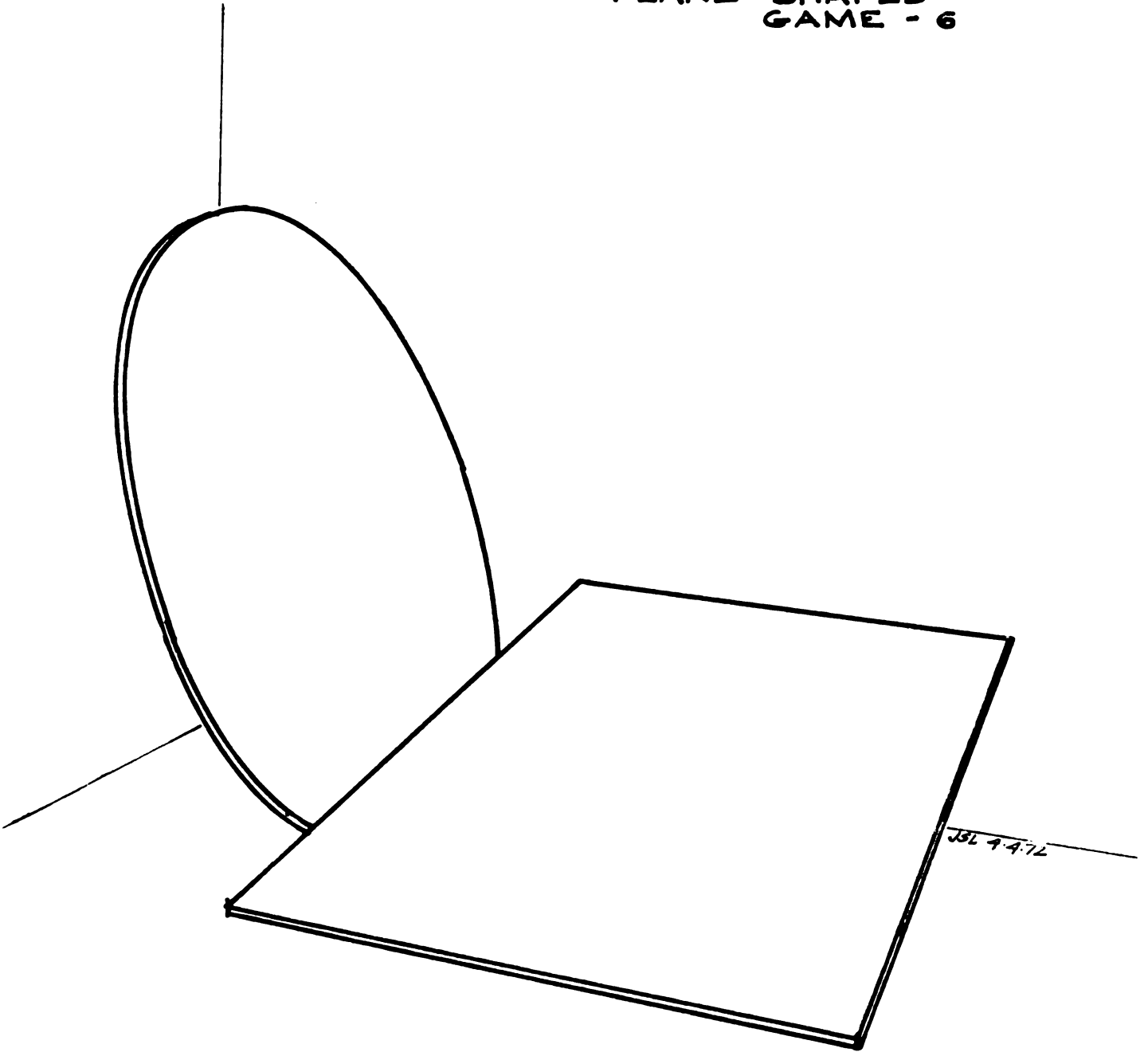
GAME - 7
CARDS MELDED
IN CORRET
POSITION



POSSIBLE WRONG POSITIONS
FOR ALL CARD GAMES



PLANE SHAPES
GAME - 6



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