AN ABSTRACT OF THE THESIS OF

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Title: A STUDY OF THE RELATIONSHIP BETWEEN THE ELEMENTARY SCIENCE STUDY UNIT ATTRIBUTE GAMES AND PROBLEMS AND THE DEVELOPMENT OF DIVERGENT-PRODUCTIVE THINKING IN SELECTED ELEMENTARY SCHOOL CHILDREN

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Abstract approved: ____________

Fred W. Fox

Acquisition of divergent-productive thinking skills by using elementary science materials constitutes the basic idea of this experiment. The data collected was used to determine statistically if the materials had a significant role in inducing such skills.

The Ss were fifth-grade students obtained from two public elementary schools in Oregon. Those Ss selected for the study were randomly assigned to control and experimental groups. Ss completed the experimental activity sessions in which they were seen for forty-five minutes on each of fifteen consecutive school days.

A series of twenty-six experimental activities comprised the treatment to which the experimental Ss were subjected. Divergent production of units, classes, relations, systems, transformations and

implications were an integral part of the activities.

The posttest consisted of Verbal Form A and Figural Form A of the Torrance Test of Creative Thinking. These were administered to the experimental Ss on two consecutive days following the treatment.

Student's t-test was performed on the T-scores for each of the seven categories, verbal fluency, verbal flexibility, verbal originality, figural fluency, figural flexibility, figural originality, and figural elaboration to determine whether or not a significant difference occurred in the experimental group.

Student's t-test was also applied to the composite scores of each group to determine whether or not a significant difference occurred between the means of the two groups.

Figural flexibility was found statistically significant beyond the .10 level. Figural originality was found statistically significant beyond the .05 level.

Among the recommendations stemming from this study are:

(1) Five- and six-year olds should be examined to determine whether or not the perceptual training of attribute blocks and subsequent divergent-productive thinking alters results obtained by Piaget indicating the age at which children think in a formal operational mode.

(2) Elementary school curricula utilize materials that lead to development of particular thinking-skill processes in varied content-oriented ways.

A Study of the Relationship Between the Elementary Science Study Unit Attribute Games and Problems and the Development of Divergent-Productive Thinking in Selected Elementary School Children

by

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To my wife, Audrey, and our children, Steve, Paul, and Ruth, go far more than mere words can express. Hopefully, the time taken from them while writing can be spent with them in the future.

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I. INTRODUCTION

Development of Elementary Science Materials

Contemporary development of elementary science programs such as the Elementary Science Study (ESS), Experiences In Science (EIS), and Science Curriculum Improvement Study (SCIS), have used as their approach to education one enabling children to learn things for themselves through being involved directly, being able to shape, change, manipulate, the subject matter they are studying, from playing with blocks to inquiring with microscopes. This approach seeks to foster inventiveness and initiative. It can be contrasted with an approach that treats education primarily as a kind of substance, as so much intellectual content, which is first in the teacher's head and then transmitted to the student's head. Selected from the three programs above will be the ESS materials.

Charles Walcott, on the staff of ESS, reaffirms a materials-centered, child-involved curriculum when he says (1965, p. 1),

> We can all agree that facts by themselves are not enough nor, by the same token, are processes, concepts, or any other single purpose approach. For science instruction in particular, all of these methods must be blended into a course of study that is recognizable science. This implies

> a program that provides real science through materials children can work with, problems they can investigate, and questions they can ask and find answers to for themselves.
>
> It is not enough to make marks on the blackboard or to talk a bit . . . The essential act of the scientist is abstraction . . . that act is his boldest and most difficult one. In it lie his errors as well as his victories, but it is exactly that action which the book, the lecture, the programmed text, never allow the student to share. Only the material can instruct in this process, and only the errors so made can lead to a real and a productive understanding.

The ESS materials were developed concomitantly with a search for answers to the questions that follow: 1. What do six to thirteen year-old children find interesting to explore?, 2. What kinds of materials and problems are able to inspire children to look at some part of the world with greater attention and care?, and 3. What sorts of questions, answers, organizational schemes, equipment, and the like turn out to be most effective in a variety of classrooms?

Each set of materials was trial tested and revised by many teachers and children in many socio-economic levels of society.

Attribute Games and Problems, invented and developed by William P. Hull, is one of the ESS units. The subject-matter of this unit is logic; but the emphasis is on developing problem-solving skills and attitudes. Students explore problems of classification and become skillful in dealing with the relationships between classes. Extensive attention will be given Attribute Games and Problems in the study which is to follow.

Psychological Bases of Elementary Science Materials

Of the contemporary psychological theories extant, those of J. P. Guilford, Professor of Psychology at the University of Southern California, and Jean Piaget, Swiss director of the Jean Jacques Rosseau Institute in Geneva, Switzerland, are paradigms of educational thought because they relate directly to a materials-centered, child-involved approach to education, and to this study.

Anderson, et al. (1970, p. 118), Karplus (1967, p. 20-21), and Thier (1970, p. 71), support teachers and other educators utilizing the results of Piaget's studies in helping to formulate curricula and elementary science materials. Hubbard (1967, p. 40), supports Guilford's model of the intellect as a means of explaining the basic structure of thinking.

One of the psychological factors of intellectual development about which Piaget writes is that of mental models. He says (1964, p. 280), "The ability to establish a mental model is based upon flexibility and persistence; fluidity of thinking . . . while rigidity hinders the correct solution." These same characteristics are consistent with Guilford's (1959) parametric model of the structure of intellect in which flexibility and non-rigidity constitute the category of divergent-productive thinking, a kind of thinking that goes searching or that takes different directions, the end result being a variety of possible solutions to the problem at hand.

Hull's analysis of the approaches to learning used by children shows that those who are most able exhibit a certain flexibility of mind with which they deal with more than one aspect of a problem without becoming confused. "A young child's thought," according to Hull (1958, p. 3), "has been called ego-centric because he cannot deal with more than one point of view at a time." Piaget has shown that skill in dealing with more than one point of view at a time is basic to advanced reasoning.

Part of being able to think in a divergent-productive manner (from Guilford's model) stems from the ability to form mental models and deal with more than one point of view at a time. Kuslan and Stone (1968, p. 55), tell of the importance of this when they say,

> The formation of mental models is important in transfer of learning because it makes possible the application of a consistent explanatory scheme to apparently unrelated phenomena. Until appropriate mental models are formed, children cannot understand the logical necessity of the phenomena they encounter.

Divergent-productive thinking is the ability to produce a variety of solutions when confronted with a problem. It stems from forming a mental model of the objects with which one is confronted and the resulting variety of approaches developed for an answer to the problem posed by the objects.

"The formulation of mental models," according to Kuslan and Stone (1968, p. 55),

> surely has implications for solving problems in science by reasonable and analytical modes of thought. Without a cognitive structure to which to relate the various aspects of the problem, the problem is inevitably left to the vagaries of trial and error.

Developing in children the ability to produce a variety of responses when confronted with problems is a perplexity facing science educators. Hull supports this statement by writing,

> A child whose learning is narrow and specific because of pressure for quick results will have difficulty when the memory load becomes too great ... It is much better strategy in the long run to have control over a few well-digested general ideas and a good sense of discrimination than it is to be burdened with a mass of poorly assimilated facts and a host of doubts as to their relevance or application.

Dienes (1970, p. 17) reaffirms this by stating,

> Young children learn best from their own ... experiences. The logical relationships that we might wish children to learn, should therefore be embodied in observable relationships between distinguishable attributes such as colour, shape, etc.

As early as 1934 Vygotsky (1962, p. 56), (a translation of an earlier work), suggested the use of blocks as a means of testing for logical thinking of which divergent-productive thinking is a part. Vygotsky's idea for using blocks lay dormant until Hull developed a block-sorting test using materials similar to Attribute Games and Problems, the unit which eventually evolved.

Guilford's Structure of Intellect

Guilford's work with organizing intellectual factors into a system lead him to developing a theory of human intelligence based upon a structure of intellect model utilizing three parameters: content, operation, and product as depicted in Figure 1.1 below.

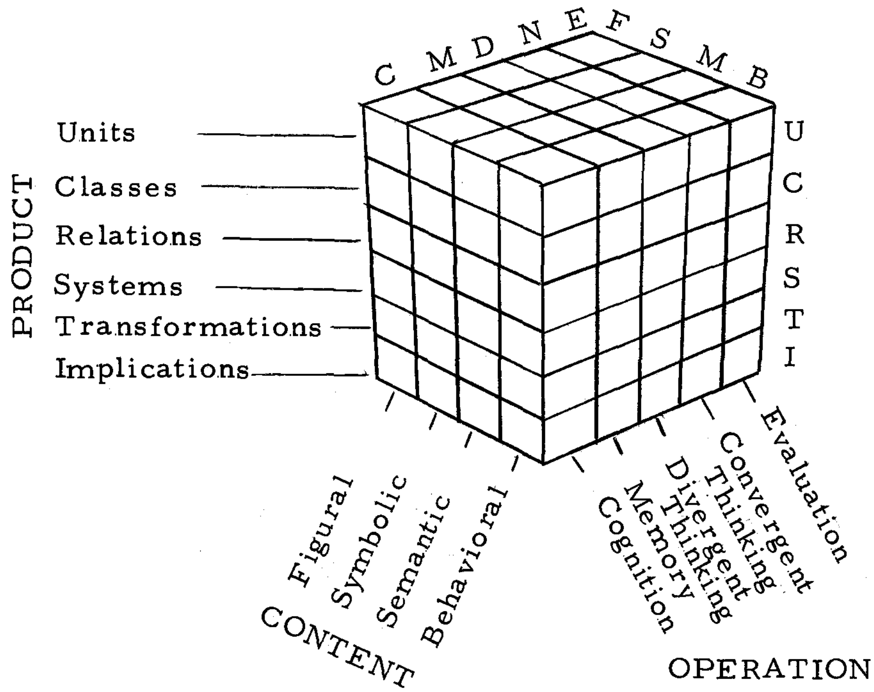


Figure 1.1. Guilford's morphological model of the structure of intellect. (After Guilford, 1959).

This model allows the placement of any intellectual factor within it by determining the factor's three unique properties. The factor might be cognition of figural units, or divergent production of symbolic systems, etc.

The advantage of Guilford's model of the intellect is that it organizes the intellectual factors into a unitary system that is empirically based. It also allows for factor analysis to be made of a matrix of intercorrelations of the factors selected.

For translating Figure 1.1 into science-teaching terms, see Appendix I.

Problem Solving and Creative Production

Two of the most complex intellectual activities are problem solving and creative production which have much in common and can be considered as basically the same phenomenon. As stated by Guilford (1967, p. 312),

> There is something creative about all genuine problem solving, and creative production is typically carried out as a means to the end of solving some problem. Both activities entail transfer recall; if only replicative recall were involved, there would be no problem solving and nothing creative about the behavioral event.

According to Guilford (1967) and Merrifield, _et al._ (1962), ". . . . multivariate experiments involving recognized problem-solving tasks fail to find a unitary dimension that can be called problem-solving ability." Some of the factors that have been identified with problem-solving and creative production abilities are verbal comprehension, conceptual foresight, originality, and semantic elaboration.

From the following matrix of divergent-production factors represented in the structure of intellect one can envisage each cell. The 4 columns represent the 4 kinds of content and 6 rows for the 6 kinds of products. Referenceto Figure 1.1 will show this kind of matrix. Each of the 24 cells represents the single factor, divergent production. Each cell has a trigram symbol that stands for its unique combination of operation, content, and product, symbolized in that order. Thus, DFU stands for divergent figural units, and DMS stands for divergent semantic systems.

CONTENT				
Figural (F)	Symbolic (S)	Semantic (M)	Behavioral (B)	PRODUCT
DFU	DSU	DMU	DBU	Units (U)
DFC	DSC	DMC	DBC	Classes (C)
DFR	DSR	DMR	DBR	Relations (R)
DFS	DSS	DMS	DBS	Systems (S)
DFT	DST	DMT	DBT	Transformations (T)
DFI	DSI	DMI	DBI	Implications (I)

Figure 1.2. Matrix of the divergent-production factors (D) represented in the structure of intellect.

A review of the literature shows that most workers in the field are concerned with testing the general category of intelligence. Prior to Guilford's structure of intellect theory various factors were not delineated. With the advent of structure of intellect theory, research in the field has been guided in a more precise manner.

This writer proposes to use the matrix in Figure 1.2 to delineate the categories involved in teaching divergent-productive thinking using the Attribute Blocks portion of the ESS unit Attribute Games and Problems. It will be by comparing empirical results with the matrix cells that acceptance or rejection of a basic hypothesis will be done.

The Importance of Divergent-Productive Thinking

Productive thinking takes place when new ideas emerge from information a person has gathered. This generation of new information can be classified into two categories: convergent-productive and divergent-productive thinking. Both are essential for the fullest intellectual functioning, especially in science education. Convergent thinking is the searching for single answers or 'right' answers as often implied in elementary arithmetic problems. Divergent thinking as defined previously causes one to search or take different directions in arriving at what may be several answers to a problem. Divergent-productive thinking has no predictable outcome.

Guilford (1967, p. 162), hypothesizes that recognized groups of productive people, writers, scientists, inventors, mathematicians, artists of various kinds, and manipulators of people, utilize divergent-productive factors in their daily life to realize their goals and achievements. Jones (1960), and Kincaid (1961), found significant correlations in small samples of art students and 46 adults. Fisichelli and Welch (1947) found art majors to be significantly higher in DMS than were unselected students. Torrance (1962), showed that when a high divergent-productive child is placed to work on a problem in a group of five, the other four being lower, the high divergent-productive child initiates ideas far out of proportion.

It would seem to this writer that being able to teach divergent-production factors in some way would facilitate the acquiring of such skills or of further developing them in an individual.

Maltzman (1960) and Mednick (1962) both assert the position that "original thinkers" can be made or the ability in a person increased. Ray (1967) further supports the hypothesis that 'original thinking' as he defines it can be developed.

If, as Hull (1958) suggests, a child's habits and thinking styles along with his attitude toward learning are thought to be influenced by the conditions of the environment in which learning takes place, then Attribute Games and Problems, may allow for and foster an atmosphere in which divergent-productive thinking can occur and develop.

The Problem

The basic problem of this study is the statistical comparison of one treatment applied to an experimental group to determine the effects of Attribute Blocks on the acquisition of divergent-productive thinking with a second group not previously exposed to the treatment materials.

The problem develops from isolation of the divergent-productive factor in Guilford's structure of intellect model and Hull's invention of the attribute materials. These two components form an integral part of the ESS.

II. RELATED RESEARCH

Introduction

A review of the literature related to this area of thinking reveals a predominance of tests developed to investigate intelligence and very little done about understanding that which the tests were to have measured. Further reading unfurls a multiplicity of definitions of words related to thinking and intelligence.

Studies on and about intelligence have had impetus since 1870 when Galton (1869) remarked on individual differences. Binet and Simon were commissioned in 1904 to find a procedure for determining how to segregate slow learners in the Paris, France schools. They devised 30 tests of varying difficulty to aid them in this task. The 1908 revision of their tests was refined to discriminate between normal children. Terman used Binet-type tests successfully in America, added some of his own, and subsequently developed the Stanford-Binet Scale in 1916. Addition of I. Q. index and other modifications have resulted in the present test. Little was done to define 'abstract thinking', the term Terman used to describe a kind of thinking. Even the addition to the field of testing of the Wechslar scales has not added precision to the meaning of that which is being tested. The major asset of the Wechsler scales, according to Guilford (1967, p. 9), has been, ". . . the recognition of the multiple aspect of this thing called 'intelligence.'" Departing from the unitary concept of intelligence purported by predecessors gave credence to the Wechsler scales.

It was at this point that Guilford's (1967) structure of intellect theory gave a taxonomy of intellectual abilities in five operations (see p. 6, Figure 1. 1) toresearchers in this field. One of the thinking operations is divergent-production about which this study is concerned.

Early Studies on Teaching Divergent Thinking

Ray (1967, p. 17) writes,

> Many persons assume that original thinkers are born, not made, that is not the position of this book, nor is it the position taken in their research by the psychologists Maltzman and Mednick, who have reported their theories as to how originality arises and reported also the experiments to which their theories have led them. Their work presumes that people are 'naturally' original . . . and that the quantity of originality can be increased.

The 'originality' written of above refers to responses by subjects (S) to words read by the experimentor (E) in terms of free-association over two trials. It was shown by Maltzman (1960) that the second trial produced more "uncommon" and "original" responses by the S's. Subsequent studies using responses from previous experiments did not produce originality. Another found originality lasting for two days although it had decreased when compared with a one-hour lapse from the testing time.

According to Ray (1967, p. 21), Gallup (1962) repeated Maltzman's standard experimental procedure and found no increase in originality at all. Ray (1967, p. 21) concludes that,

> ... originality as defined by Maltzman can be produced in this fashion, but that there is not yet enough evidence to allow exact specification of the conditions under which the phenomenon will appear.

Maltzman's (1960, p. 16) own conclusion is,

> The study reported here ... lends some support to the hypothesis that originality can be learned in the same fashion as other forms of operant behavior.

Mednick (1962) has constructed a test for selecting creative individuals based upon his definition of 'creative' which includes not only new ideas (divergent-productive thinking) but uncommon ones. However, utilizing their own procedure along with Mednick's test, Maltzman, Belloni, and Fishbein (1964, Figure 2, p. 8) found no difference between S's of high and low originality with word-association hierarchies. In the words of Ray (1967, p. 26),

> Such inconclusive results are included ... to convince the reader that work in this field has only started, and that there is a great deal to be done. But at least it seems possible to perform experiments here, in what is possibly the most complex area of human behavior.

Contemporary Studies on Divergent-Productive Thinking

At least nine areas have succumbed to investigations regarding divergent thinking. Intelligent Quotient (I.Q.), Memory, Stress, Mathematics, Programmed Instruction, Teacher Interaction with Students, School Atmosphere, and methods of teaching are amongst those receiving most emphasis.

Dellas (1970) found that operationally defined creativity could be increased by visual and affective experiences. A low correlation was found by her to exist between intelligence and creativity. She found also that while divergent thinking is differentially related to intelligence it is relatively independent and may be considered multidimensionally, its various components being independent.

Anderson (1968) found tests of divergent thinking to be less valid when administered to intellectually superior and retarded students. He concluded that divergent thinking is related to field-independence, a type of cognitive style or global field approach.

Smith (1971) concluded that students with I.Q's below 120 may be good convergent achievers, but are not typically good divergent achievers. He states that, "Apparently, a generally high level of intellectual ability is necessary for divergent achievement."

A paradox results from the above findings with that of Guilford (1967) who found little correlation with I.Q.

Pollert, et al. (1969) explored the role of memory in divergent thinking and found that it, "may play more important roles in divergent thinking than has formerly been recognized." In addition, he found that certain memory abilities may be more important than others for specific types of divergent thinking performance.

Krop, et al. (1969) investigated the role of induced stress on divergent and convergent thinking and found that certain "core" abilities may be impared.

Vaughan (1969) supports a school atmosphere avoiding stressful situations when he writes,

> Creativity ... is ... like happiness, always unattainable when directly sought, but to be approached indirectly in an atmosphere of acceptance ... The teacher and the school in America best would serve in this development of students' attitudes, sensitivity, and character indirectly by providing an atmosphere of receptive listening, rather than the present insistence on authority. An insistence on authority and the censure of divergent thoughts is believed ... to be a major cause for the loss recorded in the level of creative ability of our youth.

Of outstanding significance in support of teacher interaction with students is the study of Haddon and Lytton (1968) which shows that the preponderance of divergent and convergent children are produced in British Informal Schools in which a relationship between teacher and student is such that a child's ability to think adventurously and in new directions is fostered. Accordingly, Haddon and Lytton state,

> If the teacher can enter into the child's thinking, if she is prepared to let work develop in unexpected directions according to the child's needs and interests, if she can find and express genuine pleasure in the child's efforts, then self-initiated learning can be developed. It is in this climate that divergent-thinking abilities are seen to flourish.

Olton (1969) studied the effect of a self-instructional programmed method for teaching productive thinking skills in fifth- and sixth-grade children. His findings support his hypotheses that considerable improvement in generating ideas of high quality, asking relevant questions, and being sensitive to discrepancies of a situation can be taught. Utilizing the Productive Thinking Program, Series One: General Problem Solving, Wardrop, _et al_. (1969) found that greater gains in productive thinking skills evolved in classrooms providing support and encouragement for productive thinking.

Stallone (1968) studied the effects of selected induced sets on problems requiring divergent thinking and found groups already identified as divergent increased their performance on the posttest. He concluded that sets induced through divergent thinking exercises seem to elicit significantly increased performance on problems requiring divergent thinking.

The majority of research related to mathematics and utilizing materials similar to Attribute Games and Problems, with which this study is concerned, has been done under the direction of Zoltan P. Dienes at the Psycho-Mathematics Research Center of Sherbrooke University, Sherbrooke, Quebec, Canada. At the center, one of the areas being studied is methodology. Utilizing theories of Borel, Hilbert, Russel, and others, concern for two principles of operating have come to the fore. One is the deep-end principle in which a child is presented with the general principles first and then with the particular cases, rather than the other way around. The second is the dynamic principle in which there is free interaction between the child and the environment and discovery of certain regularities in the environment which lead to further discovery and schematization of the common structures in several concrete situations. The child here plays with the axiomatic systems in the same way as he played with the structural components of his environment, and the cycle begins anew.

While seemingly concerned with convergent thinking in teaching children logic, Dienes (1970, p. 55) remarks,

> The suggestions ... are intended as guide-lines to help teachers to construct such rich mathematical environments in which mathematical problems abound; and what is also important, in which the possibility always exists of finding solutions to problems already formulated. It is often because we are unable to formulate our difficulties that we are unable to solve them.

One may interpret this to mean that unique, original, and clever answers to problems arise after a sequentially developed experience involving convergent thinking as applied to divergent production of an answer. This is supported by Haddon and Lytton (1968, p. 178) when they write, ". . . both high convergent and high divergent thinkers, who indeed are often the same children." Dienes' work is subsequent to that of Hull's (1968) in which it was shown that five-year olds could engage in some high order logical thinking, provided the tasks were suitably chosen and adjusted to the stage of development of such young children, and provided that great care was taken that excessive verbalism did not stand in the way of the concept formation.

Barrish crosses the bounds of mathematics and methods of teaching divergent thinking in his study (1970) when he finds that a method of deductively teaching low cognitive mathematical materials proves superior to an inductive method. He also realized that levels of divergent production were not related to initial learning nor retention of the mathematical generalizations taught regardless of the teaching method.

Teaching Divergent Thinking

Crabtree (1967), utilized divergent thinking versus convergent thinking as criterion variables in determining whether or not structuring of the learning environment effected children's thinking. In the part of her program where a jointly-determined structure, teacher-integrative behavior opened opportunities for discussion periods in which children could explore ideas they had initiated relevant to the subject under study, divergent thinking occurred more frequently. Where more frequently elicited answers and highly constructed play sequences formed the major role, divergent thinking was reduced.

Grover (1966), compared two methods of teaching, a divergent and a convergent method, and found no significant mean differences between them. He was also interested in being able to predict achievement on post-divergent and post-convergent thinking tests. The fluency score of the divergent test was the least predictable and had the lowest correlation with the achievement index suggesting that the ability to be fluent was the least related of the tested abilities to typical school performance. He states, "Divergent thinking performance was more predictable for those who had studied by a divergent method than for those who had studied by a convergent method." This is surprising in view of the fact that the difference between group means did not approach statistical significance.

Bills' (1970) study was an attempt to increase divergent thinking of students with a five week experimental treatment utilizing student inquiry patterned after that developed by Richard Suchman. The results indicated that the inquiry treatment was not able to significantly increase the creative production of the students. However, an interesting sidelight was the report from the teachers involved in his study that the students enjoyed the inquiry sessions and were motivated to seek the solutions to problems from outside sources when discussions were left open-ended. This supports or is supported by Hull's (1968) work and that of Vaughan (1969).

Of major importance to the teaching of divergent-productive thinking is a study by Graham (1970) in which certain thinking activities such as, classifying, observing, comparing, summarizing, and interpreting, lead to increased verbal flexibility and increased non-verbal fluency, both integral parts of divergent-productive thinking. All of the activities used by Graham are part and parcel of the Attribute Games and Problems.

Of some significance to the teaching of divergent thinking in a tangential sense is a study by Taylor and McKean (1968) in which success in student teaching by a select group of college students showed that the low divergent thinkers were ranked as more successful than high divergent thinkers, even though they had lower grade point averages. If, according to the results of this study, divergent thinking is not rewarded in higher education, and this mode of thinking is done by creative and original people, then teacher education programs might warrant a revamping.

Summary

Early investigators into intelligence dealt with it as a unitary phenomenon. Contemporary development of a theory of the intellect gave workers in the field a taxonomy with which to investigate the multifaceted dimensions of intelligence.

Early trials in teaching found that some qualities of divergent thinking could be taught and retained for short periods of time. Later a paradox developed in which some researchers felt divergent thinking could not be taught. By investigating certain aspects of what is defined as intelligence clarification is being sought within the taxons of the structure of the intellect.

Little correlation has been found to exist between divergent thinking and intelligence quotient. More of a relationship exists with field-independence, a type of cognitive style.

Direct correlation has been found by some researchers to exist between the school atmosphere and teacher attitude toward children. When they offer an environment in which the child is treated as humanly as possible and the teacher works outside the framework of an authoritarian atmosphere, then self-initiated learning can take place.

Programmed materials have been developed and used successfully to improve productive thinking skills. However, classrooms (presumably teachers, too) that support and encourage productive thinking allow for greater gains to be made by children.

Mathematics has received great attention in the development of divergent thinking skills as they relate to the logic of problem-solving. The majority of research is done at the University of Sherbrooke, Quebec, Canada, under the direction of Dr. Zoltan P. Dienes.

Teaching for divergent-productive thinking skills has utilized structured and unstructured environment, open-ended and elicited-answer discussions, divergent and convergent teaching methods, and inquiry patterns of student involvement in the classroom.

In only one study (Wardrop, 1969) was a particular series of activities found to increase the divergent thinking abilities of children.

This study will be an attempt to show how a readily attainable set of materials will enable any classroom teacher with a minimum of training to teach for divergent productive thinking skills.

III. THE STUDY

Introduction

The basic problem of this study is the statistical comparison of one treatment of elementary science materials applied to an experimental group to determine its effects on the acquisition of divergent-productive thinking with a second group not previously exposed to the treatment materials. It is proposed to test this with selected elementary children.

Experimental Design

Campbell and Stanley (1963) describe 12 factors which jeopardize the internal and external validity of experimental designs. Two methods for minimizing the effects of these confounding variables are the random assignment of subjects to treatment groups, and the limitation of treatment time.

The experimental design will consist of a posttest only to determine acquisition of divergent-productive thinking skills. According to Campbell and Stanley (1963, p. 195),

> While the pretest is a concept deeply embedded in the thinking of research workers in education and psychology, it is not actually essential to true experimental design . . . the most adequate all-purpose assurance of lack of initial biases between groups is randomization.

Two fifth-grade classes were selected at random from the population of fifth-grade classes. The toss of a coin determined which would be the experimental and which the control group. Ten students from each class were randomly assigned to the treatment and control group. The statistical design has the general conceptual base of design 6 in Stanley and Campbell (1963, p. 178).

Major Hypothesis

The hypothesis to be tested has the following null form:

H_{01}: There will be no difference between the two groups in their performance on tests for divergent-productive thinking.

The particular divergent-productive thinking skills to be tested for are: verbal fluency, verbal flexibility, verbal originality, figural fluency, figural flexibility, figural originality, and figural elaboration (see page 27, 28 for a complete description of each category).

Minor Hypotheses

Eight minor hypotheses will be tested which have the following null form:

$H_{1\ minor}$: There will be no difference between the experimental and control groups on the test for verbal fluency.

$H_{2\ minor}$: There will be no difference between the experimental and control groups on the test for verbal flexibility.

$H_{3\ minor}$: There will be no difference between the experimental and control groups on the test for verbal originality.

$H_{4\ minor}$: There will be no difference between the experimental and control groups on the test for figural fluency.

$H_{5\ minor}$: There will be no difference between the experimental and control groups on the test for figural flexibility.

$H_{6\ minor}$: There will be no difference between the experimental and control groups on the test for figural originality.

$H_{7\ minor}$: There will be no difference between the experimental and control groups on the test for figural elaboration.

$H_{8\ minor}$: There will be no difference between the means of the experimental and control groups.

Population

The Ss were fifth-grade students from one selected Oregon Public Elementary School District 509J (Washington Elementary School, and Garfield Elementary School).

Limitations

1. The study is limited to one selected elementary school district in Oregon.

2. The study is limited to the acquisition of divergent-productive thinking skills.

Assumptions

1. Random assignment eliminates the confounding variables of history, testing, statistical regression, and selection.

2. The experimenter bias is minimized by the randomization procedure.

3. The length of time of the study will allow for the acquisition of divergent-productive thinking skills.

Definitions

Verbal Fluency

The ability of a subject to produce a large number of ideas with words.

Verbal Flexibility

The ability of a subject to produce a variety of kinds of ideas, to shift from one approach to another, or to use a variety of strategies in a verbal manner.

Verbal Originality

The ability of a subject to produce ideas that are away from the obvious, commonplace, banal, or established.

Figural Fluency

The ability of a subject to produce a large number of ideas with figures.

Figural Flexibility

The ability of a subject to produce a variety of kinds of ideas, to shift from one approach to another, or to use a variety of strategies in a figural manner.

Figural Originality

The ability of a subject to produce ideas that are away from the obvious, commonplace, banal, or established when dealing with figural content.

Figural Elaboration

The ability of a subject to develop, embroider, embellish, carry out, or otherwise elaborate ideas.

Divergent Production of Units

The two-fold abilities of a subject to produce words filling certain structural requirements and ideational fluency, calling up many ideas in a situation relatively free from restrictions, where quality of response is unimportant.

Divergent Production of Classes

Also called semantic spontaneous flexibility which is the ability to produce a diversity of ideas when there is freedom to do so.

Divergent Production of Relations

Also called associational fluency which is the ability to think of words that fulfill particular requirements of meaning.

Divergent Production of Systems

Also called expressional fluency which involves facility in producing organized continuous discourse.

Divergent Production of Transformations

The ability to produce uncommon or clever responses or remote associations.

Divergent Production of Implications

Also called semantic elaboration which is the ability to supply details that contribute to the development of an idea or the variations of an idea.

Treatment Sessions

The 10 Ss in the experimental group worked with the E in a regular classroom provided by the elementary school. Each session was approximately 45 minutes in duration for fifteen concescutive school days followed by two days for testing. The treatment sessions occurred during the time of Ss regular science class. At the conclusion of the study testing of the control group was done on the same days as the experimental group.

Each treatment session involved an attempt by the E to set a room atmosphere most conducive to enquiry learning. The E had to be able and willing to listen rather than talk, to observe more than to show, to help the Ss in their progress without engineering more than the framework in which they operated, and to have respect for and confidence in their abilities to build confidence in what they were pursuing.

After initial contact with the attribute block materials took place, subsequent activities were pursued as the Ss desire to continue was verbally expressed to the E. This process continued until all Ss were involved with the last activity.

Treatment Materials

The attribute blocks part of the Attribute Games and Problems unit of the Elementary Science Study (ESS) comprised the materials with which this study was concerned.

The attribute blocks consist of an array of small, wooden blocks of four colors (red, blue, green and yellow), two sizes (large and small), and four shapes (square, circle, diamond, and triangle), for a total of 32. Also included are six colored cloth loops and 21 cards on which a specific value of an attribute is printed. By utilizing these materials in a sequence of activities it is the opinion, yet the very hypothesis of this study, that divergent-productive thinking can be enhanced or taught.

A set of attribute blocks can be obtained commercially (see appendix 2) or found on file in the Oregon State University Library.

Experimental Activities

The following sequence of problems comprise the treatment sessions in which the experimental group was engaged.

Activity 1. The entire box of blocks is shaken by the E and the question asked of the Ss, "What's in the box?" Also asked is, "How many are in the box?" By this method, the Ss curiosity is aroused and motivated to inquire and concentrate on the materials. Proceeding in a leisurely fashion with the questions, the children generate the total set of blocks by closely observing them one at a time as they are taken from the box.

One is engaged in divergent production of relations (associational fluency) at this point. Divergent production of implications is operating as well when the Ss supply details from their observations that contribute to the development of the set as they perceive it.

Activity 2. This problem consists of directions to take out all the pieces and see what you can do with them. Ss are asked to see how many ways they can build with them, to make an unusual construction, or build what they think a usual construction would look like.

Because of the strong perceptual impact and intrinsic interest the children have with the blocks this problem fits into a category called, by David Hawkins (1965), "messing about." This is a time when the Ss are experimenting with symbol systems and systems of representation. Pertaining to this activity Hull (1968) states,

> The child who has had ample opportunity to create systems of his own may be better prepared to explore those presented to him in problem-solving situations.

It has been the experience of the E that this time is necessary before further activity with the blocks can be pursued.

Activity 3. The Ss are asked to put all the blocks of one shape into some orderly construction or arrangement even though they differ in color and size. A game is introduced in which another person takes one piece from the blocks and the person who arranged the blocks is asked to tell which one is missing. (The latter person is not watching when the block is removed, of course.) The process is repeated only by beginning with a color instead of a shape. By doing this activity the Ss are introduced verbally to the attributes of shape and color by being told that shape and color are attributes of the blocks after doing the activities described above.

Activity 4. As in activity 3 the Ss were introduced to the attributes shape and color, activity 4 introduces them to the attribute size. Ss are asked to put all the large diamonds into one group and all the small diamonds into another. They are asked to make a group of the large triangles, and a group of the small triangles and the same with the circles and squares. Next the Ss bring all the large pieces together into one pile, and the small pieces together into another pile. Ss are told the A Blocks set is now divided into two groups according to size. They are told that size, like color and shape, is an attribute of this set. Size, shape, and color are the three attributes used to describe the A Blocks.

Activities 3 and 4 are vocabulary-building activities involving the tactile and visual senses as well. Attention is focused upon the basic three attributes of the set of A Blocks. The activities following build a feeling and understanding for values or the attributes.

Activity 5. Ss are given the following directions: "One attribute of this set is shape. Using all the blocks, make groups (subsets) so that each subset contains only pieces of the same shape, large and small. You will have a subset of all the triangles, a subset of diamonds, a subset of squares, and a subset of circles. Triangle, diamond, square, and circle, are called values of the attribute shape." Two questions follow: "1) What are the values of the attribute color?, and 2) What are the values of the attribute size?" E places the chart below on the chalkboard and asks the questions above to the Ss involved with this problem.

Attributes	Values			
Shape	?	?	?	?
Color	?			
Size	?			

The purpose in establishing a meaning for the term value is to make communication clear. Consistent use by the E helps the Ss learn the terms naturally and in a way meaningful to them. There is no need for children to memorize or repeat any of the words used in these activities; what is important is that they feel at ease with the ideas the words imply.

Activity 6. Ss are directed to arrange the set of blocks into subsets (groups) so that each subset contains only those pieces that have the same color and the same shape. Five questions follow: "1) How many subsets are there?, 2) How many blocks are in each subset?, 3) How do the pieces within a subset differ from each other?, 4) Do you have a group of yellow diamonds?, and 5) Can you name the other groups?" Questions of this sort require Ss to identify members of subsets as well as to count them. This leads to a greater awareness of the abstract nature of number. Because number is not a property of an object, it is more abstract than words like attribute and value. Divergent production of relations (associational fluency) is again brought into play in this activity as the Ss are gaining experience by having to think of characteristics they've observed in the blocks that fulfill particular requirements of the meanings for attribute and value.

Activity 7. Ss are directed to arrange the blocks in subsets so that the pieces in each subset are alike in color and size. Four questions follow: "1) How many subsets are there?, 2) How many blocks are there in each subset?, 3) How do the blocks within a subset differ from one another?, and 4) Can you think of a name for each subset?" Ss are further directed to choose a different combination of two attributes and try to answer these questions again. This is followed with the question, Is there another combination of two attributes you have not tried?

Activity 7 requires a constant shifting forth and back between two ideas: positive and negative information and likenesses and differences. Divergent production of transformations is occurring in this activity when the Ss produce remote associations between the various combinations of attributes possible. Divergent production of implications is utilized when the Ss must supply details that contribute to the development of an idea or the variations of an idea.

Activity 8. Ss are asked to choose a value and make a subset of all the pieces having this value. Ss are directed to choose a value of a different attribute, and make a subset of the pieces having this value. They are then directed to take from these two subsets all the pieces that have both the values they have chosen. Four questions follow: 1) "How many pieces were in your first subset?", 2) "How many pieces were in your second subset?", 3) "How many pieces share both values?", and 4) "Can you form a subset containing a different number of pieces by choosing other values?"

This activity requires a shift in focus from considering combinations of attributes to that of considering combinations of values. This resulting shift of thinking involves sets comprising the intersection of two values. Both divergent production of transformations and of implications are involved here as in activity 7.

Activity 9. Ss are directed to form a subset of all the pieces which are either yellow or diamond. This subset will contain all the yellows and all the diamonds. Ss are asked, "How many pieces are there in the subset?" Ss form a subset of all the pieces which are either large or red. The subset will contain all the large pieces and all the reds. Ss are asked how many pieces are there in this subset. A culmination of this activity lies in the question asked of the Ss, "Can you tell without using the blocks how many pieces there would be in a subset formed of pieces which are: Either triangles or green?, and Either small or blue?"

As in the following activity Ss are dealing with unions. The requirements in terms of divergent thinking skills are similar to activities 7 and 8; divergent production of transformations and divergent production of implications.

Activity 10. Ss put into the A Blocks box all the pieces that are either red or circle. Put the remaining pieces aside. Take out of the box all the pieces that are not circles. Ss are asked in what way are the pieces they have taken out alike. Ss put back the pieces that are not circles and take out all the pieces that are not red. They are asked in what way are all the pieces that they have taken out alike. Ss have posed the following situation: "Suppose a box contains all the pieces that are either yellow or square." Ss are asked, 1) "What can you say about the pieces that are not square?" and 2) "What can you say about the pieces that are not yellow?" Ss are asked to practice this kind of game until it is easy for them.

Although not apparent to the reader, the researcher reminds one that while the sequence of activities seems a rigorous scheduled program of working one after the other, in keeping with the room atmosphere alluded to on page 30, this is not the case. Many activities turn into games to be played many times with a partner who may be the E or another S. Although a total time constraint was applied to the study, no time constraint was applied to particular activities with individual Ss.

Activity 11. Ss are asked to answer eleven questions without looking at the blocks pertaining to what has been done with the A Blocks up until now. They are as follows: 1) "How many red pieces are there?", 2) "How many triangles are there?", 3) "How many small pieces?", 4) "How many large circles?", 5) "How many small yellow pieces?", 6) "How many large blue diamonds?", 7) "How many green squares?", 8) "How many non-red circles?", 9) "How many non-square blues?", 10) "How many non-large triangles?", and 11) "How many non-circle, non-yellows?" This problem serves primarily as a review of the materials and communication of the vocabulary being used concurrently with the activities. It provides the E with an idea of who is able to abstract the attributes and values of the blocks. While convergent production of classes and relations is the most prevalent thinking ongoing, it is the belief of the E that divergent thinking of classes and relations is utilized in conjunction with the convergent thinking skills in order to assemble the mental abstractions into meaningful entities or answers to the questions.

Activity 12. Ss are asked to group the blocks in subsets by color. "Ask your partner to choose a color subset and make a building or a design with these blocks. Can you make a similar arrangement with a subset of another color?" They are directed to start again and group the blocks by size. "Ask your partner to build something with the large blocks. Can you make a similar arrangement using the small blocks?" Ss are asked to start again and group the blocks by shape. "If your partner builds something with two shapes (for example, all the squares and all the triangles) can you make a similar arrangement using the diamonds and the circles?" These games involve a kind of map-making in which one value stands for, or represents, another value of the same attribute.

This activity introduces the idea of representation. Divergent production on implications is found in this skill because Ss develop their ability to supply details that contribute to the development of an idea or the variations of an idea. Although many variations can be developed with this activity, the writer directed Ss who worked on this activity at length toward activity 13 because of limitations of the study in which mapping, per se, was not considered apropos.

Activity 13. Ss are directed to put the blocks in the box and asked to name all the pieces without looking at them.

This represents an exercise in organizing experience, not a test of memory. This allows the Ss to review and consolidate a skill in divergent production of implications to some extent in that Ss are developing variations of ideas although this skill could be a combination of classes and comprehension of relations.

Activity 14. Ss are confronted with a lengthy activity as follows: "In the A Blocks set there are four colors, four shapes, and two sizes. Before counting the blocks, can you tell how many there are altogether? Choose two values of the attribute shape, three values of the attribute color, and one value of the attribute size. How many pieces are there in the subset that has all the possible combinations of these values? Here is an example, Suppose you choose the following values:

Shape	Color	Size
circle	red	large
diamond	yellow	
	blue	

In this example, the subset formed would have all the large red, yellow, and blue circles, and all the large red, yellow, and blue diamonds. How many pieces are there in a subset that has four values of shape, three of color, and one of size? Form such a subset if you are not sure. How many pieces will there be in a subset that has two values of shape, three of color, and two of size? Whatever values you choose, you can find out whether a piece belongs in the subset by checking to make sure it has at least one of the values of each attribute, shape, color, and size."

Involved here, in part, is the divergent production of units (ideational fluency) in which the Ss can develop the idea that multiplying the number of values of each attribute yields the number of pieces in the subset.

Activity 15. Ss try to do these activities in their heads: "How many subsets will you have when the A Blocks are grouped by color? (All the pieces in a subset must have the same color.) How many pieces will be in each subset? How many subsets will there be, and how many pieces will there be in each subset, when the clocks are grouped by size? By shape? By size and shape? If you are not sure of your answers, make each of the subsets and count the blocks in it. It may help if you write your answers on a piece of paper like this:"

Group	Number of subsets	Number of blocks in each subset
Color		
Size		
Shape		
Shape and Size		
Shape and Color		
Color and Size		

While this card reviews one-, two-, and three-attribute groupings as in activity 11, it does so in a different form. The divergent production skills are similar to those in activity 11 (p. 38).

Activity 16. Ss choose two values of each attribute - two sizes, two colors, two shapes. For example, "choose:

Size	Color	Shape
large	red	triangle
small	blue	square

You will have the following pieces:

large red triangle

large red square

large blue triangle

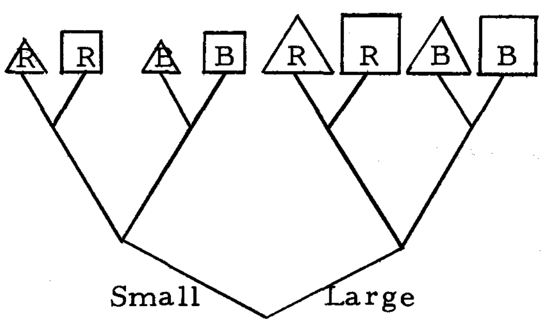
large blue square

small red triangle

small red square

small blue triangle

small blue square



Ask someone to remove one or more pieces from your subset. Can you tell what is missing? Make a different subset using two values of each attribute. Can you identify one or more pieces removed from this subset? Practice making subsets of this kind until you can do it easily."

Commentary for 16 will follow activity 17 as they both require similar thinking skills.

Activity 17. Ss choose two values of color and two values of shape. "Take out all the pieces that have these colors and these shapes. Put any two of the eight pieces together to make a pair. Pair the remaining six pieces to match the first two. For example, if the pieces in the first pair are alike except for color, the pieces of the other pairs must also be alike except for color. Each of these pairs will have one difference in common - color. Can you make pairs that have two common differences? Can you make pairs that have three common differences?"

The process of identifying pieces missing from a subset is complicated, although it may be carried out swiftly when one begins to think about the task analytically. After an initial awareness that what one perceives is not random, divergent production of relations (associational fluency) and divergent production of classes (semantic spontaneous flexibility) are involved in producing a diversity of ideas about an approach to solving the problems and the ability to think of blocks that fulfill particular requirements of meaning within the constraints of the block array.

Activity 18. Ss are asked to take all the yellow and all the green circles and diamonds and arrange these eight blocks in some orderly way. "One of these pieces is:

not yellow

not a diamond

not small

Which piece is it? Another piece in the set is not large, is a circle, and is not yellow. Which piece is this? Notice that in these examples some values have been stated negatively - it is not yellow - while others have been stated positively - it is a circle. Try this game with a partner. Take turns asking about different combinations of positives and negatives. Can you play the game without looking at the pieces?"

Activity 18 introduces the Ss to negative terminology to insure clear communication in later activities.

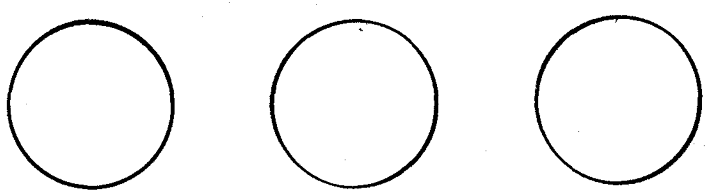
Activity 19. Ss are directed to set out the following pattern of small blocks:

red square			red diamond
	green triangle		
		yellow circle	
			blue diamond

"Can you complete this arrangement using the rest of the small blocks? Ask someone to remove one of the pieces when you are not looking. Can you tell which one is missing? All the blocks in a row have the same color, and all the blocks in a column have the same shape. Such an arrangement is called a matrix. Leave the matrix you have made on the table when you are ready to go on."

While this activity and a subsequent one present matrices as a method of classification, it is of the writer's opinion that working with matrices in this way offers another way of thinking about problem-solving. That is, divergent production of transformation or of implications may be strengthened, enhanced, or developed by making one aware of various paths to the solution of similar problems.

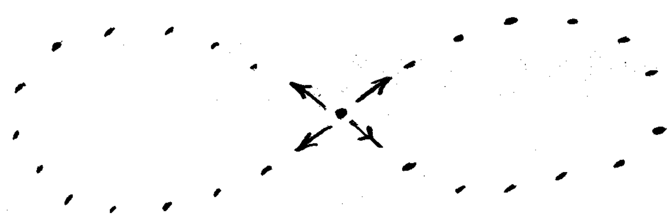
Activity 20. Ss are asked to take three of the loops from the A Blocks box and put them on the table as follows:



"Then, choose a block - it does not matter which one. Place this block on the table outside of the three loops. In the first loop place all the blocks that differ from it in one way. In the second loop place all those that differ from your chosen block in two ways. In the third loop, place all the blocks that differ from it in three ways. Choose a different block and play the game again. Practice until you can do it quickly and easily."

The primary purpose of this activity is to focus attention upon grouping by differences in attributes for subsequent activities.

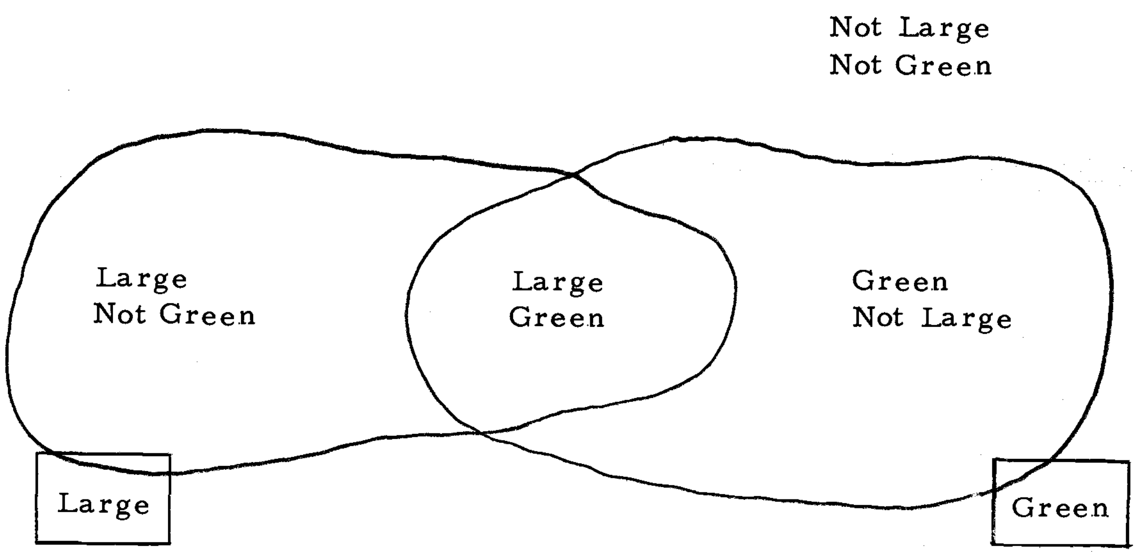
Activity 21. Ss place a block on the table. They find a block that differs from it in only one way and lay it next to the first block. "Now find a block that differs from the second block in only one way and lay this on the table in line with the first and second blocks." Ss perceive and try to answer this question: "Can you arrange all the A Blocks in a single line so that all adjacent pieces differ from each other in only one way? Try to make your line into a circle." This requires finding end pieces that differ in only one way. Another question requires the Ss to look at a different configuration. "Can you lay out a figure eight in which all adjacent pieces differ in one way only?



Notice that the center block - at the crossover - has four adjacent pieces. All four must differ from the center block in only one way." The last question causes additional concentration on attribute and value differences as follows: "Can you make circles and figure eights with two differences between adjacent pieces? Three differences?"

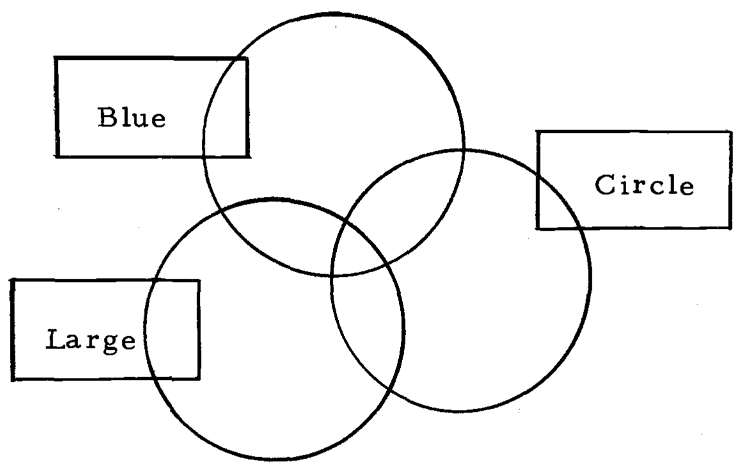
The major asset this activity instigates is the extension of experience in classifying to a series of increasingly complex tasks involved with divergent production of transformations by making what may be remote associations of various combinations of attributes.

Activity 22. This activity is demonstrated by the E to communicate in a visual manner intersections of sets and classes of attributes and/or values which will be dealt with in subsequent activities. At the chalkboard, E draws two loops, labeling one loop Green and the other loop Large. Then, saying to the Ss, "If the loop labeled Green overlaps (intersects) the loop labeled Large, you can name the subsets that belong in the three spaces created by the intersecting loops, as well as the space outside the loops in this way:"



E continues by saying, "Suppose you have two such intersecting loops, one labeled Yellow and the other Triangle. What are the names of all the spaces, including the spaces outside the loops? Make up other problems like these. Can you name the spaces without putting the blocks in them? Imagine the blocks and loops and try naming the subsets."

Activity 23. Ss arrange any three loops and label them with the label cards like this:



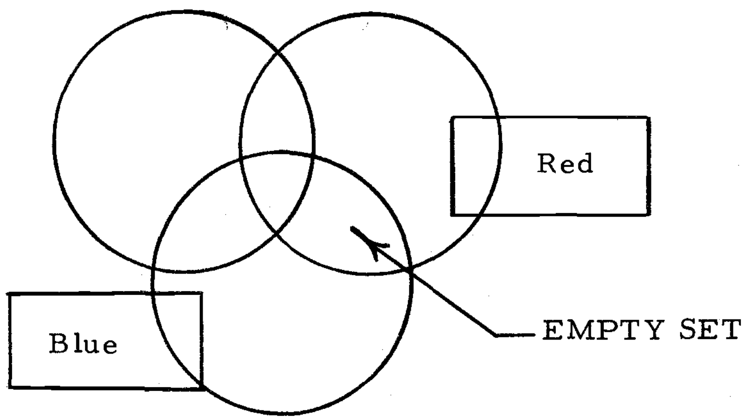
The "N" label cards are not used at this time. Ss then place blocks in the spaces where they belong. For example, the space that is in both the Blue loop and the Large loop but not in the Circle loop must have in it all the large blue not-circles, and only the large blue not-circles. "Check each of the loops in turn to be sure that it has all its pieces and only its pieces. Name each of the subsets you have made, including the subset of pieces outside all the loops. Make up other problems like this by labeling each loop with different values from those used here."

This activity repeats, with three attributes, the type of problem presented with two attributes in activity 22. The addition of the third attribute makes the game considerably more challenging because of additional subsets.

Activity 24. Ss lay out the three-loop pattern using any three loops as in activity 23. "Label each loop with the negation (N) of a value using the label cards with the appropriate N-value. One label might be N-Green, another N-Circle, a third N-Small. Place blocks in the proper spaces. Remembering only the pieces that are not green must go in the N-Green loop, and all of them must go in this loop. All pieces that are not circles and only these pieces must go in the N-Circle loop, etc."

This game provides progressively more difficult versions of the three-loop game introduced in activity 23. Activity 24 provides systematic practice in dealing with negations. Activity 25 provides students with an explanation of empty sets which can be encountered during this problem when Ss are free to choose value cards on their own.

Activity 25. Ss lay out the three-loop pattern. "Shuffle the set of label cards, both positive and negative. Without looking, select three cards. Several interesting combinations of values and negations may occur. For example, two of your labels might be values of the same attribute, say red and blue. The space made by the intersection of the two loops cannot be filled since no block is both red and blue. A set (or subset) with nothing in it is called an empty set.



Another possibility is that one of your label cards will be for a value and another for its negation. What happens when one loop is labeled Circle and another N-Circle? Which combination of labels leaves the fewest pieces outside the three loops? Do any combinations leave no pieces outside? Just one piece? Which combination leaves most of the pieces outside? Look at the label cards you selected. Before placing the pieces called for in the loops, see if you can predict how many pieces will be left outside."

By the time Ss are involved with this activity and those immediately preceeding it their ability to think in a manner conducive to divergent production of transformations and of implications is also developing and they are in a position to use these skills. This writer does not feel Ss can verbalize the degree of development or exact methods of using these divergent productive thinking skills, but can demonstrate by more intricate choice of label cards and ingenious placement of them. It is at this point in the sequence of activities that Ss are handling what Hull (1968, p. 82) has called, "a manageable complexity." While the games are manageable, they become more and more comples as the Ss continue to be motivated to invent and modify problems of their own.

This writer feels a note of warning to the reader is important at this point. Unless you are actively involving yourself with the materials while studying this paper it may be you cannot grasp fully the meaning of the games described herein as 'activities.'

Activity 26. Ss read the following statements and begin this last activity in the study. "When you feel sure you have mastered the previous three-loop games, find a partner who is also an expert. Start by using only the positive label cards. Choose a label for each loop and place it face down by its loop. Your partner must discover what the labels of the three loops are by placing pieces in the spaces and finding out from you whether they belong there or not. Each of the thirty-two blocks belongs in only one particular space, although not all will necessarily go into the loops, and there may be more pieces in some spaces than in others. In order to give correct answers to your partner, you may want to draw a small diagram for yourself showing the labels you have given to the loops, and refer to the diagram as you answer. You will tell him that a piece is correctly placed only if it is in its unique space - that is, either inside one of the seven spaces created by the loops or in the space outside the loops."

"A much more difficult version of this game can be created by using only negative labels, and telling your partner that you are using only negative labels. The most difficult version requires you to use any combination of labels, not telling your partner whether they are all positive, all negative, or a combination. Much of the difficulty of these games stems from the difficulty of remembering what you have learned from each trial of a piece in a space. You may want to figure out some way of recording this information."

This activity alludes to divergent production of systems because it requires one player to put ideas into apt and colorful situations to create more complex situations or 'puzzles' for the other partner to solve. Divergent production of transformation is involved because one is caused to produce uncommon or clever responses or remote associations of prior block configurations in order to classify and clarify the situation.

The writer is in agreement with Hull (1968, p. 84) who writes,

> The explorations children make with attribute materials can provide them with a model which may be useful for thinking in a wide variety of situations, a model which may help them become more sensitive to the world around them, more aware of their own thinking about it, a model which may lead them to an increased confidence in their own intellectual performance.

Posttests on Divergent-Productive Thinking

Two batteries of test activities, one verbal and one figural, of the Torrance Tests of Creative Thinking, Verbal Form A and Figural Form A, were used in the study (Torrance, 1966). The Verbal Test consists of seven parallel tasks, requiring a total of 45 minutes in addition to the time necessary for giving an orientation, passing out booklets, and giving instructions. Each task brings into play different types of divergent-productive thinking. The activities involve: asking questions about a drawing, making guesses about the causes of the event pictured (divergent production of units, ideational fluency); making guesses about the possible consequences of the event (divergent production of transformations); producing ideas for improving a toy so that it will be more fun for children to play with (divergent production of implications); thinking of unusual uses of cardboard boxes (divergent production of units and of classes); asking provocative questions; and thinking of the varied possible ramifications of an improbable event (divergent production of transformations and of implications).

The Figural Test includes three activities with an over-all administration time of 30 minutes. The first task, Picture Elaboration, is designed to stimulate originality and elaboration (divergent production of transformations and of implications). The two succeeding tasks, Incomplete Figures and Repeated Figures, increasingly elicit greater variability in fluency (divergent production of units); flexibility (divergent production of classes); originality (divergent production of transformations); and elaboration (divergent production of implications).

Choosing this test for this study was affected by Torrance's (1966, p. 4-5) recommendation that it can be used to:

> ... assess the differential effects of various kinds of experimental programs, new curricular arrangements or materials, organizational arrangements, teaching procedures, and the like.

Secondly, other kinds of tests almost always measure recognition of reproductive kinds of achievement and mental growth. Because the goal of this study is to determine the effects of a set of materials on a change in intellectual growth, this test is most apt.

Test Validity

The complexity of the validity problem as it refers to tests of creative thinking ability can be seen by a review of the literature pertaining to the area and the lack of unanimity of researchers in thinking of creative thinking as one set of criterion behaviors.

This writer agrees with the model Torrance (1966, p. 23) sets forth when he writes,

> It has seemed reasonable to the author to think of creativity as a process. With this approach, one can then think in terms of the kinds of abilities necessary for the successful operation of the process in various situations or for the production of various kinds of products. He can also think in terms of the qualities of the products resulting from the process. He can think of the kinds of personality characteristics, group dynamic variables, and other environmental characteristics that facilitate or impede the kind of functioning described by the process definition.

Being unable to set forth the universe of possible behaviors of any one individual or group of humans, the Verbal and Figural Form A of the Torrance Tests of Creative Thinking sample a wide range of the abilities in such a universe. In particular, they cover many of the facets of divergent-productive thinking referred to in the series of experimental activities in this chapter.

Two features of these tests making them appropriate to this study and valid in terms of the above, are; 1) To insure content validity, a consistent and deliberate effort has been made to base the test stimuli, the test tasks, instructions, and scoring procedures on the best theory and research now available. And 2) the tests can be administered at all educational levels making it possible to determine whether or not children identified as creative behave in ways similar to the ways in which eminent creative people of the past behaved when they were children.

Test Scoring

Scoring directions for both the Verbal Form A and Figural Form A of the Torrance Tests of Creative Thinking used in this study are provided in the Torrance Tests of Creative Thinking Directions Manual and Scoring Guide. Directions for administering the tests are also given in the manuals and were strictly adhered to by this writer.

For comparative purposes, comparison group norms were supplied in the Torrance Tests of Creative Thinking Norms-Technical Manual, Research Edition (Torrance, 1966). After the scoring of the individual tests is accomplished, the raw scores in each category for each S is converted to a T-score or standard score. Comparison of scores on tests from this study were then compared with the scores supplied in the Norms-Technical Manual, Research Edition. The converted T-scores from the tests in this study can be seen in Table 4.1 (p. 60).

The tables from the Norms-Technical Manual, Research Edition, used for comparison with the test results from this study were as follows: For the Verbal portion of the test in this study, the T-Score Conversion Table for Fluency, Flexibility, and Originality of Verbal Form A of the Torrance Tests of Creative Thinking Based on Fifth Grade Data, Table 5.8, was used; and for the Figural portion of the test in this study, the T-Score Conversion Table for Fluency, Flexibility, Originality, and Elaboration for Figural Form A of the Torrance Tests of Creative Thinking Based on Fifth Grade Data, Table 5.2, was used.

IV. PRESENTATION AND INTERPRETATION OF THE DATA

Introduction

The purpose of this study was to assess the differential effects of specific elementary science materials on the acquisition of divergent-productive thinking skills by selected elementary school children.

Two classes of fifth-grade classes of one Oregon Public Elementary School District 509J (Garfied and Washington Elementary schools) were randomly selected to serve as the control and experimental groups respectively. A coin toss determined which class became the control. Ten students were randomly selected from each class and assigned to the respective group. All Ss in the experimental group attended each experimental activity session each day for fifteen consecutive school days. There was no attrition. Each experimental activity session lasted approximately forty-five minutes, during their regularly assigned science class time. All Ss were tested on the same day at the conclusion of the experimental activities. Testing of control and experimental Ss was accomplished within a consecutive three-hour period of the school day at the respective Ss' schools.

Presentation of the Study Data

Table 4.1 represents the T-scores obtained from the basic test data. They represent standardized values derived from Torrance's

(1966, p. 61, 67) T-score conversion tables based on fifth grade data.

The statistical treatment of the data in Table 4.1 was done by using Student's t-test. The test statistic is in the following form:

$$t = \frac{\overline{X}_E - \overline{X}_C}{s_{\overline{X}_1 - \overline{X}_2}}$$

where,

$\overline{X}_E$ = the average for the experimental group

$\overline{X}_C$ = the average for the control group

and,

$$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{2s^2}{n}}$$

where,

$s_{\overline{X}_1 - \overline{X}_2}$ = the sample estimate of the standard error of $(\overline{X}_E - \overline{X}_C)$.

n = the number of subjects in the group

s^2 = a pooled estimate of the variance

Table 4.2 represents the calculated means and resulting Student's t-values from which significance was determined.

Table 4.3 represents the calculated means and resulting Student's t-values from which significance was determined from the composite T-scores of each group of Ss.

Graphs 4.1 through 4.9 were drawn from the data in Table 4.1.

Table 4.1. T-scores converted from verbal and figural test scores of Ss.

	Student	Verbal Fluency	Verbal Flexibility	Verbal Originality	Figural Fluency	Figural Flexibility	Figural Originality	Figural Elaboration	Composite T-scores
Control	1	48	55	56	74	60	45	59	397
	2	26	25	37	40	44	45	97	314
	3	47	57	48	55	44	50	44	345
	4	32	37	40	47	50	50	51	307
	5	37	49	39	48	44	43	36	296
	6	45	55	50	59	57	60	69	395
	7	40	50	49	34	40	37	64	314
	8	35	53	45	37	39	52	54	315
	9	34	38	40	30	37	38	43	260
	10	35	35	46	42	33	34	62	287
Experimental	11	33	37	38	57	59	54	67	345
	12	40	52	49	30	37	39	75	322
	13	43	52	55	60	57	50	60	377
	14	38	44	41	52	57	63	78	373
	15	42	38	44	50	50	79	60	363
	16	60	75	49	70	72	84	87	497
	17	26	24	34	34	37	39	54	248
	18	38	47	39	59	60	64	61	368
	19	35	37	45	59	48	53	60	337
	20	38	37	42	45	50	59	55	326

Table 4. 2. Calculated means and Student's t-values from unpaired t-test.

	Control means	Experimental means	Student's t-value
Verbal Fluency	37. 9	39. 3	. 394
Verbal Flexibility	45. 4	44. 3	. 170
Verbal Originality	45. 0	43. 6	1. 627*
Figural Fluency	46. 6	51. 6	. 875
Figural Flexibility	44. 8	52. 7	1. 820**
Figural Originality	45. 4	58. 4	2. 438***
Figural Elaboration	57. 9	65. 7	1. 211

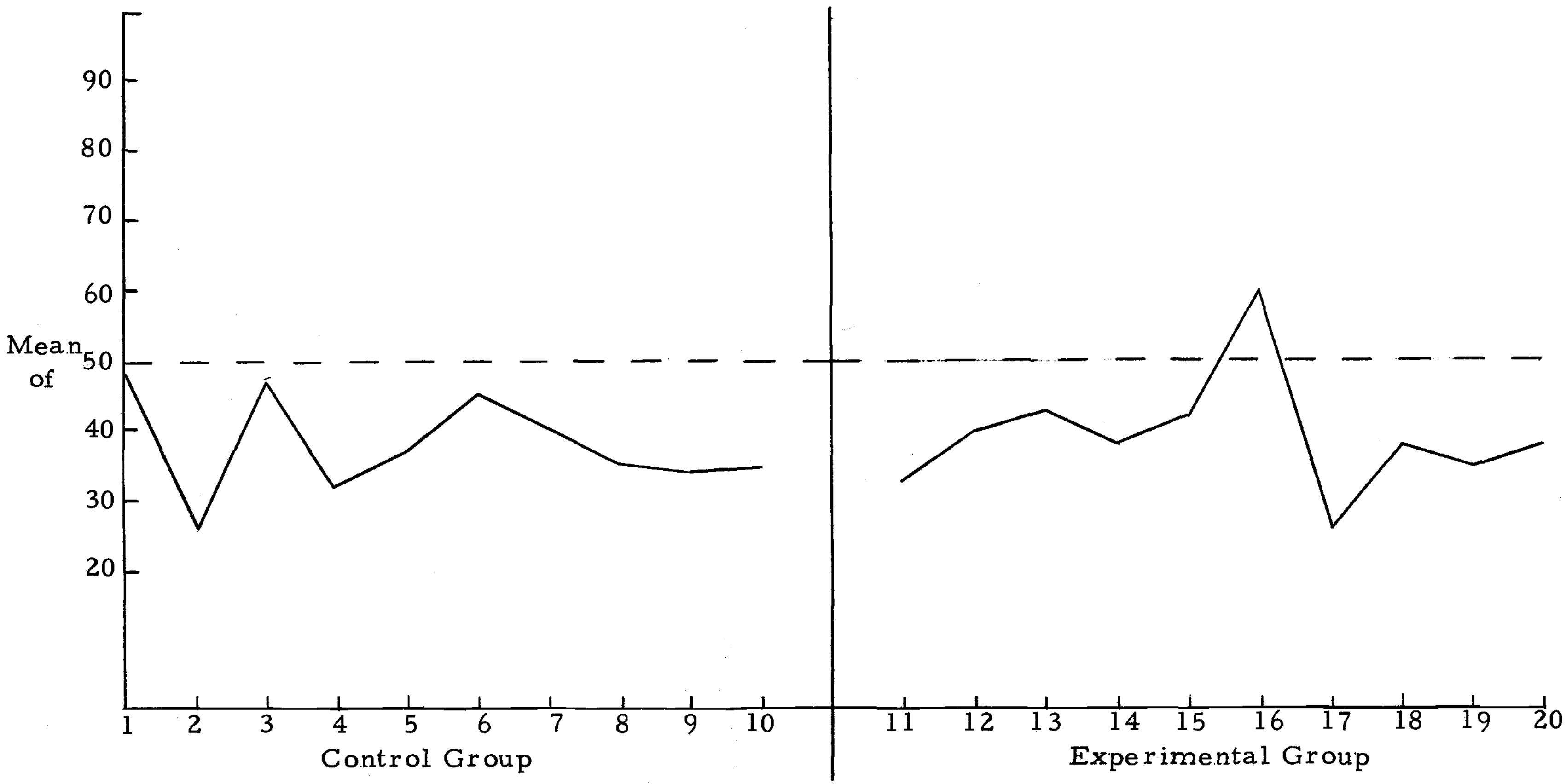
* Significant at the . 20 level

** Significant at the . 10 level

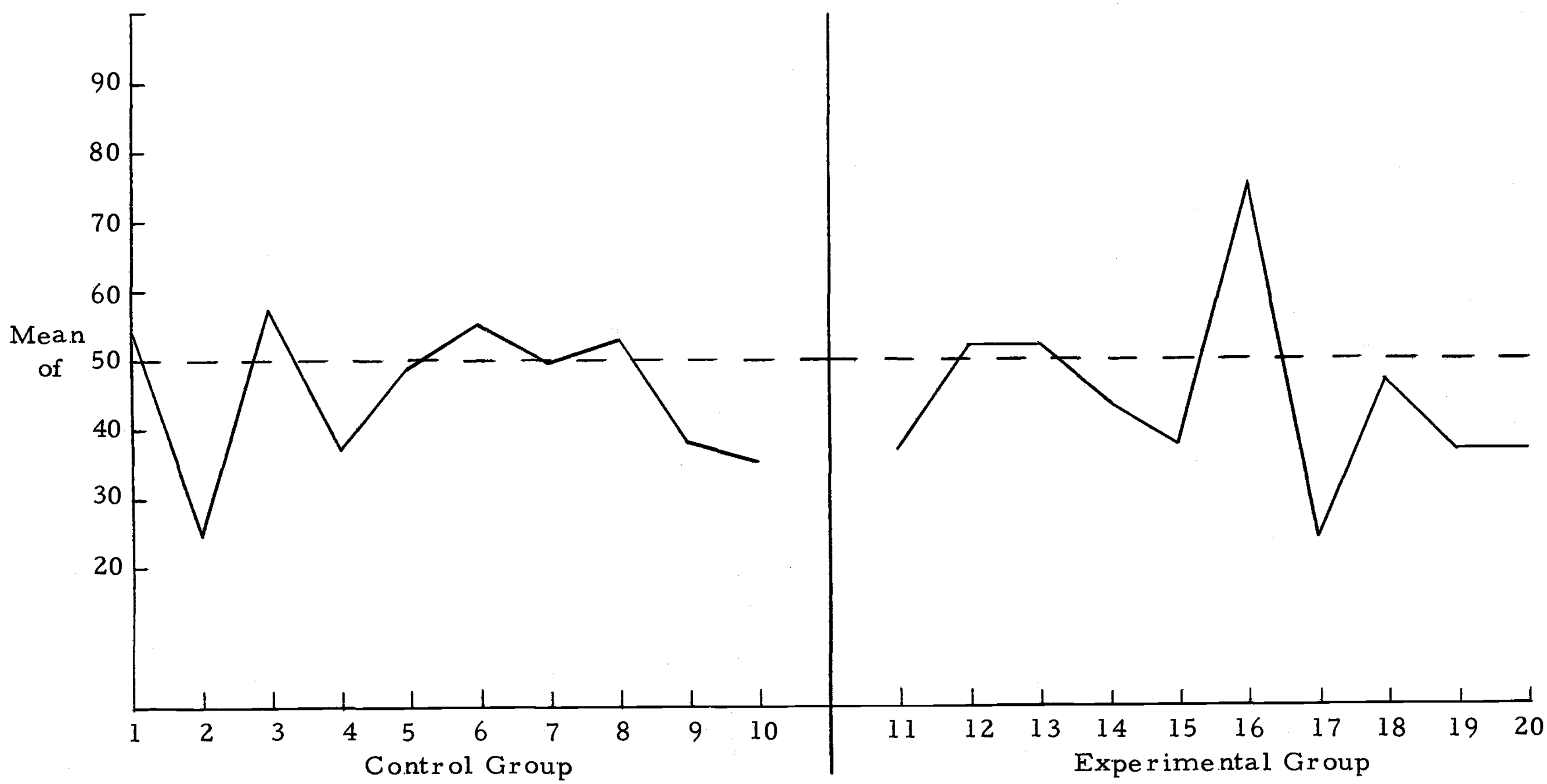
*** Significant at the . 05 level

Table 4. 3 Calculated means and Student's t-value from unpaired t-test on composite scores.

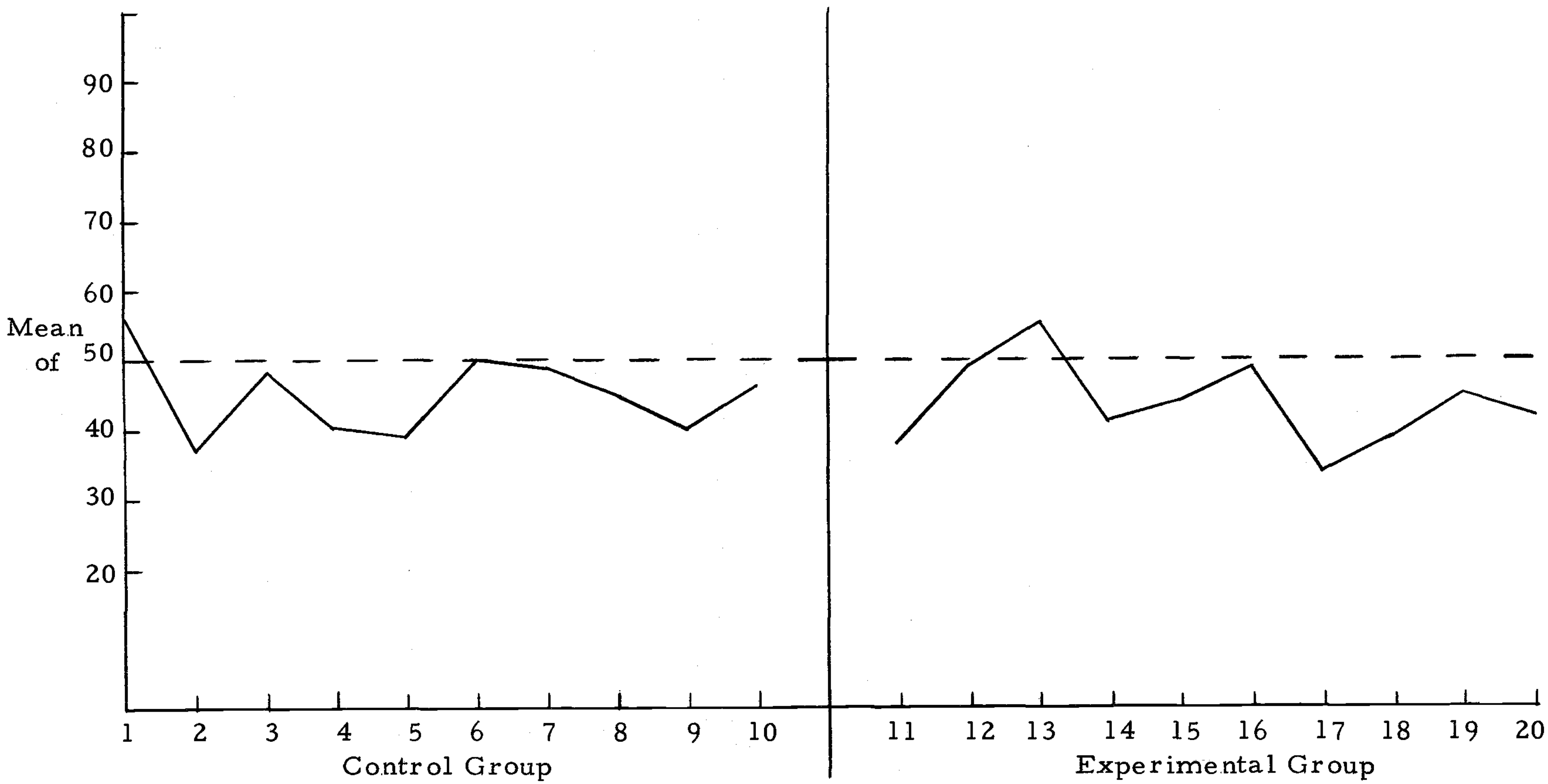
	Control	Experimental
Means	323	355. 6
Student's t-value	1. 307	



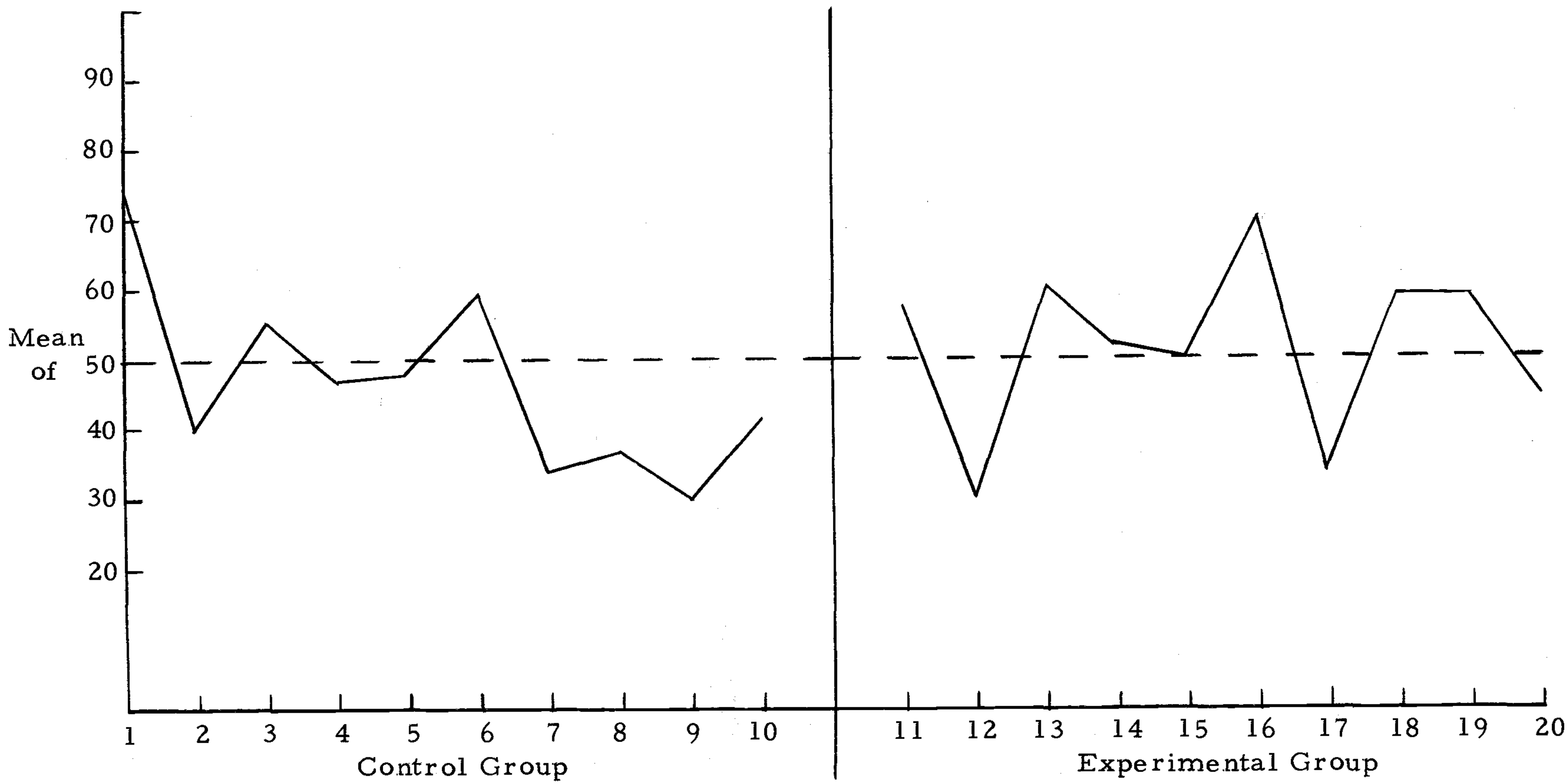
Graph 4. 1. Comparison of T-scores for Verbal Fluency. (This graph was drawn from the data in Table 4. 1).



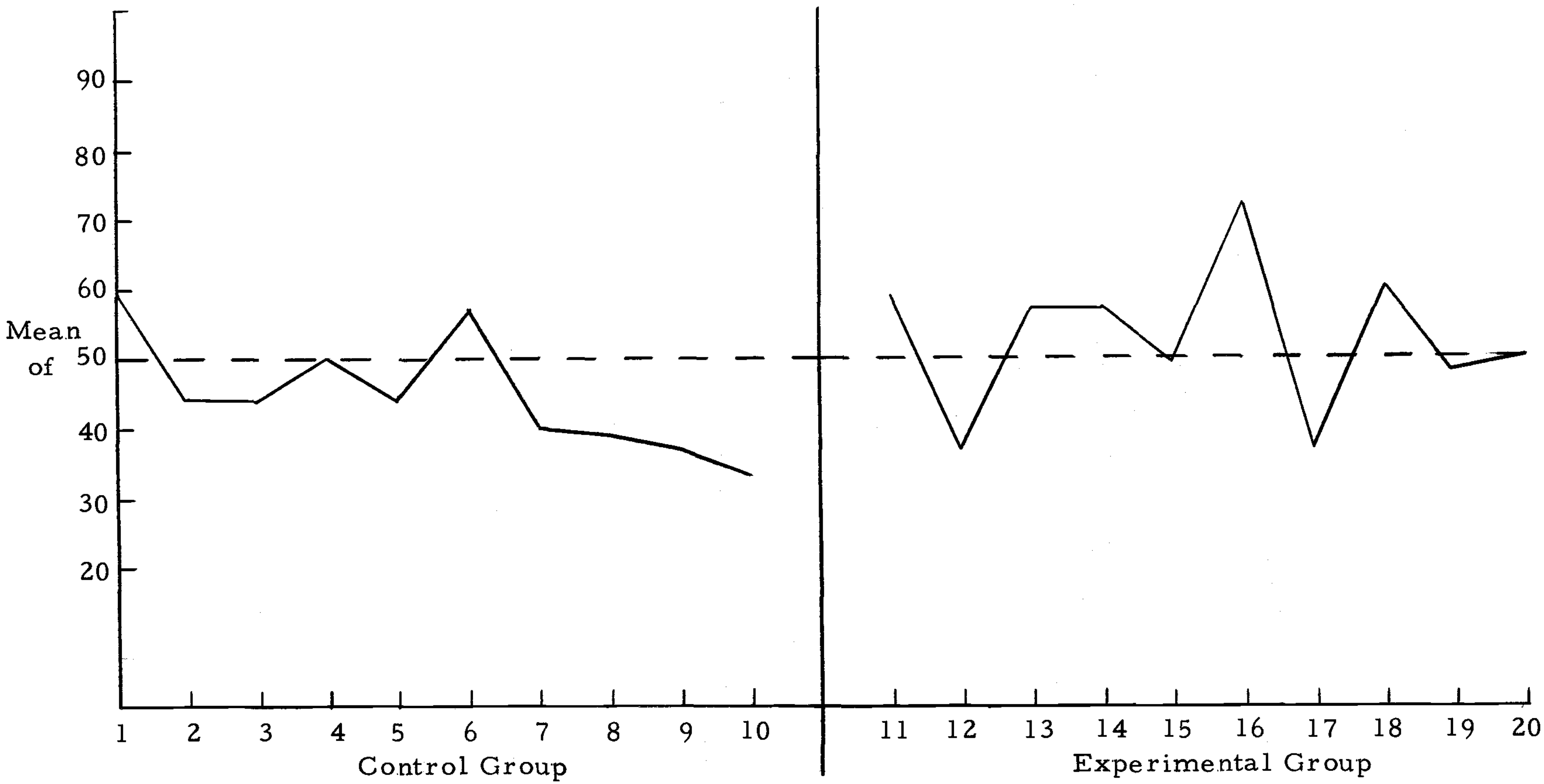
Graph 4. 2. Comparison of T-scores for Verbal Flexibility. (This graph was drawn from the data in Table 4. 1).



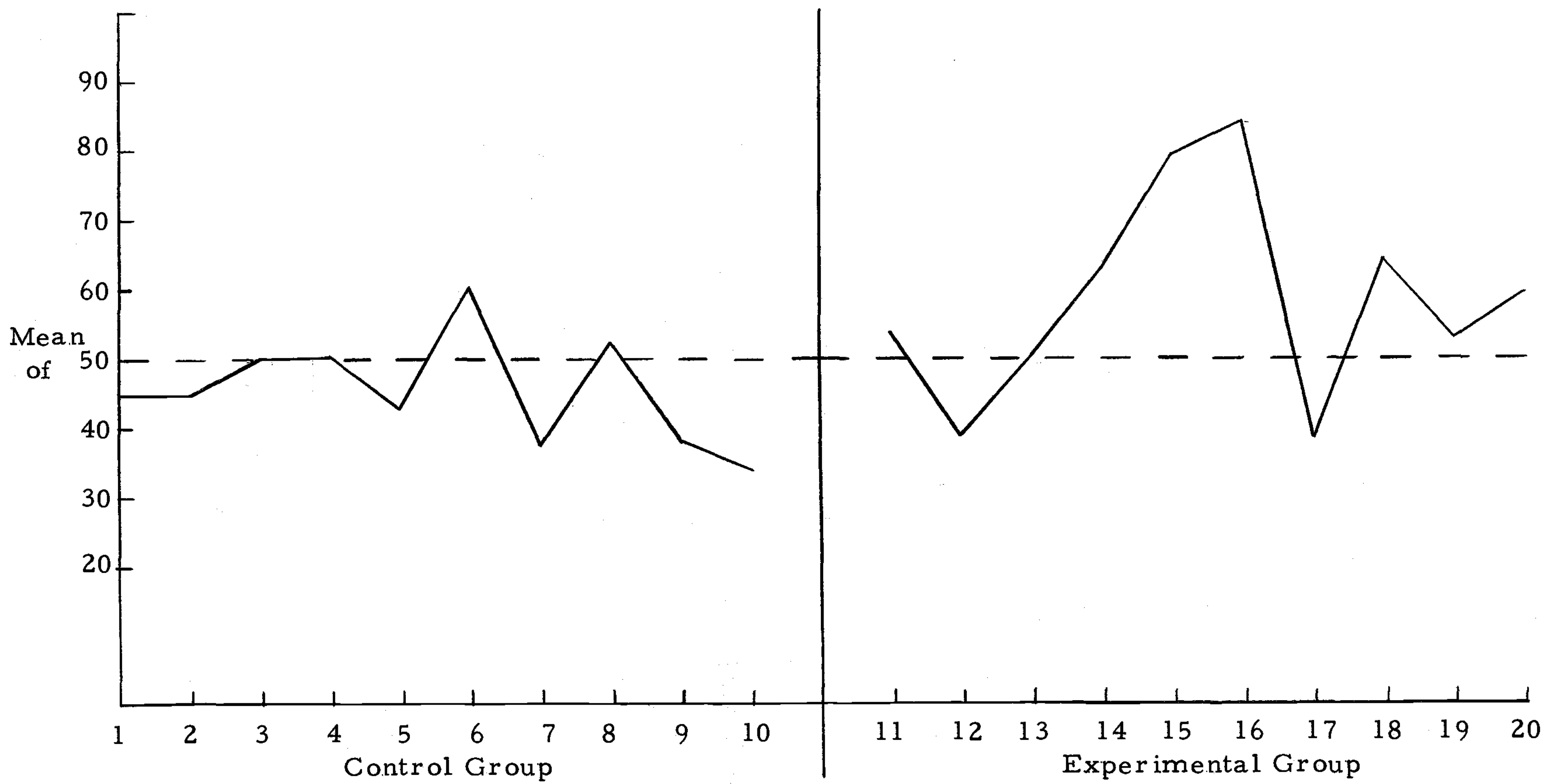
Graph 4.3. Comparison of T-scores for Verbal Originality. (This graph was drawn from the data in Table 4.1).



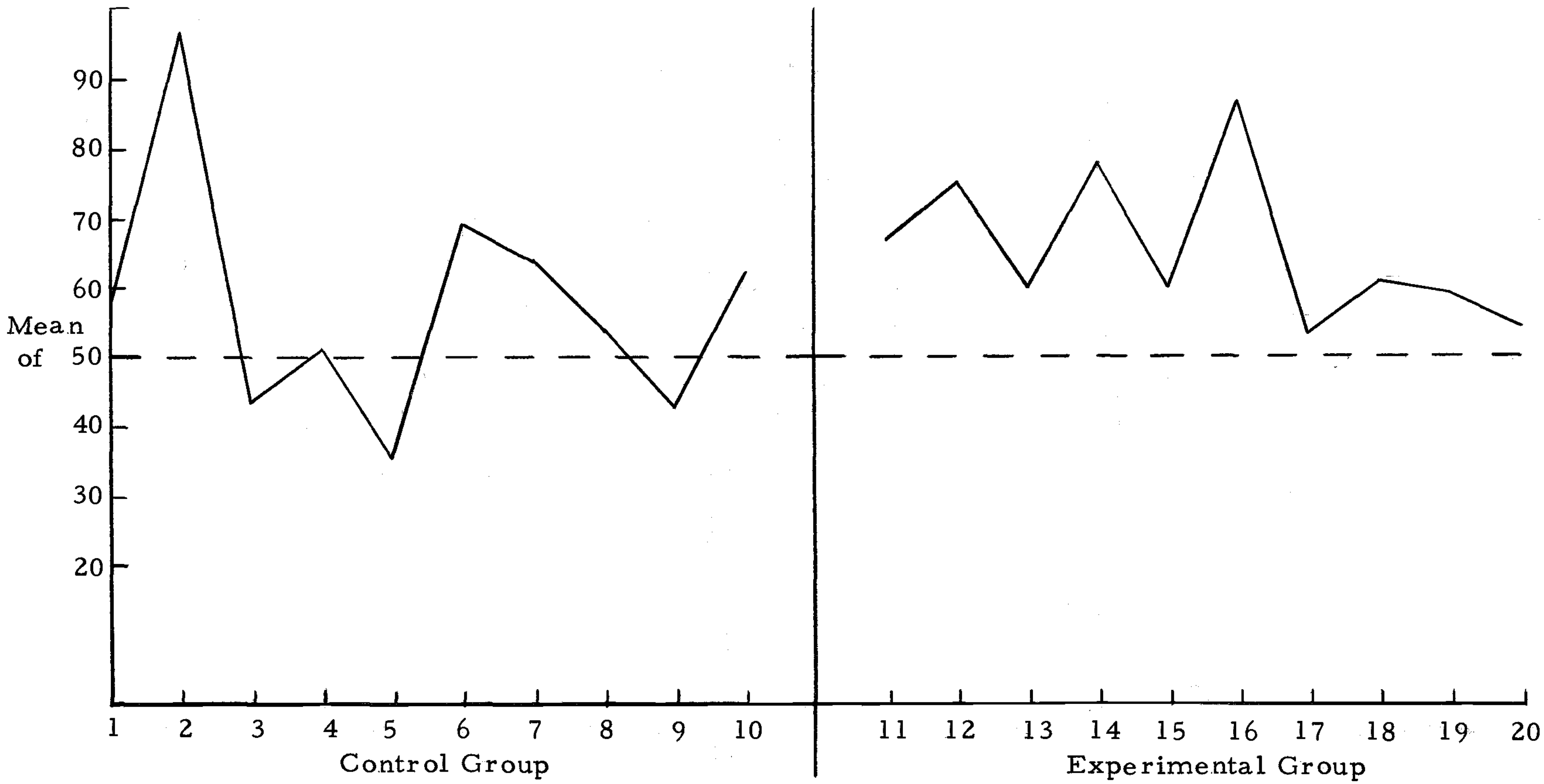
Graph 4.4. Comparison of T-scores for Figural Fluency. (This graph was drawn from the data in Table 4.1).



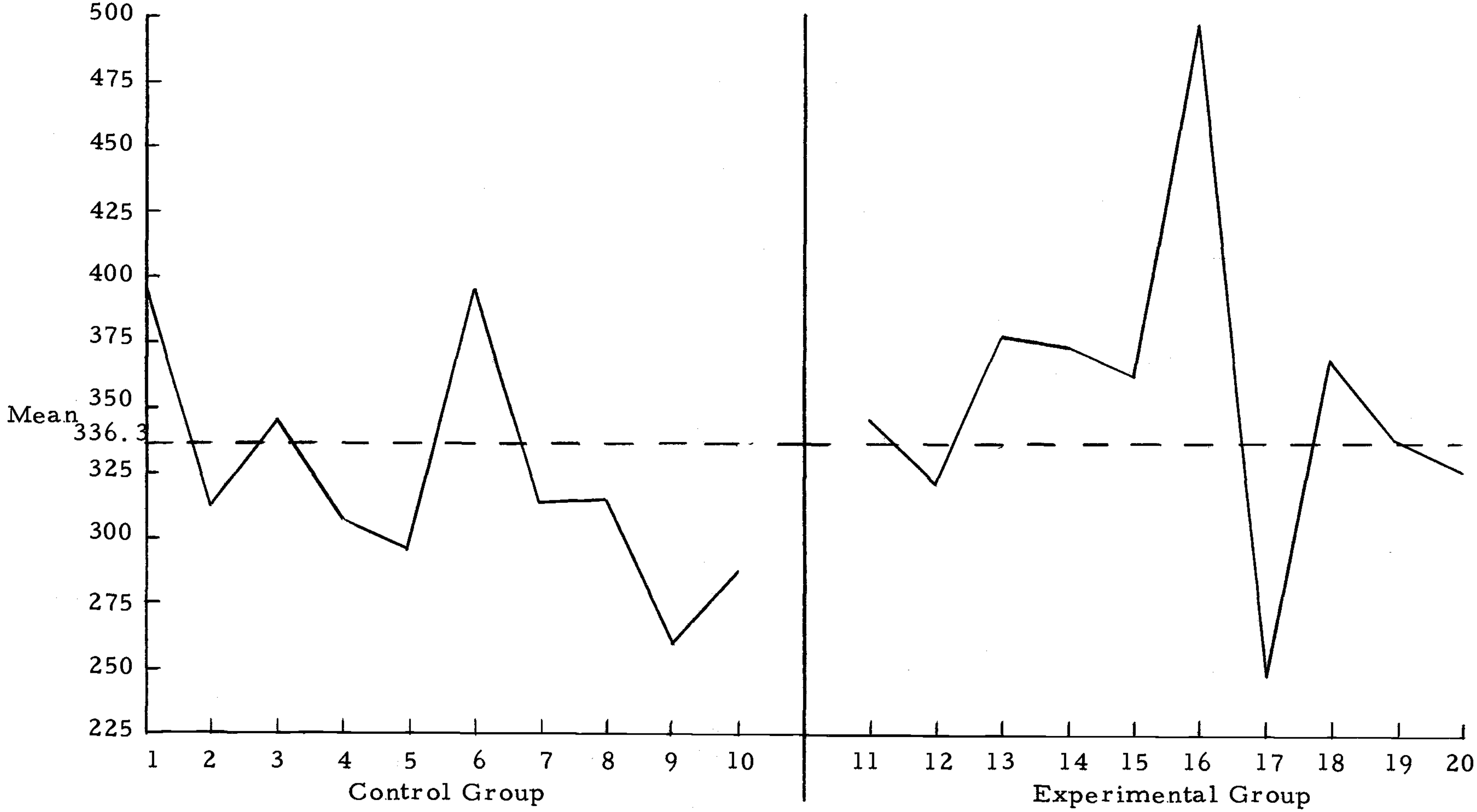
Graph 4.5. Comparison of T-scores for Figural Flexibility. (This graph was drawn from the data in Table 4.1).



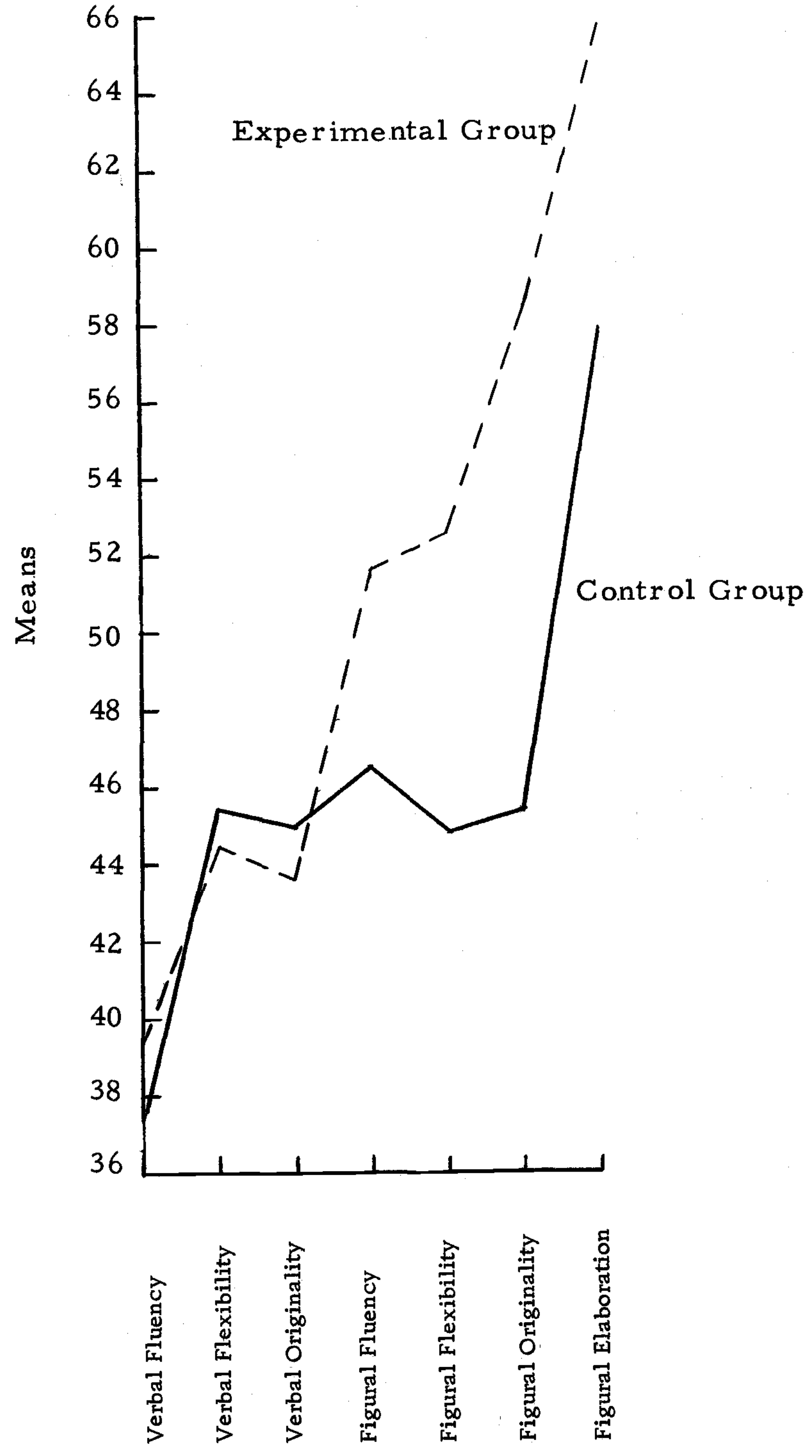
Graph 4.6. Comparison of T-scores for Figural Originality. (This graph was drawn from the data in Table 4.1).



Graph 4.7. Comparison of T-scores for Figural Elaboration. (This graph was drawn from the data in Table 4.1).



Graph 4.8. Comparison of Composite T-scores.



Graph 4.9. Comparison of calculated means from unpaired t-test.

Test of Major Hypothesis

The data from Table 4.2 and 4.3 was scrutinized to determine whether a significant difference occurred between the experimental and control groups.

Based on Tables 4.2 and 4.3 the hypothesis:

H_{01}: There will be no difference between the two groups in their performance on tests for divergent-productive thinking.

was not rejected. That is, the treatment made differences in three categories of divergent-productive thinking skills. This writer believes that an extended time spent with experimental activities would produce a more significant difference in more of the categories.

Test of Minor Hypotheses

The data from Table 4.1 was subjected to the Student's t-test to determine whether or not a significant difference occurred between the means of the experimental and control groups in any of the seven categories: verbal fluency, verbal flexibility, verbal originality, figural fluency, figural flexibility, figural originality, and figural elaboration. The results from this test can be observed in Table 4.2. Three of the categories can be observed to have significant differences.

Based on Table 4.2 the hypothesis:

$H_{3\ minor}$: There will be no difference between the two groups in their performance on tests for verbal originality.

was not rejected at the .20 level. The treatment may allow an individual to make a mental leap or departure from the obvious and the commonplace in terms of generating original ideas.

$H_{5\ minor}$: There will be no difference between the experimental and control groups on the test for figural flexibility.

was rejected at the .10 level. That is, there is sufficient evidence that the experimental group was more effective in producing many different kinds of configurations from a basic idea.

$H_{6\ minor}$: There will be no difference between the experimental and control groups on the test for figural originality.

was rejected at the .05 level. That is, there is sufficient evidence that the experimental group was more effective in producing more original kinds of configurations than would non-treatment subjects.

Based on Table 4.3 the hypothesis:

$H_{8\ minor}$: There will be no difference between the means of the experimental and control groups.

was not rejected for the composite T-scores. That is, there was no evidence to infer that the treatment was more effective than no treatment in terms of developing all facets of divergent-productive thinking skills. An extension of treatment time may allow for a significant difference to emerge.

Summary

Based upon the unpaired t-test there was found to be significant differences in three categories: verbal originality, figural flexibility, and figural originality.

The null hypothesis:

H_{01}: There will be no difference between the two groups in their performance on tests for divergent-productive thinking.

was not rejected. $H_{3\ minor}$ was not rejected at the .20 level for verbal originality. $H_{5\ minor}$ was rejected at the .10 level for figural flexibility. $H_{6\ minor}$ was rejected at the .05 level for figural originality.

Based upon the composite data from Table 4.3 the null hypothesis:

$H_{8\ minor}$: There will be no difference between the means of the experimental and control groups.

was not rejected for all composite scores as there was no significant evidence the experimental and control groups were different. However, an extension of time for the treatment group may allow for significant differences to emerge.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to assess the differential effects of a specific set of elementary science materials, the attribute block portion of the The Elementary Science Study materials, Attribute Games and Problems, on the acquisition of divergent-productive thinking skills by selected elementary school children.

The experimental Ss were fifth-grade children who had had no previous experience with the materials. The Ss were obtained from one public elementary school district in Oregon and involved with the materials for fifteen consecutive school days, each experimental activity session lasting approximately forty-five minutes during the time they would have normally had a science period. All Ss in the experimental group completed all the experimental activities, and, with the control group, all portions of both parts of the tests. The control group were children from a different elementary school in the same district. The classes from which the Ss came were randomly selected from the school district population of fifth-grade classes. Ss were randomly selected from each class and randomly assigned to one of the two groups.

The experimental activities involving the Ss were designed to develop strategies calling upon divergent-productive thought modes.

These strategies involved the manipulation of the blocks in a framework of activities which required the Ss to create new ideas (divergent production of implications) as well as producing uncommon or clever responses (divergent production of transformations).

Other areas of divergent thinking (divergent production of units, classes, relations, and systems) were brought into play in various experimental activities.

Throughout the treatment sessions in which the Ss were actively involved in the experimental activities an atmosphere conducive to enquiry learning was maintained by the E.

At the conclusion of the experimental activities the Torrance Test of Creative Thinking, Verbal Form A and Figural Form A, was administered to the experimental and control groups in two sessions on consecutive days.

Conclusions

Raw data from the test results was compared with standardized values derived from Torrance's T-score conversion tables based on fifth grade data and converted to T-scores. Student's t-test was used to determine the level of significance of the converted T-scores. From these results it was inferred that the treatment effects were significant in three categories of divergent-productive thinking: verbal originality, figural flexibility, and figural originality.

Although the level of significance was .20 for the verbal originality, this writer did not reject the null hypothesis:

> H_{01}: There will be no difference between the two groups in their performance on tests for divergent-productive thinking.

because this is part of the divergent-thinking skills involved in an Ss ability to produce ideas that are away from the obvious, commonplace, banal, or established. Torrance (1966, p. 73) writes,

> The person who achieves a high score on Verbal Originality usually has available a great deal of intellectual energy and may be perceived as rather nonconforming. He is able to make big mental leaps or "cut corners" in obtaining solutions, but this does not mean that he is erratic or impulsive in his behavior. In fact, the making of original responses requires the ability to delay immediate gratification or reduction of tension in order to get away from the obvious, easy, but low quality response.

For these reasons and the obvious importance of the mental skill described, this writer concludes that the results could be important.

The significance of .10 for figural flexibility indicates the Ss might be quite flexible in viewing, manipulating, and otherwise using figural elements. This category is related to verbal flexibility. The conclusion this writer reaches is that Ss may be quite restricted in shifting approaches in dealing with words, hence the lack of significance in the category verbal flexibility, but adept in shifting approaches with figural objects.

H_{01} was rejected at the .10 level for figural originality and the inference made that those scoring high in this category have an ability to delay gratification or reduction in tension when they are producing ideas away from the obvious, commonplace, banal, or established. The reader will note the similarity here with the verbal originality category.

The null hypothesis:

$H_{8\ minor}$: There will be no difference between the means of the experimental and control groups.

was not rejected for all the composite scores because the Student's t-value of 1.307 approached significance. At what level this would become significant would be based upon the prediction that an extended time for the experimental activities sessions would increase the t-value of significance.

Recommendations for Additional Research

Based upon the data gathered in this study, the investigator recommends that,

1. The length of time for experimental activities be expanded to take advantage of individuality in developing mental skills.

2. The additional sequence of materials in the ESS unit Attribute Games and Problems (Colored Cubes, and People

Pieces) be utilized using the design of this study.

3. Five- and six-year olds should be examined to determine whether or not the perceptual training of attribute blocks and subsequent divergent-productive thinking alters results obtained by Piaget indicating the age at which children think in a formal operational mode.

Recommendations for Elementary Curricula

1. Elementary schools utilize materials that lead to the development of particular thinking-skill processes in their curricula that can be utilized in many content-oriented ways.
2. Materials and strategies be utilized to allow a student to gain confidence in his own abilities to handle manageable complexities rather than be coerced into convergent thinking of 'adult-centered' answers.
3. Science educators perceive an elementary school science program as one which capitalizes on young children's curiosity of natural phenomena and use this as a basis or vehicle to emphasize the development of specific thinking skills of creative and critical thinking.

Epilogue

This study attempted to correlate Guilford's Structure of Intellect Theory with a set of elementary science materials and Torrance's Tests of Creative Thinking in a way meaningful to the interpretation of teachers in the American classroom. Hopefully, this writer believes that an increase in awareness on the part of classroom teachers to the application and practicality of using contemporary elementary science materials coupled with theory can and will prove useful and productive in terms of what children learn.

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APPENDICES

APPENDIX I

IMPLICATIONS FOR SCIENCE LEARNING FROM THE STRUCTURE OF INTELLECT THEORY

Implications for science learning from the structure of intellect theory (Adapted from Hubbard, 1967, p. 42-3).

The following table will serve as a guide to Figure 1.1, p. 6, for translating elements of the Guilford model into elementary science teaching terms.

OPERATIONS LEVEL - Functioning	Science learning
1. Cognition Perceiving and understanding information	Understanding terminology of science Familiarization with historical discoveries Learning theories underlying modern science Acquiring science laboratory skills
2. Memory Retaining what is learned	Remembering how to use tools in laboratory work Recognizing science concepts, principles, etc.
3. Divergent Thinking Searching for new answers	Inventing solutions to new science problems Reorganizing known information into new concepts

OPERATIONS LEVEL - Functioning	Science learning
4. Convergent Thinking Searching for the right answer	Discovering more precise methods for using materials Refining an ability to explain a concept Producing science materials relative to a standard
5. Evaluation Making decisions on goodness or correctness	Making fine discriminations Employing knowledge and logical argument to appraise science work Making judgements
CONTENTS LEVEL - Kinds of Information	
1. Figural Information representing nothing but itself	Size, shape, color and space as entities which together compose real objects
2. Symbolic Coded material	Abbreviations for chemicals, arithmetical computation, etc. Relationships of sets, patterns in nature, regulatory functions, etc.
3. Semantic Meaning attached to things	Verbal explanation of science as in history and theory Visual organization of figural and symbolic material

PRODUCTS LEVEL - Outcomes of Thinking

1.	Units Single items of thought	Being able to remember an amoeba Understanding the concept of a cell Discovering how to make a new smell with two chemicals
2.	Classes Series of units	Knowing all the names of protozoans Being able to make subsets of different triangle-shaped blocks
3.	Relations Relationships between units	Seeing and drawing comparisons between man and apes Being able to discriminate between differences of protozoans
4.	Systems Patterns composed of units	Understanding the taxonomy of protozoans Understanding a matrix of blocks
5.	Transformations Modifications of known arrangements	Reorganizing shapes to make a new system Describing similar historical sequences in biology Learning to see familiar things in an unusual way
6.	Implications Predictions based on available information	Anticipating the outcome of an experiment Foreseeing a trend in one area of science

APPENDIX II

SOURCE OF ATTRIBUTE GAMES AND PROBLEMS MATERIALS

The materials for Attribute Games and Problems can be obtained from:

McGraw-Hill Book Company
Webster Division
Manchester Road
Manchester, Missouri 63011

or from the eastern distribution office at:

330 West 42nd Street
New York, New York 10036

or from the western distribution office at:

8171 Redwood Highway
Novato, California 94947

The Attribute Games and Problems unit is made up of three components; A-Blocks (used in this study), Color Cubes, and People Pieces. A teacher's guide and problem cards are also available. The individual order numbers follow should one wish to get individual components of the unit:

A-Blocks	07-018481-X
Color Cubes	07-018483-6
People Pieces	07-018482-8
Teacher's Guide	07-018479-8
Problem Cards	07-018480-1