7913053

LEE, SANDRA GALE
CREATIVITY AND ITS IMPLICATIONS FOR SECONDARY COLLEGE-PREPARATORY MATHEMATICS EDUCATION.

THE UNIVERSITY OF NORTH CAROLINA AT GREENSBORO, ED.D., 1978

University Microfilms International 300 N. ZEEB ROAD, ANN ARBOR, MI 48106

CREATIVITY AND ITS IMPLICATIONS FOR SECONDARY COLLEGE-PREPARATORY MATHEMATICS EDUCATION

by

Sandra Gale Lee

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

Greensboro
1978

Approved by

Lois V. Edinger
Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

Dissertation Adviser: Lois V. Edinger

Committee Members: William P. Love

Andrew E. Long, Jr.

Richard H. Weller

Dwight F. Clark

November 2, 1978
Date of Acceptance by Committee

November 2, 1978
Date of Final Oral Examination

LEE, SANDRA GALE. Creativity and Its Implications for Secondary College-Preparatory Mathematics Education. (1978)
Directed by: Dr. Lois Edinger. Pp. 140.

A great deal of research has been done in the area of creativity since 1950. Nevertheless, there is still a scarcity of creativity in the schools today. There are several reasons for this situation. Part of the problem is a lack of consensus as to the meaning of creativity. The term creativity is often used by educators to mean any fun and non-intellectual activity. This misuse of the term causes the student to believe that creativity can be achieved with little effort. Another extreme position is to reserve the term only for those creative geniuses who have produced highly acclaimed products. This reflects an elitist viewpoint of creativity.

Neither of these perspectives was espoused in this paper. Creativity was regarded as a universal trait to be developed in every human being. For purposes of this study, creativity was defined as an ability to go beyond the commonplace and ordinary, an ability to combine information and/or experience in a unique and insightful way.

Another reason for the lack of creativity in schools is that creativity is not valued by the general public. To many, creativity is to be worked toward only if time is "left over" after everything "important" has been achieved. Until administrators, teachers, and the general public realize that creativity is an essential ingredient in the curriculum, there can be little hope for developing the creative individual.

The lack of creativity in the schools is particularly evident in the area of secondary mathematics. Very little has been written

regarding creativity in this area. Mathematics teaching today is mechanistic and skill-oriented; mathematics is regarded primarily in terms of computational abilities. This trend shows signs of spiraling because of the pressures of the "back-to-basics" proponents. Since creativity was regarded as a generalized trait, mathematical creativity was defined in this study by inserting the word mathematics at appropriate points. Hence, mathematical creativity was defined as an ability to go beyond the commonplace and ordinary in mathematics, an ability to combine mathematical information and/or experience in a unique and insightful manner. This definition was later expanded by listing traits of mathematical creativity.

Creativity is an elusive quality which exists in degrees. There is no classroom which can be classified as either totally creative or totally uncreative. Just as every individual possesses some degree of creativeness, every classroom has some degree of creativity. Unfortunately, it occurs in the classroom sporadically. If creativity is a significant goal, then some effort must be made to plan for it.

The model developed in this study represents a conscious effort to plan for creativity in secondary mathematics college-preparatory classrooms. Findings in the literature on creativity, mathematics, curriculum, and mathematics education form the theoretical basis for the model. The model consists of three basic components: creative course content, creative strategies, and flexible classroom organization. Each of the components is influenced by several criteria.

Creative course content should reflect a large background of information, reveal the essential nature of mathematics, be "holistic," contain problems with many correct answers, sometimes be "irrelevant," and allow student choice. Creative strategies should be influenced by the creative teacher's behavior and role, the inquiry-discovery approach, the need for requiring synthesis, encouraging different approaches in problem-solving, and allowing inquiry in depth. Flexible classroom organization should allow for active (exploratory) and quiet (reflective) periods, various grouping arrangements, modular scheduling, student input, and measurement of higher levels of the cognitive domain through more open-ended testing.

ACKNOWLEDGEMENTS

This writer expresses sincere appreciation to her committee chairman, Dr. Lois Edinger, who so generously gave her time and assistance during the process of this study. She further expresses her gratitude to other committee members for their help--Dr. Dwight Clark, Dr. Richard Weller, Dr. William Love, and Dr. Andrew Long.

She also wishes to thank her mother, Mrs. Evelyn Lee and her sisters, Janie and Kathleen, for their interest and encouragement.

TABLE OF CONTENTS

Page

CHAPTER

LIST OF FIGURES

CHAPTER I

Background and Introduction

Although there is a preponderance of research and rhetoric in the area of creativity, schools today are no more creative than they were fifty years ago. There have been very few underlying changes of any nature in the curriculum through the years. In the words of one writer:

> Despite numerous advances in our society, the same subjects that are being taught now were taught fifty years ago. Upon awakening, Rip Van Winkle would be surprised at the modern buildings, materials, and furniture, but would be right at home with the curricula.[1]

Many indictments have been leveled against the schools because of their lack of creativity. Lawrence Peter's criticism of colleges could be applied to almost any grade or educational level:

> Undergraduate courses tend to produce passive, conforming students who deny nothing, who absorb and regurgitate, who express only neutrality. Any malcontent who refuses to enact this role is considered an incompetent student and does not graduate. The passive, conforming undergraduate is eligible for promotion to graduate school where it is assumed that he will be a competent creative scholar. . . . Within the educational hierarchy creativity cannot flourish.[2]

Among those who criticize the schools for a lack of creativity are individuals reputed to be highly creative themselves. Albert Einstein, in explaining why he was unable to think about scientific problems for

---

[1]Alfred DeVito, "Survival Through Creative Education," Journal of Creative Behavior 10 (No. 1, First Quarter 1976): 45.

[2]Lawrence Peter, "The Peter Principle: We're All Incompetent," Phi Delta Kappan 48 (March 1967): 340.

a year after his final exam, says: "It is nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry."[3] These quotations vividly illustrate the need for a careful re-examination of our schools with respect to creativity.

Very few teachers consciously nurture creativity in their classrooms. J. P. Guilford maintains:

> No one knows as yet how we can best educate for creativity. The better teachers have probably always made some contributions in these directions, often without being able to say explicitly just what they did or why. On the other hand, we suspect that poor teaching has actually many times put the brakes on development towards creativity, . . .[4]

Creativity is much too important to be left to chance any longer. It is the responsibility of educators to determine how best to develop and sustain creativity.

Creative behavior is important in every subject, ability, and grade level. This study, however, is concerned with creativity in high school college preparatory mathematics. An extensive review of the literature on creativity leads one to conclude that secondary mathematics is one area of the total curriculum in which creativity is almost ignored. Kilpatrick writes that very few studies of creative behavior have dealt directly with mathematics. Even in those few the focus was primarily

---

[3]George Leonard, Education and Ecstasy (New York: Dell Publishing Company, 1968), p. 233.

[4]J. P. Guilford, "Creativity: Its Measurements and Development," in A Source Book for Creative Thinking, eds. Sidney J. Parnes and Harold F. Harding (New York: Charles Scribner's Sons, 1962), p. 164.

on constructing instruments to gauge mathematical creativity.[5]

Although "new math" was not designed primarily for the purpose of developing creativity, many of its stated objectives seemed to give promise in this direction. As an example, one well-known "new math" group, School Mathematics Study Group (SMSG), boasted that it viewed the mathematics program as a whole rather than as a collection of separate subjects. One of its aims was to "break down compartmentalization."[6] While the aim would have enhanced creativity, neither SMSG nor any other curriculum group adequately achieved this. In fact, many of the "new math" objectives were never fulfilled. In 1974 the National Advisory Committee on Mathematics Education (NACOME) was formed to examine the status of mathematics teaching in grades K-12. Shirley Hill, chairman of that committee, asserts: ". . . evidence we could accumulate raised serious questions in our minds that the fundamental principles of 'new math' curriculum and instruction ever made their way into any broad cross section of American schools . . ."[7]

Very few major changes have occurred in the high school mathematics curriculum over the past fifty years. The rationale behind this static state of the secondary college preparatory mathematics curriculum is explained by Morris Kline:

> Our high school curriculum is a relic of the nineteenth century. It was fashioned by college professors of limited knowledge and

---

[5]Jeremy Kilpatrick, "Problem-Solving and Creative Behavior in Mathematics," in Studies in Mathematics, ed. School Mathematics Study Group, 19 (Leland Stanford Junior University, 1969), p. 166.

[6]E. G. Begle, "SMSG: The First Decade," The Mathematics Teacher, 61 (March 1968): 242.

[7]Shirley Hill, "Issues from the NACOME Report," The Mathematics Teacher, 69 (October 1976): 441-442.

> handed down to the high schools when the colleges decided that they were prepared to start mathematics education at a higher level. The high schools took over these courses and, like obedient children, accepted the role of preparing students for college work: thus the constant refrain of "educating the college bound." This ghost of the past haunts us, and we do not seem to be able to shake ourselves free of it.[8]

A comparison of A Guide to Curriculum Study, published in 1959 by the North Carolina Board of Education, and High School Curriculum Guide, published in 1976 by the North Carolina State Department of Public Instruction, reveals the lack of change between the earlier mathematics, "new mathematics," and present mathematics curricula. The 1959 Guide contains a list of course outlines in use prior to that date and recommended "new math" course outlines. These two sets of outlines are more similar than the authors of the Guide indicate. The one significant change was the fusion of plane and solid geometry which created more unity within the geometry curriculum.

Some other changes were new terminology, the inclusion of properties of the number system, and the use of "unifying" ideas such as set. Unfortunately, these changes were often superficial and improperly implemented. A further comparison between the "new math" changes proposed in the 1959 Guide and the 1976 Curriculum Guide again showed few significant curriculum altérnations.

Morris Kline observes that one difficulty with the "new math" curriculum was the speed with which "new math" programs were developed. In many instances, curriculum groups did not satisfactorily test their material before putting it in the schools. As a result, some of the texts which purported to present new math actually presented

---

[8]Morris Kline, "NACOME: Implications for Curriculum Design," The Mathematics Teacher 69 (October 1976): 453.

traditional mathematics with a sprinkling of symbolism, terminology, and jargon or with a high degree of abstraction.[9]

The secondary mathematics curriculum currently in use does not foster creativity; indeed, it appears headed in the opposite direction. Many mathematics teachers do not attempt to work toward mathematical creativity unless time is "left over" from "more pressing matters." One experiment in a culturally enriched surburb demonstrated that a group of students enrolled in an advanced algebra course who had completed a year of geometry were less creative with verbal content and no more creative with figural content than students who had not taken the additional mathematics course.[10]

Fitzgerald deplores the fact that most mathematics teaching is "mechanistic" and "skill oriented."[11] This trend appears destined to accelerate, due at least in part to the efforts of the "back-to-basics" proponents. The fact that mathematics is primarily regarded in terms of computational abilities could be illustrated by the title of the 1978 NCTM Yearbook--Developing Computational Skills. The advertisement reminds teachers that it is "a very timely yearbook. . . because of the renewed emphasis on basic skills and the public concern for the

---

[9]Ibid., pp. 449-450.

[10]This experiment was cited in Ann Dirkes, "Intellectual Development through Interdisciplinary Problem Solving," School Science and Mathematics 75 (April 1975): 321. No further information was available since the original source was an unavailable unpublished dissertation also by Dirkes.

[11]William M. Fitzgerald, "The Role of Mathematics in a Comprehensive Problem Solving Curriculum in Secondary Schools," School Science and Mathematics 75 (January 1975): 40.

achievement of computational skills."[12] The "back-to-basics" advocates stress an ability to manipulate numbers rather than an ability to reason creatively. This produces students who are, at best, competent technicians. Hence, according to Fitzgerald, students leave mathematics classrooms with little conceptual understanding of mathematics and with negative attitudes toward mathematics.[13]

In a recent newspaper article George Polya, internationally known for his creative approaches as a mathematics educator, summarizes the current dilemma in mathematics education: "Schools should teach mathematics better. It tends to be the least popular subject. Mathematics teachers should arouse the kids and make them like mathematics."[14] Only through a more creative approach can mathematics teachers accomplish this goal.

Statement of the Problem

In light of the evidence that is available, the problem to be examined is: can creative behavior be nurtured in the secondary college preparatory mathematics curriculum? More particularly, how can it be nurtured in the secondary college preparatory mathematics curriculum? Other questions raised in this study include:

1. What strategies should the teacher employ?
2. What course content is necessary?

---

[12] Advertisement from National Council of Teachers of Mathematics, 1978.

[13] Fitzgerald, "The Role of Mathematics in a Comprehensive Problem Solving Curriculum in Secondary Schools," School Science and Mathematics, p. 40.

[14] Alton Blakeslee, "Math Takes the Guesswork Out of Life," The High Point Enterprise, 7 May 1978, Sec. 18C.

3. How should the mathematics classroom be organized to facilitate creative behavior?

Purpose of the Study

The purpose of this study is to develop a theoretical model for a creative high school college preparatory mathematics classroom. This model will draw its theoretical base from findings in the literature on creativity, mathematics, curriculum, and mathematics education. Certain aspects of the model have been investigated through actual practice in the classroom.

Limitations

1. The model is concerned only with structuring for creativity at a particular level, grade, and subject area--college preparatory secondary mathematics.

2. The model is more theoretical than pragmatic. It is essential, however, that theory precede and serve as a guide to the practical.

3. This study does not address itself to implementation of the model. Indeed, the prevailing high school structure may prevent certain aspects of the model from being implemented (e.g. modular scheduling).

Definition of Terms

For the purposes of this study, creativity is defined as an ability to go beyond the commonplace and ordinary, an ability to combine information and/or experience in a unique, insightful, and useful way. Since the writer regards creativity as a generalized trait, mathematical creativity is defined by using the basic definition given above and inserting the word mathematics at appropriate points. Thus, mathematical creativity is an ability to go beyond the commonplace and ordinary in mathematics, an ability to combine mathematical information and/or experience in a unique, insightful, and useful way. An elaboration of traits for mathematical creativity identified by the writer is found in Chapter III.

Design of the Study

The dissertation is philosophical in form and emphasis. Procedures used in the study are:

1. Review of the literature is conducted in the areas of creativity, general curriculum, the nature of mathematics, and the secondary mathematics curriculum.

2. From this review, tentative components of the model are determined.

3. Components of the model are examined in relation to practical classroom experience.

4. The model for a creative secondary mathematics classroom is further developed and presented.

Significance

The present structure and approach in secondary mathematics classrooms greatly limits the students' mathematical creativity. Many may see creativity and mathematics education as incompatible. In fact, one could hypothesize that high school mathematics is one of the most ignored areas in the present school curriculum with respect to creativity. This could be one reason for the negative attitudes of many students toward mathematics alluded to by Polya and Fitzgerald.

The model for a creative secondary college preparatory mathematics curriculum is hardly a panacea for the ills of mathematics education; rather, it is one step in the direction of inducing more creative behavior in mathematics classrooms. Through the model, a theoretical framework is provided to facilitate further research on creativity in mathematics education. The model also furnishes some guidelines for the development of materials and curricula designed to foster mathematical creativity. A valuable by-product of utilizing the model may be the development of more positive attitudes toward mathematics.

Organization of the Thesis

Chapter II contains a review of the existing literature pertinent to the study.

Chapter III provides a philosophical basis for the model.

Chapter IV is the development and presentation of the model for a creative secondary college preparatory mathematics classroom.

Chapter V provides a summary of the study and some general conclusions.

CHAPTER II

REVIEW OF THE LITERATURE

Early Theories of Creativity

Kneller notes that the ancient theories of creativity equated it with either divine inspiration or madness.[1] The divine inspiration concept had an elusive, mysterious quality. In the words of Taher A. Razik, education professor at the University of New York at Buffalo, creativity was conceived as a "property of genius which mysteriously accounts for his uncommon ability and which, by definition, the common man cannot understand or possess."[2] Creativity was regarded as an elitist power held only by a chosen few.[3] In the Middle Ages, the scientific pioneers--alchemists, physicists, anatomists--were sometimes suspected of owing their knowledge and skill to the devil.[4]

The Renaissance begot men such as Michaelangelo and Leonardo da Vinci who strengthened the viewpoint that creativity was a peculiar gift of a few geniuses.[5] This idea continued in the nineteenth century

---

[1]George F. Kneller, The Art and Science of Creativity (New York: Holt, Rinehart and Winston, Inc., 1967), pp. 18-20.

[2]John H. Douglas, "The Genius of Everyman," Science News, 23 April 1977, p. 268.

[3]Henry A. Murray, "Vicissitudes of Creativity," in Creativity and Its Cultivation, ed. Harold H. Anderson (New York: Harper and Brothers Publishers, 1959), p. 100.

[4]Arthur Koestler, The Act of Creation (London: Hutchinson and Company, 1964), p. 13.

[5]Douglas, "The Genius of Everyman," p. 268.

Romantic era, with particular emphasis on the arts and poetry as the major creative endeavors.[6] John Keats summarized the prevailing attitudes of his time when he proclaimed: "Men of genius are ethereal chemicals operating on a mass of neutral intellect."[7] During this same period, some even hypothesized that creative individuals were members of some rare anthropological species.[8]

The vestiges of the early religious or mystic explanations of creativity remained as late as the twentieth century. Kunkel and Dickerson (1947) saw the creative person as being shaped by forces outside his control--"for the source of creativity is not the individual but the We . . . not the individual but God who manifests himself in the We, of which the self is a part."[9] This mystical or religious myth has failed the test of evidence and serves only to impede educational programs aimed at fostering creativity.[10]

At the close of the nineteenth century, the first attempts were made to research creativity scientifically. Hereditary Genius, written by Sir Francis Galton and published in 1892, was devoted to a demonstration of the hereditary linkages among persons of outstanding achievement. Galton maintained that the important quality in genius was an

---

[6]Irving A. Taylor, "Psychological Sources of Creativity," Journal of Creative Behavior 10 (No. 3, Third Quarter 1976): 194.

[7]Douglas, "The Genius of Everyman," p. 268.

[8]Koestler, The Act of Creation, p. 13.

[9]Taylor, "Psychological Sources of Creativity," p. 193, citing Kunkel and Dickerson, How Character Develops (New York: Scribners, 1947).

[10]Douglas, "The Genius of Everyman," p. 268.

inherited, unacquirable intelligence and insisted that the best way to produce geniuses was to breed them.[11]

Another prevailing early myth was that of the close relationship between creativity and neurosis or even insanity. Lombroso (1891), Lange-Eichbaum (1932), and Jacobson (1909) wrote extensively on this relationship.[12] Nordau and Lombroso regarded the creative individual as an unbalanced pathological freak, suffering from hypotrophied cerebrum or a victim of some mental degeneracy akin to epilepsy.[13] Kubie (1958) and Roe (1959) refute this belief.[14] Kubie points out that with mental illness comes a freezing of behavior into unaltering repetitive patterns, obviously deterimental to creativity. Neurosis blocks creativeness in every field.[16]

There was a consensus among the renowned participants at the Interdisciplinary Symposia on Creativity at Michigan State University (1959) that neurosis either accompanies or causes a degraded quality of

---

[11] Francis Galton, Hereditary Genius: An Inquiry Into Its Laws and Consequences, 1976 facsimile (1892; rpt. New York: Horizon Press, 1952), pp. 1-4.

[12] Sidney J. Parnes, "Creativity: Developing Human Potential," Journal of Creative Behavior 5 (No. 1, First Quarter 1971): 19.

[13] Koestler, The Act of Creation, p. 13.

[14] E. Paul Torrance, Guiding Creative Talent (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962), pp. 133-134.

[15] Lawrence S. Kubie, "Blocks to Creativity," in Explorations in Creativity, eds. Ross L. Mooney and Taher A. Razik (New York: Harper and Row Publishers, 1967), p. 35.

[16] Lawrence S. Kubie, "Creation and Neurosis," in The Creativity Question, eds. Albert Rothenberg and Carl R. Hausman (Durham, N. C.: Duke University Press, 1976), p. 148.

one's creativity.[17] Torrance and Rogers also agree that creativity and neurosis have no relationship.[18] In other words, those neurotic persons who are also creative, are creative despite their neurosis. The disease results in the lowering of their achievement level.

Definitions and Theories of Creativity

Before any meaningful study of creativity can be achieved, one must have some familiarity with the various definitions and theories of creativity. While there is some degree of commonality in the research, there are many different orientations on creativity. Creativity is generally considered from any one of four categories or a combination of two or more of these categories: (1) the person who creates, (2) the mental process involved, (3) the environmental and cultural influences, (4) creative products. Although at one time creativity was studied primarily from a product standpoint, more recently there has been increased emphasis upon the creative process.[19] Many significant contributions have been made in the field of creativity. The following are definitions and theories of some of the foremost experts in this field.

Much of our research in creativity began with J. P. Guilford's Structure-of-the-Intellect Model. This model was devised around 1950 by Guilford and his associates at the University of Southern California.

---

[17] Harold H. Anderson, "Creativity in Perspective," in Creativity and Its Cultivation, p. 248.

[18] Torrance, Guiding Creative Talent, pp. 133-134; Parnes, "Creativity: Developing Human Potential," p. 19.

[19] Kneller, The Art and Science of Creativity, p. 3.

In this model, thinking abilities were classified through the use of factor analysis. The three dimensions of the model are operations, content, and product.[21] These dimensions are related since an operation acts on a given content to produce a product.

I. Mental Operation

   A. Cognition--discovery, rediscovery, or becoming aware of

   B. Memory--retaining that which has been cognized

   C. Divergent thinking--thinking in different directions, sometimes searching and seeking variety; many alternatives are found

   D. Convergent thinking--information leads to a single right or conventional answer

   E. Evaluation--assessment of that which has been cognized, memorized or produced to determine its correctness, suitability, or adequacy

II. Content

   A. Figural--concrete material as it is perceived through the senses

   B. Symbolic--letters, digits, and other conventional signs

   C. Semantic--verbal meanings or ideas

III. Product

   A. Units--segregated items of information

   B. Classes--aggregations of items of information having common properties

   C. Relations--recognized connections between items of information

   D. Systems--organized items of information having interrelated parts

---

[21] J. P. Guilford, Intelligence, Creativity, and Their Educational Implications (San Diego, California: Robert R. Knapp, Publisher, 1968), p. 54.

E. Transformations--changes of various kinds in information; this includes modifications in arrangement, organization, or meaning

F. Implications--extensions of information through extrapolating and foreseeing consequences[22]

One very significant creative operation identified by Guilford is divergent thinking. Divergent thinking includes fluency, flexibility, originality and elaboration.

Fluency is the sheer number of correct responses. Ideational fluency refers to an ability to produce a variety of answers to hypotheses when confronted with a problem.

Flexibility implies a change in meaning, use, strategy, or direction of thinking. One way of determining flexibility is by the number of categories into which ideas fall. The flexible individual has an ability to adapt to changing instructions, is free of inertia of thought, and uses a variety of approaches.

Originality involves uniqueness; that which is infrequently thought of by others. It might be determined by statistical infrequency of responses.

Elaboration is the number of details added to a basic idea.[23] It is sometimes referred to as one of the final steps in the total creative production.[24]

Two other basic traits of the creative individual as identified by Guilford are sensitivity to problems (in the category of

---

[22]Ibid., pp. 54-55. [23]Ibid., pp. 99-103. [24]Ibid., p. 211.

evaluation) and redefinition ability (in the category of convergent thinking).[25]

E. Paul Torrance defines creativity:

> . . . the process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results.[26]

Torrance recognizes that creative behavior deals with much more than divergent mental operations and the transformation product. Sensitivy to problems includes finding problems within one's environment and defects, needs, and deficiencies in one's world.[27] Many of Torrance's books--Guiding Creative Talent, Education and the Creative Potential, Encouraging Creativity in the Classroom, Creative Learning and Thinking--discuss environmental factors which induce creative behavior and have implications for classroom teachers.

Abraham Maslow identifies two types of creativity--special talent creativity and self-actualizing creativity. Those "gifted" individuals who turn out highly acclaimed products such as paintings, novels, theories, poems, etc., are exhibiting special talent creativeness. Self-actualizing creativeness, on the other hand, is within

---

[25] J. P. Guilford, "Traits of Creativity," in Creativity and Its Cultivation, p. 157.

[26] E. Paul Torrance, "Education and Creativity," in The Creativity Question, p. 217.

[27] E. Paul Torrance, Education and the Creative Potential (Minneapolis: The University of Minnesota Press, 1963), p. 94.

the realm of everyone and is regarded by Maslow as the most important type of creativity. The personality of the individual, not the concrete achievements or products, is stressed within self-actualizing creativity. Self-actualized individuals are more spontaneous and expressive, less controlled and inhibited in their behavior, and less self-critical. They show a tendency to do everything creatively, whether it be child-rearing or painting. Their ideas and impulses are freely expressed, without fear of ridicule from others.[28]

Erich Fromm also specifies two categories of creativity: (1) creativity in the sense of creating something new which can be seen or heard by others, (2) creativity as an attitude in which one has the ability to see (or be aware) and respond.[29] His second category, much like that of Maslow's self-actualization, he characterizes as most important. He sees awareness, both inside and outside of oneself, as a part of creativity.[30] Three essential conditions for creativity are: (1) the ability to be surprised, (2) the ability to concentrate, (3) the ability to accept conflict.[31] Fromm summarizes his perspective on creativity very succinctly:

> ". . . creativity in this sense does not refer to a quality which particularly gifted persons or artists could achieve, but an attitude

---

[28]Abraham H. Maslow, "Creativity in Self-Actualizing People," in Creativity and Its Cultivation, p. 85.

[29]Erich Fromm, "The Creative Attitude," in Creativity and Its Cultivation, p. 44.

[30]Ibid., p. 47. [31]Ibid., pp. 48-51.

> which every human being should and can achieve. Education for creativity is nothing short of education for living.[32]

Rollo May defines creativity as bringing something new into birth.[33] He believes that genuine creativity is distinguished by an intensity of awareness and heightened consciousness.[34] May writes much in the spirit of Maslow and Fromm:

> Any penetrating explanation of the creative process must take it as the expression of normal man in the act of actualizing himself. . . . And any enduring description of creativity must account for it in the work of the scientist as well as the artist, the thinker as well as the aestheticist, and must not rule out the extent to which it is present in the captains of modern technology as well as in a mother's normal relation with her child.[35]

Carl Rogers states that the creative process is "the emergence in action of a novel, relational product, growing out of the uniqueness of the individual on the one hand, and the materials, events, people, or circumstances of his life on the other."[36] Rogers differs from Maslow, Fromm, and May in stipulating that in order for creativity to occur, there must be some observable product.[37] However, similar to these three, he regards the mainspring of creativity as man's tendency to actualize himself, to become his potentialities.[38] He enumerates three inner conditions of creativity: openness to experience, internal

---

[32] Ibid., p. 54.

[33] Rollo May, "The Nature of Creativity," in Creativity and Its Cultivation, p. 57.

[34] Ibid., p. 61. [35] Ibid., p. 58.

[36] Carl R. Rogers, "Toward a Theory of Creativity," in The Creativity Question, p. 297.

[37] Ibid., p. 296. [38] Ibid., p. 298.

locus of evaluation, and the ability to "toy" with ideas.[39]

Margaret Mead and Theodule Ribot each maintain that if a person creates something new to him, he is being creative.[40] Ribot points out that a person may, in his ignorance, invent that which has been previously invented.[41] Despite the fact that this adds nothing to the world's existing knowledge, it is a creative act for the individual.

Frank Barron defines creativity as "the ability to bring something new into existence."[42] Unlike Rogers, he does not insist on the necessity of an observable product. Creativity is an internal process, continually in action but not always outwardly visible. The creative individual is more observant; he sees things both as others do and as others do not.[44] Creativity involves the reshaping of given materials whereby something new is made by the reconstitution of something old.[45]

Jerome Bruner sees creativity as being the result of

---

[39]Ibid., pp. 299-301.

[40]Margaret Mead, "Creativity in Cross-Cultural Perspective," in Creativity and Its Cultivation, p. 223; Theodule Armand Ribot, Essay on the Creative Imagination (New York: Arno Press, 1973), p. 156.

[41]Ribot, Essay on the Creative Imagination, p. 156.

[42]Frank Barron, "The Psychology of Creativity," in The Creativity Question, p. 190.

[43]Frank Barron et al., "Process Versus Product in Creativity: A Spontaneous Discussion of the Conference Participants," in Widening Horizons in Creativity: The Proceedings of the Fifth Utah Creativity Research Conference, ed. Calvin W. Taylor (New York: John Wiley and Sons, Inc., 1964), p. 112.

[44]Frank Barron, "The Needs for Order and for Disorder as Motives in Creative Activity," in Scientific Creativity: Its Recognition and Development, eds. Calvin W. Taylor and Frank Barron (New York: John Wiley and Sons, Inc., 1963), p. 159.

[45]Barron, "The Psychology of Creativity," p. 190.

"combinatorial activity" or placing things in new perspectives.[46] By ordering elements in such a way that one becomes aware of relationships that were not previously evident, creativity occurs.[47] Bruner warns that this means divorcing oneself from the obvious.[48]

Sarnoff Mednick's definition also centers around the combination aspect of creativity.

> The creative thinking process . . . is the forming of associative elements into new combinations which either meet specified requirements or are in some way useful. The more mutually remote the elements of the new combination, the more creative the process or solution.[49]

Arthur Koestler, writing in The Act of Creation, coins the phrase "bisociation" in discussing creative combinations. He distinguishes the various routines of associative thought on a single plane from the "bisociative" creative leap, which connects previously unconnected frames of reference and causes one to experience reality on several planes simultaneously.[50]

The more recent brain hemispheres theory of creativity offers a physiological basis for Guilford's distinction between convergent and divergent abilities.[51] The left hemisphere of the brain specializes in verbal material--recalling, classifying, explaining, and analyzing it.

---

[46] Jerome Bruner, "The Conditions of Creativity," in Contemporary Approaches to Creative Thinking, eds. Howard Gruber, Glenn Terrell, and Michael Wertheimer (New York: Atherton Press, 1967), p. 6.

[47] Ibid., p. 5. [48] Ibid., p. 12.

[49] Sarnoff A. Mednick, "The Associative Basis of the Creative Process," in The Creativity Question, p. 228.

[50] Koestler, The Act of Creation, pp. 35-36.

[51] Douglas, "The Genius of Everyman," p. 268.

The right hemisphere works with spatial forms and analogies. It is synthesis-oriented and operates in a holistic and relational manner. There are indications that the right hemisphere can take facts from the left hemisphere and make them more meaningful, or elaborate new combinations from existing information.

From clinical research, it appears that a functional balance and a flexible relationship is to be desired between both hemispheres in order to promote mental and bodily health. Unfortunately, however, environmental and schooling conditions promote a one-sided training of the left hemisphere. Very little is done to develop the more creativity-related right hemisphere.[52]

Traits of the Creative Individual

Three of the basic traits of the creative individual are the abilities to analyze, synthesize, and evaluate--the three upper levels of the cognitive domain. Analysis could be thought of as the preparation stage of the creative process.[53] In many cases, merely analyzing or breaking down the problem shows that the real problem is something other than the original interpretation.[54] Through analysis, one discovers relationships--likenesses and differences.[55]

---

[52] Wolfgang Luthe, Creativity Mobilization Technique (New York: Grune and Statton, 1976), pp. 6-7.

[53] John E. Arnold, "Creativity in Engineering," in Creativity: An Examination of the Creative Process, ed. Paul Smith (Freeport, New York: Books for Libraries Press, 1959), p. 38.

[54] Alex F. Osborn, Applied Imagination, 3rd ed., rev. (New York: Charles Scribner's Sons, 1963), p. 117.

[55] Ibid., p. 108.

Synthesis, or production, is the second phase of the creative process.[56] It is generally accepted as the most fruitful phase, therefore, the essence of creativity.[57] If the creator has properly executed the analysis stage, he has identified and isolated certain independent variables that affect the problem. Using these variables and combining past knowledge, he gets a cross-multiplying effect. One idea is associated with another until the creator finds a worthwhile combination.[58] Wescott and Meyer define an individual as creative if that which he produces is derived from combining two or more ideas in a new way.[59]

Ribot uses the term "mental chemistry" to stress the individual character of the synthesized product.[60] Creative is too often used to mean something totally "new" in the context of all of the world's knowledge. Koestler asserts that this is untrue; the creative act does not create something out of nothing. Instead, it selects and combines that which is already existing.[61] Stein agrees that a creative product arises

---

[56] Arnold, "Creativity in Engineering," p. 38.

[57] Osborn, Applied Imagination, p. 342.

[58] Arnold, "Creativity in Engineering," p. 41.

[59] Alvin M. Wescott and James A. Smith, Creative Teaching of Mathematics in the Elementary School (Boston: Allyn and Bacon, 1968), p. 2; Rochelle Meyer, Identification and Encouragement of Mathematical Creativity in First Grade Students, Part I, Chapter I-IV. (Bethesda, Md.: Eric Document Reproduction Service, ED 038 292, 1970), p. 4.

[60] Ribot, Essay on the Creative Imagination, p. 82.

[61] Koestler, The Act of Creation, p. 120.

from reintegration of already existing materials or knowledge.[62]

Dr. William Shockley, a scientist who received the Nobel Prize for his work on transistors and other solid state devices, claims that even the most creative thinker will evolve very few completely new ideas. Shockley points out that a man with two ideas relative to an invention can create in two ways, but a man with three pertinent ideas can arrive at six possible inventions. Assume you have acquired ten thousand ideas in your lifetime; the number of possible combinations would exceed all of the grains of sand on all of the beaches of the world.[63] One patent attorney states that out of the 50,000 patents issued annually, approximately 40,000 of them are merely improvements on ideas already patented.[64]

The evaluation, or decision-making, stage is essential to creativity.[65] It should not, however, be necessarily considered the last step in the creative process. After evaluating his product, the creative individual may decide to re-analyze and re-synthesize his components, creating a new and improved product. Thus, the evaluative process may be a prelude to new knowledge.[66]

To prepare for creativity, one must be open-minded and free

---

[62] Morris I. Stein, "Creativity and Culture," in Explorations in Creativity, p. 109.

[63] Myron S. Allen, Morphological Creativity (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962), pp. 40-41.

[64] Osborn, Applied Imagination, p. 345.

[65] Arnold, "Creativity in Engineering," p. 38.

[66] Benjamin S. Bloom et al., eds., Taxonomy of Educational Objectives: Classification of Educational Goals, Handbook I, Cognitive Domain (New York: David McKay Company, Inc., 1956), p. 185.

from prejudice. This implies being able to suspend judgment until all available ideas have been acquired and synthesized. The open-minded individual is willing to change. In the words of Mark Bernard, "Those who have an excessive faith in their ideas are not well fitted to make discoveries."[67] Allen insists that a concept firmly fixed in one's mind may prove to be the strongest barrier to the acceptance of ideas that would lead to the development of a better concept.[68] Rogers implies this when he discusses the importance of permeability of boundaries in beliefs.[69] According to Ghiselin:

> The first need is therefore to transcend the old order. Before any new order can be defined, the absolute power of the established, the hold upon us of what we know and are, must be broken. New life comes always from outside our world, as we commonly conceive that world.[70]

Henle states that it is important that one be free from assumptions prevalent in one's field of knowledge.[71] This is sometimes quite difficult to achieve. Hadamard points out that in mathematics, and by extension in other fields, too close a connection to past ideas hinders the formation of new ideas.[72] Lillian Lieber, author of The Education

---

[67] Jacob W. Getzels and Philip W. Jackson, Creativity and Intelligence (New York: John Wiley and Sons, Inc., 1962), p. 83.

[68] Allen, Morphological Creativity, p. 62.

[69] Rogers, "Toward a Theory of Creativity," p. 300.

[70] Brewster Ghiselin "Introduction," in The Creative Process, ed. Brewster Ghiselin (New York: Mentor, The New American Library, 1952), p. 14.

[71] Mary Henle, "The Birth and Death of Ideas," in Contemporary Approaches to Creative Thinking," p. 36.

[72] Jacques Hadamard, An Essay on the Psychology of Invention in the Mathematical Field (Princeton, N. J.: Princeton University Press, 1949), p. 48.

of T. C. Mits, describes an approach used by the creative mathematician:

> Not to break entirely with the past, but mold it and modify it to suit new needs. . . . one way in which a mathematician is enabled to make up a new system is to take some old familiar word, like "parallel," examine into its various properties, retain some of these but discard others, thus obtaining a new freedom without entirely cutting loose from the past.[73]

Euclidean geometry, the geometry of flat surfaces, was accepted for years as the "correct" geometry. However, by analyzing the parallel postulate, non-Euclidean geometry came into existence.[74]

Another way of thinking of this tentativeness of present knowledge is in terms of destruction. Wertheimer discloses, "Creative thinking is the process of destroying one gestalt in favor of a better one."[75] Picasso affirms this in his statement, "Every act of construction is first an act of destruction."[76] Parnes believes that any creative act must include destruction--not destruction for destruction's sake, but destruction for the sake of greater construction. By standing sufficiently detached from his work, an individual is able to criticize or destroy the work when necessary.[77]

---

[73] Lillian R. Lieber, The Education of T. C. Mits (New York: W. W. Norton and Company, Inc., 1942), pp. 161-162.

[74] Ibid., p. 144.

[75] R. W. Gerard, "The Biological Basis of Imagination," in The Creative Process, p. 231.

[76] Helen E. Hughes, "Creativity in Women," American Association of University Women Bulletin, November 1976, p. 8.

[77] Sidney J. Parnes, "Creativity: Developing Human Potential," Journal of Creative Behavior 5 (No. 1, First Quarter 1971): 24.

Societies, to some extent are anti-creative and frequently label the creative individual a radical or a heretic.[78] Creativity then must involve a certain degree of courage, a willingness to "go into battle" when one threatens the status quo. Ghiselin recognizes the creativity ". . . requires courage to move along, often counter to popular pre-possessions, and toward uncertainties."[79] The courage required for Kepler to adhere to his new notion of infinity as the second focus of a parabola is reflected in his assertion: "The idea seems absurd, but I can find no flaw in it."[80] Rogers muses over the anxiety of separateness for the creator, the feeling, "I am alone. No one has ever done just this before. . . . Perhaps I am foolish, or wrong, or lost, or abnormal."[81]

Sensitivity is another essential quality for the creative person. One could define sensitivity as a total awareness, particularly of incongruencies and deficiences. Cobb calls sensitivity "the seeing eye"[82] and remarks that the creative mind takes note of things which the ordinary mind passes over unnoticed.[83] George Washington Carver is an example of one creative individual who was able to take an ordinary object--a peanut--and discover a multitude of uses. Stein, Osborn, Rogers,

---

[78]Hughes, "Creativity in Women," p. 8.

[79]Ghiselin, "Introduction," p. 19.

[80]R. W. Gerand, "The Biological Basis of Imagination," p. 250.

[81]Rogers, "Toward a Theory of Creativity," p. 302.

[82]Stanwood Cobb, The Importance of Creativity (Metuchen, N. J.: The Scarecrow Press, Inc., 1967), p. 58

[83]Ibid., p. 54.

and Parnes all view sensitivity (or "openness to experience" according to Rogers) as a significant element in creativity.[84] Stu Hample in his "Letters to God" has a cartoon which accentuates a lack of sensitivity to one's environment: "Dear God: I want to be an inventor, but I don't know what to invent." The sensitive individual discovers what to invent; he is a problem-finder as well as a problem-solver.[85]

The creative individual realizes the importance of identifying the total problem and what it entails. John Dewey insists that "a problem well defined is a problem half solved."[86] According to John Arnold, new solutions to problems cannot be achieved

> . . . unless you have stated your problem so broadly, so basically, so all inclusively and generically that you do not preclude even the remotest possibilities--so that you do not precondition your mind to a narrow range of acceptable answers.[87]

Einstein, thinking much in the same vein, declares that the formulation of a problem is much more significant than its solution. The real advances in science are made by those who dare to raise new questions or examine old problems from new angles.[88] After one finds the problem, he must clearly state it. This point is underscored by Wendell Johnson:

---

[84] Stein, "Creativity and Culture," p. 110; Osborn, Applied Imagination, p. 87; Rogers, "Toward a Theory of Creativity," pp. 299-300; Parnes, "Creativity: Developing Human Potential," p. 22.

[85] Parnes, "Creativity: Developing Human Potential," p. 22.

[86] E. Glenadine Gibb, Creative Problem-Solving (Bethesda, Md.: ERIC Document Reproduction Service, ED 037 367, 1970), p. 21.

[87] Ibid., p. 24. [88] Ibid.

> My graduate students . . . propose problems which preclude the possibility of clear discussion. They propose questions for investigation, for which they desire to obtain precise answers, but which are so stated as to be unanswerable. Apparently they have never been taught that one cannot get a precise answer to a vague question.[89]

A willingness to experience failure is demanded of the creative person. This is one reason for the anti-creative attitude of success-oriented societies such as the United States. Saul Bass asserts:

> In a success-oriented culture, the concept of failure looms as a fate worse than death . . . yet failure is built into creativity. . . . In this sense one can say that progress is a history of failures.[90]

Allen makes the claim that creative discoveries come about as a result of a positive discontent or a constructive dissatisfaction. The only creative discoveries made when one is content are made by accident. Creative people do not want the world as it presently exists; instead, they want a new better world.[91]

Calvin Taylor's list of personality characteristics of the creative individual are generally agreed upon by most writers in the field. They are as follows: autonomous, self-sufficient, independent in judgment, open to the irrational in themselves, stable, dominant and self-assertive, complex, self-accepting, and adventurous. Other

---

[89] Frank Alexander Armstrong, Idea Tracking (New York: Criterion Books, 1960), p. 48.

[90] Saul Bass, "Creativity in Visual Communication," in Creativity: An Examination of the Creative Process, p. 129

[91] Allen, Morphological Creativity, p. 66.

personality characteristics which may differ, depending upon the creative field of endeavor, are: liking ideas vs. people vs. things, socialization and interpersonal involvement, and introversion-extroversion.[92]

Creativity From a Western vs. Eastern Orientation

There is a basic difference between creativity as it is viewed by the Eastern world and creativity from a Western world perspective.[93] The Eastern world sees creativity as "process-centered" or self-actualizing. In process-centeredness, the goal is to become more insightful or more enlightened, to be more attuned with oneself. There is no emphasis on a creative product; often the creative person will forego the temptation to create a product. This is consistent with Maslow's "humanistic psychology" and his concept of self-actualization previously mentioned. The major interest of the Eastern world is not in identifiable products, nor is the interest in the creative geniuses who have produced them. Instead, creativity is defined broadly as the universal heritage of every human being.[94] Eastern philosophy is evidenced by participation in introspective techniques such as yoga and meditation.[95]

---

[92] Calvin W. Taylor, "A Tentative Description of the Creative Individual," in A Source Book for Creative Thinking, eds. Sidney J. Parnes and Harold F. Harding (New York: Charles Scribner's Sons, 1962), p. 182.

[93] Stanley Krippner and Myron Arons, "Creativity: Person, Product, or Process?" Gifted Child Quarterly 17 (No. 2, Summer 1973): 120.

[94] Ibid., pp. 121-122.

[95] Sidney J. Parnes and Angelo M. Biondi, "Creative Behavior: A Delicate Balance," Journal of Creative Behavior 9 (No. 3, Third Quarter 1975): 156.

The Western world does not tend to see creativity from this viewpoint. Over the past several centuries, creativity has been thought of as "product-centered." This product-centeredness reflected a growing concern with conquering or domination of nature. Without some observable product or contribution--whether it be scientific, artistic, or technological--the person was not accepted as creative. The strategy has been, for the most part, to identify the creative product and then attempt to understand the person who created it.[96]

To illustrate this preoccupation with products, one might observe that in 1976, 4,242 different prizes and awards were given in the United States, most of them in "creative" areas. In terms of cash, more than one million dollars was awarded that year in the United States.[97] The top five money prizes in 1976 began with the Alfred B. Nobel Prize, worth $160,000, and ended with the National Medal for Literature worth $10,000.[98] The saying might well be "get in and create and get out and collect." This lavish reward for the individual who is able to produce some acclaimed product has caused many people to regard creativity only in these terms. Schools are too often searching only for those creative geniuses who will be able to produce rather than adhering to Maslow's theory of self-actualization.

---

[96]Krippner and Arons, "Creativity: Person, Product, or Process?" p. 122.

[97]Richard Pietschmann, "The Rewards of Creativity," Mainliner, July 1977, p. 32.

[98]Ibid., p. 34.

Preoccupation with products might also be explained by the fact that private enterprise has supplied much of the impetus for creativity research. Presently, most major industries support creativity research as well as creativity training institutes, while public education rarely supports these endeavors. This interest by industries has been motivated by the hope that creative products could be developed, which would, in turn, increase profits.[99]

Levels of Creativity

Although creativity has been previously defined, that definition is rather inclusive--it could apply both to a high school mathematics student and Einstein. Hence, its communication effectiveness is limited. Irving Taylor resolves this problem by defining five levels of creativity.

Expressive--In this fundamental stage of creativity, the important traits are spontaneity and freedom, rather than originality or quality of the product. The freedom from inhibition gained at this level is essential in order to attain the mastery and proficiency for subsequent growth in creativity.

Productive--At this point, the individual is able to produce objects showing some degree of mastery over portions of his environment. A new level of proficiency is achieved by the individual although his product may not be stylistically discernible from the product of others.

Inventive--The person at this level of development shows ingenuity and flexibility in perceiving new and unusual relationships between

---

[99]William E. Roweton, James W. Farless, and Herbert L. Spencer, "Notes on Creativity Research: Little Hope for Classroom Teachers," Contemporary Education 44 (February 1973): 227.

previously separated parts. The "creator" does not directly contribute to new basic ideas, but to new uses of old parts.

Innovative--The individual at this state has mastered basic assumptions of a field and is able to make improvements through modification. As an example, those artists and scientists who cultivate and further develop certain principles are at the innovative level.

Emergentive--Here an entirely new principle emerges at an abstract level around which a new school of thought flourishes. Einstein, Freud, and Picasso all attained this level of creativity. Although only a very small percentage of people fall into this category, it represents the most influential category in the progress of the world.[100]

With the exception of unusual cases, the first three levels are the only levels public school teachers could realistically hope to achieve in the classroom.

Inducing Creativity

Creative ideas cannot be forced and many times do not coincide with the most exhausting periods of work in one's field. The more conscious and concentrated the effort, the more blind one's insight may be to the solution. A certain unconscious period of gestation is sometimes necessary, especially at the emergentive level of creativity. The French mathematician, Poincaré, faced with a difficult mathematics problem which he had labored on unsuccessfully, went to bed. He could

---

[100]Irving A. Taylor, "The Nature of the Creative Process," in Creativity: An Examination of the Creative Process, pp. 55-60.

not sleep: "Ideas arose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination."[101] Another moment of insight occurred for Poincaré while at the seashore: "One morning, walking on the bluff, the idea came to me, with just the same characteristics of brevity, suddenness and immediate certainty."[102] Both of these situations illustrate the importance of illumination which Poincaré asserts is "a manifest sign of long unconscious prior work."[103]

Wallas has designated illumination as one of the four stages in the creative process. Each of these stages is listed and explained as follows:

(1) Preparation--collecting raw data and attempting to reorganize it;

(2) Incubation--experiences began to mill around and flow together;

(3) Illumination--a largely involuntary moment of insight; it might flash into consciousness quite suddenly;

(4) Elaboration--translating subjective notions into objective form.[104]

Richard Crutchfield, writing in "Conformity and Creative Thinking," warns that an intense desire to be creative could hamper creativity. He sees two motives impelling the creative act. The first is a task-involved motivation or one intrinsic to the problem at hand. The creator

---

[101]Henri Poincaré, "Mathematical Creation," in The Creative Process, p. 36.

[102]Ibid., p. 37. [103]Ibid., p. 38.

[104]Graham Wallas, "The Art of Thought," in Creativity, ed. P. E. Vernon (Middlesex, England: Penguin Books, 1970), pp. 91-97.

becomes identified with and immersed in his creation. He seeks to create for the joy and satisfaction he finds within the creative process, product, or both.[105] Guilford verifies the importance of intrinsic rewards for creativity.[106]

The second motivation mentioned by Crutchfield is one which is ego-involved or extrinsic to the problem. The individual attempts to create because of some external reward such as power, wealth, status, self-enhancement, etc. If the motivation is ego-involved, the solution of the problem is relegated to means, subordinate to some external end.[107] Crutchfield, as could be predicted, affirms that the quantity and quality of creative acts will generally be higher under conditions of task-involvement than under conditions of ego-involvement.[108] Allen goes so far as to state that no high level creative work comes from external compulsion applied to the research worker. Creative work is done when there is deep inner desire on the part of the researcher.[109]

Many of the current writings on creativity have historical precedents. For centuries, man has searched for ways to train other men to be creative. René Descartes, a French mathematician and philosopher of the

---

[105] Richard S. Crutchfield, "Conformity and Creative Thinking," in Contemporary Approaches to Creative Thinking, eds. Howard E. Gruber, Glenn Terrell, and Michael Wertheimer (New York: Atherton Press, 1962), p. 122.

[106] J. P. Guilford, The Nature of Human Intelligence (New York: McGraw-Hill Book Company, 1967), p. 318.

[107] Crutchfield, "Conformity and Creative Thinking," p. 121.

[108] Ibid., p. 123.

[109] Allen, Morphological Creativity, p. 64.

early seventeenth century, was particularly interested in the problem of discovery in the sciences and philosophy. He thought that in the proper study and following of the "Rules for the Direction of the Mind," creativity could be attained. Descartes did not believe that the various sciences could or should be isolated from each other and studied in isolation. The mind is essentially one regardless of the area in which it applies its powers. From this he deduced that there is only one method whereby new truth is gained.[110]

Descartes asserted that the most important task of philosophy is to develop the right method. This right method would consist of simple and certain rules leading to true knowledge. If the search for truth were attempted without method, the truth would not likely be found; if it were found, it would be primarily by luck or accident. Truth acquired by chance, rather than by method, would be worse than no truth gained.[111]

In his Discourse on Method, Descartes set forth certain rules, scme of which are advocated by writers in the area of creativity today. Rules two and three are the very heart of his method. Rule two states that any problem must be broken into its constituent elements in order to be studied more readily. By breaking a problem into pieces, one creates "chaos." Rule three states that one must "order" chaos, beginning with those elements most simple and surely known, proceeding to the most complex. When a definite order is not apparent, one must "suppose an

[110]George J. Seidel, The Crisis of Creativity (London: University of Notre Dame Press, 1966), pp. 20-31.

[111]Ibid., p. 21.

order." Descartes meant that a hypothetical order must be imposed where a natural order is not found. An illustration of this would be a coded message having the appearance of a meaningless mass of letters, numbers, or symbols. Since no order readily appears, an effort must be made to impose an order in the elements.[112]

Although much can be gained from Descartes' method, Seidel mentions several problems inherent in the method. One problem is Descartes' rule to begin ordering by finding that which is most simple and certain. Finding such certitude at the beginning is difficult, if not impossible.[113] It is also unfair to the data of the many problems and disciplines to demand a single and solitary method. Being creative is not simply a matter of creating new solutions with old tools or an accepted method; it must also pertain to creating the new tools and methods necessary to gain new solutions. A particular method may be of use here and now, but eternal and universal validity should never be accorded to it. The choice of one rigorously applied method will, in the end, deter creativity.[114]

In the last ten years, much has been written about techniques for facilitating creativity.

Brainstorming

Brainstorming originated in the late 1940's in the advertising firm of Batten, Barton, Durstine, and Osborn. It has been used extensively by such prestigious firms and organizations as General Electric, IBM, RCA, Union Carbon and Carbide, U. S. Steel, the Army, The Department

[112]Ibid., pp. 23-24. [113]Ibid., pp. 28-29. [114]Ibid., pp. 30-31.

of Commerce, the Veterans' Administration, the U. S. Civil Service, and the U. S. Treasury.[115] There are four rules basic to brainstorming:

1. Suspend all judgment and argumentation. Keep statements constructive.

2. Try to get a large volume of ideas by keeping statements very brief.

3. Create an environment in which every idea is accepted.

4. Encourage participation to build or "hitchhike" on others' ideas.[116]

The critics of brainstorming, such as Irving Taylor, claim that group methods are not the most effective means for producing the highest forms of creativity. When a group comes together, a great deal of superficial association occurs.[117] Bass maintains that group participation actually reduces the variety of answers. In a group one tends to pursue the same train of thought, the same approach to the problem.[118] John Arnold asserts that usually whatever comes from a group is the most daring idea that the least daring man could accept.[119].

The advocates of brainstorming point out countless successful experiences with the technique. Pleuthner admits that brainstorming is not a substitute for the individual working alone; it is another

---

[115]Carl E. Gregory, The Management of Intelligence (New York: McGraw-Hill Book Company, 1967), p. 194.

[116]Ibid., p. 196.

[117]Taylor, "The Nature of the Creative Process," p. 80.

[118]Bass, "Creativity in Visual Communication," pp. 125-126.

[119]Arnold, "Creativity in Engineering," p. 44.

tool for the creative person.[120] It is designed to be used as an idea starter, not at the intensive level of creativity.[121] One advantage of group ideation is the sharing of uncommon experiences. When the group is composed of individuals of diverse disciplines and backgrounds, the thinking of all is stimulated through different viewpoints.[122] In the words of Thomas Carlyle, "the lightning spark of thought generated in the solitary mind, awakens the likeness in another mind."[123] Research at the State University of New York at Buffalo showed that students consistently produced more good ideas when following the principle of deferred judgment. (Twice as many good ideas per individual was the average.)[124] In another study done by Meadow-Parnes, a group brainstormed an assigned problem while an equal number of people individually attacked the same problem without deferred judgment. The brainstorming group produced 70 percent more good ideas in the same period of time.[125]

Attribute Listing

New ideas can be generated by itemizing the important attributes of something, then thinking of each attribute as a source of potential

---

[120] Bill Pleuthner, et al., "Brainstorming and Testing for Creativity," in Creativity: An Examination of the Creative Process, p. 194.

[121] Walter J. Friess, "A Case History on Creativity in Industry," in Creativity: An Examination of the Creative Process, p. 186.

[122] Gregory, The Management of Intelligence, p. 194.

[123] Taylor, "Psychological Sources of Creativity," p. 194.

[124] Gibb, Creative Problem-Solving, p. 10.

[125] Osborn, Applied Imagination, p. 129.

change. In mathematics, one might examine axiom systems in which the relevant attributes, the axioms themselves, have been enumerated.[126] Another example might be improving an object having a certain shape, color, function, and movement. In changing the object, the function might be preserved and the shape, color, and movement could be varied.

Morphological Analysis-Synthesis

The morphological analysis-synthesis technique is similar to that of attribute listing.[127] Students analyze the structure of the problem, identify two or more important variables or dimensions (i.e. color, shape) of a problem, and list specific values for each (i.e.--red, blue, green; round, square, rectangular). All possible combinations of each are examined by using one value for each variable. As an illustration, if students were asked to "invent" a line of toasters, all combinations of fifteen shapes, twenty colors, and five sizes would instantly result in 1,500 possible products.[128]

Myron Allen has used the morphological approach by establishing up to six parameters. He associates the various factors in each parameter through a device called a "morphologizer." Ideas are compared and interrelated by writing diverse information on sliding strips which may be moved up and down, changing the relationship of each idea to the

---

126 Meyer, Identification and Encouragement of Mathematical Creativity in First Grade Students, Part I, Chapters I-IV, p. 21.

127 This process is sometimes referred to as simply morphological analysis.

128 Gary A. Davis, "Training Creativity in Adolescence: A Discussion of Strategy," Journal of Creative Behavior 3 (No. 2, Spring 1969): 99.

others.[129] The obvious drawback to morphological analysis-synthesis is that it is rigid. While it guarantees an enormous number of idea combinations in a short time, it can prevent the problem from being approached more imaginatively.

Checklist

One type of checklist sometimes used in mathematics consists of writing the techniques found successful in previous problems and trying each one or a combination of them in a particular problem.[130] An idea checklist is a list of statements or words in an attempt to generate ideas or solutions to problems.[131] As an example, items on a checklist could be thought of as possible sources of change with respect to a given problem.

The following checklist has seven items for consideration in changing a problem: (1) add and/or subtract something, (2) vary color, (3) change materials, (4) rearrange parts, (5) vary shape, (6) change size, (7) modify style or design. In one study, college students using this checklist produced a significantly larger number of creative ideas for improving a kitchen sink than the control group did without the checklist.[132] In another study, Roweton found that the idea checklist

---

[129] Allen, Morphological Creativity, p. 102.

[130] Meyer, Identification and Encouragement of Mathematical Creativity in First Grade Students, Part I, Chapters I-IV, p. 22.

[131] William E. Roweton, "Creativity: Idea Quantity and Idea Quality" (Bethesda, Md.: ERIC Document Reproduction Service, ED 038 665, 1970), p. 7.

[132] Davis, "Training Creativity in Adolescence: A Discussion of Strategy," p. 100.

enhances idea fluency more than idea quality.[133]

Synectics

Synectics is a technique which was gradually developed by W. J. J. Gordon. It was first employed in the late 1940's and was later refined and marketed by Gordon and his associates under the name of Synectics, Inc.[134] Today, over two hundred businesses and industries in the United States and abroad have invested over $100,000,000 in the synectics technique.[135] Massachusetts Institute of Technology (MIT), the Rockefeller Foundation, the Department of Defense, and Harvard have all contributed to it both financially and through consultative services.[136] Materials developed by Synectics Education Systems have influenced over ten thousand classrooms.[137]

Synectics could be defined as the joining together of seemingly irrelevant elements.[138] One of the premises behind the synectics technique is that every human has potential for invention which is never

---

[133] Roweton, "Creativity: Idea Quantity and Idea Quality," p. 7.

[134] James F. Marian and Donald V. Rogan, "Synectics: An Explanation of the Process and Some Comments on Its Application in the Secondary School" (Bethesda, Md.: ERIC Document Reproduction Service, ED 061 140, 1966), p. 1.

[135] W. J. J. Gordan, "Metaphor and Invention," in The Creativity Question, p. 251.

[136] Marian and Rogan, "Synectics: An Explanation of the Process and Some Comments on Its Application in the Secondary School," p. 1.

[137] Gordan, "Metaphor and Invention," p. 251.

[138] Marian and Rogan, "Synectics: An Explanation of the Process and Some Comments on Its Application in the Secondary School," p. 5.

developed.[139] The synectics process involves two basic activities--making the strange familiar and making the familiar strange. In making the strange familiar, three procedures are used: analysis, generalization, and model-seeking or analogy. After breaking down the elements (analysis), the individual attempts to identify patterns among the elements (generalization). Model-seeking is equivalent to searching for something within one's knowledge that is similar to that which is being examined. Lord Rutherford, after analyzing and generalizing about the data relevant to the structure of an atom, found a model in the solar system. Scientists later accepted his analogy and discussed the atom by considering it a micro-solar system.[140]

In making the familiar strange, one must consciously distort the everyday ways of looking at and responding to the world. It might be described as an attempt to achieve a new look at the same old world. Three analogies are utilized in making the familiar strange:

1. Personal analogy is an empathic identification with something outside oneself. As an illustration, Dr. Rich, the G. E. scientist, imagines himself a light beam whose reflection is being measured.[141]

2. Direct analogy could be defined as a comparison of one thing with another.[142] The way a clam opens and closes could be studied in

---

[139] Ibid., p. 1

[140] George M. Prince, "The Operational Mechanism of Synectics," The Journal of Creative Behavior 2 (No. 1, Winter 1967): 4.

[141] W. J. J. Gordan, "Metaphor and Invention," p. 254.

[142] Ibid.

designing a self-closing dispenser.[143]

3. Symbolic analogy involves a close-coupled phrase within which the words fight each other. Pasteur used this idea when he based his antitoxin research on the expression "safe attack."[144]

Assessment of General Creativity

Early attempts at identifying giftedness had their theoretical base in intelligence and achievement. The emphasis on high IQ and scholastic achievement was measured by such tests as the Stanford-Binet IQ Test, the Wechsler scales, the California Test of Mental Maturity, Multiple Aptitudes Tests, Primary Mental Abilities Tests, etc. It was not until the 1950's with Guilford's development of the Structure-of-the Intellect model, that creativity was considered an essential dimension of mental functioning. Hence, tests constructed to measure intellectual abilities did not have any items which would require creative abilities until the late 1960's.[145]

Today there is a profusion of tests available to measure creativity. Due to the fact that there is no universally accepted theory of creativity, each test simply reflects the biases of its developer. One major problem with creativity tests is that many researchers tend to view creativity entirely as a cognitive process or, on the other hand,

---

[143] J. H. McPherson, "Environment and Training for Creativity," in Creativity: Progress and Potential, ed. Calvin W. Taylor (New York: McGraw-Hill Book Company, 1964), p. 136.

[144] W. J. J. Gordan, "Metaphor and Invention," p. 254.

[145] Joe Khatena, "Measurement and Identification of the Creative Potential" (Bethesda, Md.: ERIC Document Reproduction Service, ED 116 431, 1973), p. 1.

entirely a complex set of personality or biographical traits. The former tend to ignore the possibility of affective components and the latter ignore underlying cognitive abilities in creative problem-solving.

One example of a test measuring personality traits is the Allport, Vernon and Lindzey Study of Values. There are six values on the test: Theoretical, Economic, Aesthetic, Social, Political, and Religious. It was found that the creative student scored highest in the Aesthetic category with Theoretical the second highest. His scores were lowest in Economic and Religious dimensions. These findings were later corroborated by MacKinnon.[146]

Another well-known test that taps both personality and biographical correlates of creativity is Calvin Taylor's Alpha Biographical Inventory (1966). This test has had an extensive validation history with NASA scientists, college students, and high school students. It is a three-hundred-item survey relating to areas of family life and developmental history, academic background, and adult life and interests. It is specifically designed for high school juniors and seniors and can be scored for both creativity and academic success.[147] Extensive research involving adult scientists and engineers provided background for the

---

[146]Paul Heist, "Considerations in the Assessment of Creativity" in The Creative College Student: An Unmet Challenge, ed. Paul Heist (San Francisco: Jossey-Bass, Inc., 1968), pp. 216-217.

[147]Terence L. Belcher and Gary A. Davis, "Interrelationships Among Three Standardized Creativity Tests and IQ" (Bethesda, Md.: ERIC Document Reproduction Service, ED 046 982, 1971), p. 2.

test.[148] In the opinion of Belcher and Davis, the ABI is probably one of the most valid and accurate instruments available to estimate creative potential of high school juniors or seniors. One important limitation of the ABI is its insensitivity to efforts to improve creative thinking--an individual's personal history cannot be altered. If creativity training is to be evaluated, the instrument must be sensitive to training efforts.[149]

Another well-known test, the Remote Associates Test (RAT), was developed by Sarnoff Mednick in 1967.[150] The RAT is designed to measure the individual's capacity to bring together remote associates to form creative solutions. The test consists of sets of two or three words, each set having a common associate which the subject must produce.[151] While it is easily administered and scored with only thirty right or wrong items, it reflects verbal intelligence more than a creativity test should. (It has a correlation of .69 with the Henmon-Nelson IQ test.) There is also a distinct possibility that in some cases, the Remote

---

[148] Calvin W. Taylor and Robert L. Ellison, "Predictors and Criteria of Creativity," in Climate for Creativity: A Report of the Seventh National Research Conference on Creativity, ed. Calvin W. Taylor (New York: Pergamon Press, 1972), p. 150.

[149] Belcher and Davis, "Interrelationships Among Three Standardized Creativity Tests and IQ," p. 6.

[150] Gary A. Davis, "In Frumious Pursuit of the Creative Person," Journal of Creative Behavior 9 (No. 2, Second Quarter 1975): 76.

[151] Dennis Ridley, "Definitions and Criteria of Creativity: A Literature Review" (Bethesda, Md.: ERIC Document Reproduction Service, ED 108 235, 1969), p. 5.

Associates Test punishes imaginative answers.[152] Mednick admits:

> The correlations that have been attained between the Remote Associates Test and the standard measures of intelligence indicate that the high scorer on the Remote Associates Test also tends to be in the upper IQ range.[153]

Another personality-type test is the Barron and Welch Art Scale (1963). While the test has a very good validation history, one might question if simply indicating whether you like each of eighty smudgy drawings is as thorough a prediction instrument for creativity as could be desired.[154]

Guilford and Torrance could be classified as foremost psychologists in the field of cognitive creativity measurement. In scoring both Guilford's and Torrance's divergent thinking tests, four categories are used: fluency, flexibility, originality, and elaboration.[155]

Guilford (1967) attempts to assess divergent thinking by requiring a subject to respond to many stimuli, each attempting to measure a specific component of the Structure-of-the-Intellect model.[156] Much of the work measuring high school creativity has involved modifications of Guilford's test.[157] Taylor, Smith, Ghiselin and Ellison, and MacKinnon all report zero correlations between the Guilford test scores and

---

[152] Davis, "In Frumious Pursuit of the Creative Person," p. 76.

[153] Belcher and Davis, "Interrelationships Among Three Standardized Creativity Tests and IQ," p. 3.

[154] Davis, "In Frumious Pursuit of the Creative Person," p. 76.

[155] Khatena, "Measurement and Identification of the Creative Potential," p. 4.

[156] Ibid., p. 5.

[157] Torrance, Guiding Creative Talent, p. 31.

real-world productivity.[158] Taylor and Holland also insist that the evidence for validity of the tests is incomplete and vague.[159]

The Torrance Tests of Creative Thinking (1966) measure creative abilities through the presentation of several complex tasks. The two forms of the test, Figural and Verbal, are structured to bring about the expression of several abilities at the same time. There are seven verbal subtests, requiring forty-five minutes of testing time: (1) Asking Questions, (2) Guessing Causes, (3) Guessing Consequences, (4) Product Improvement, (5) Unusual Uses, (6) Unusual Questions, (7) Just Suppose Activities.[160] Each verbal subtest instructs the subject to list as many different ideas as he can. For example, he might be told to list unusual uses for cardboard boxes or tin cans, think of improvements for a stuffed dog, ask questions about a curious picture, or predict consequences of an unlikely event.[161]

Since the subjects give free responses to semi-structured tasks, the test must be scored by hand. The guides for scoring are fairly clear and the manual discusses errors to avoid. Nevertheless, the test battery is difficult to score and scorers must receive some training and experience with the instrument. The reported correlations between

---

[158] Davis, "In Frumious Pursuit of the Creative Person," p. 76.

[159] Calvin W. Taylor and John L. Holland, "Development and Application of Tests of Creativity," in Explorations in Creativity, p. 225.

[160] Khatena, "Measurement and Identification of the Creative Potential," pp. 5-6.

[161] Belcher and Davis, "Interrelationships Among Three Standardized Creativity Tests and IQ," p. 2.

scores of experienced and inexperienced scorers are in the high 90's, ranging from .66 to .99. The time needed to score the tests is not approximated, although it appears that a test might take considerable time, even for an experienced scorer.[162]

Torrance attempts to be as objective as possible for quantification of responses--how many categories? how many responses? One suggestion for improvement would be that the Torrance tests make more of an effort to develop a system of qualitative analysis of creative responses. This criticism could be directed toward many of the creativity tests. Almost all interpretations of the data derived from test measures have been based on a quantitative scoring system.[163]

While the manual insists that the tests evaluate creativity in terms of Guilford's divergent production factors, there is no evidence which shows any relationship with Guilford's model. In general, the tests appear to be based on Torrance's thoughts about creativity rather than any systematic theory. They should be regarded as an attempt to measure some aspect of creativity rather than something which accurately evaluates all dimensions of creative thinking. Some of the rationales for the scales are vague and the interpretations for the scores are at least questionable.[164] Instructional sets in the Torrance tests can

---

[162] Leonard L. Baird, "Torrance Tests of Creative Thinking" in The Seventh Mental Measurement Yearbook, Volume I, ed. Oscar Buros (Highland Park, N. J.: The Gryphon Press, 1972), pp. 836-837.

[163] Khatena, "Measurement and Identification of the Creative Potential," p. 8.

[164] Baird, "Torrance Tests of Creative Thinking," p. 837.

influence the actual test scores.[165] Another problem on the Torrance tests, as well as on many other cognitive creativity tests, is whether the tasks would be regarded as creative and challenging by the examinee. Treffinger proposes that each task be accompanied by a rating scale. Some of the questions that could be used are: Have you worked on this problem before? Did you solve it? What did you think about the problems you have solved here? Were they interesting? Challenging?[166]

The Torrance Tests of Creative Thinking need to be linked to reality by showing that they predict socially valuable behavior. For example, a student could improve a toy in a testing situation, and yet be unable to make original and useful contributions in real-life situations.[167] Davis contends that the Torrance tests, as compared to other cognitive creative tests, report satisfactory validities.[168] Belcher and Davis see the Torrance tests as quite useable.[169] Nevertheless, a great deal of work is needed to ascertain the validity of the tests for predicting real-life creativity.

---

[165] Davis, "In Frumious Pursuit of the Creative Person," p. 76.

[166] Donald Treffinger, "Problems in Assessment of Creative Problem Solving" (Bethesda, Md.: ERIC Document Reproduction Service, ED 038 663, 1970), p. 6.

[167] Baird, "Torrance Tests of Creative Thinking," p. 837.

[168] Davis, "In Frumious Pursuit of the Creative Person," p. 76.

[169] Belcher and Davis, "Interrelationships Among Three Standardized Creativity Tests and IQ," p. 7.

Assessment of Mathematical Creativity

In the past, identification of mathematically talented students has been done by intelligence and achievement tests despite evidence that creativity does not closely correlate with these variables. Recognizing this, attempts have been made in recent years to create tests to measure mathematical creativity.[170] The following is a list of developers of mathematical creativity tests:

1. R. W. Meyer, University of Wisconsin, 1970, Doctoral Dissertation

2. E. W. Evans, University of Michigan, 1965, Doctoral Dissertation

3. H. S. Spraker, University of Virginia, 1960, Doctoral Dissertation

4. D. A. Buckeye, Indiana University, 1968, Doctoral Dissertation

5. Gregory Ralph Baur, Indiana University, 1970, Doctoral Dissertation

6. W. E. Mainville, Michigan State University, 1972, Doctoral Dissertation

7. Linda Rae Jensen, University of Texas at Austin, Doctoral Dissertation

8. H. L. Prouse, 1967, reference in The Mathematics Teacher December 1976.[171]

---

[170] James A. Dunn, "Tests of Creativity in Mathematics," International Journal of Mathematical Education in Science and Technology 6 (No. 3 1975): 327-328.

[171] Ibid., p. 331.

Evans' battery of creativity tests is designed for grades five through eight. A composite score on the battery significantly correlates with measures of intelligence, achievement, attitude toward mathematics, and general creativity. Kilpatrick states that Evans' tests are clever and although firm information on reliability and validity is lacking, the battery shows definite promise.[172]

Prouse's test for creativity is designed for seventh graders. It consists of ten items--seven measures of divergent thinking and three measures of convergent thinking. One type of problem that is often used on Torrance's test is the question: How many uses can you think of for a brick? Prouse attempts to translate this into mathematical terms by the problem: Using the symbols =, -, x, ÷, ( ) write as many true equations as possible with the numbers 2, 3, and 8 in that order. Another item in the Prouse test is Make-Up Problems Test. This consists of a paragraph in the form of a story containing a great deal of mathematical and other types of information. The student is asked to originate as many problems as possible using the information in the paragraph.[173] Getzels and Jackson also used this type of mathematical item on their creativity test.[174] In assessing the Prouse test, Kilpatrick reports that one study gave no indication that the Prouse test was superior to other measures, including teacher ratings, in identifying gifted

---

[172] Jeremy Kilpatrick, "Problem-Solving and Creative Behavior in Mathematics" in Studies in Mathematics, ed. School Mathematics Study Group, 19 (Leland Stanford Junior University, 1969), p. 167.

[173] Dunn, "Tests of Creativity in Mathematics," pp. 328-329.

[174] Getzels and Jackson, Creativity and Intelligence, pp. 205-208.

students.[175]

Aiken's general assessment on creativity tests is quite accurate: "With regard to creativity in general and mathematical creativity in particular, there is an obvious need for better tests and inventories."[176]

Creativity and its Relationship to Intelligence as Measured by IQ Tests

Since the validity of many creativity tests is questionable, one must accept any findings on the relationship between creativity and intelligence as tentative. According to Guilford, many psychologists espouse the theory that creativity correlates highly with intelligence. In other words, creative behavior is only to be expected from those individuals having high IQ's.[177] This concept is not only inadequate, it is also responsible for impeding an understanding of creativity.[178]

In 1966, Guilford found a positive but low correlation between traditional intelligence tests (California Test of Mental Maturity administered to 90 percent of the group) and his tests of divergent thinking. In his results, individuals with high intelligence test scores had divergent scores ranging from low to high; individuals with low intelligence scores rarely had high divergent production scores.

---

[175] Kilpatrick, "Problem-Solving and Creative Behavior in Mathematics," p. 166.

[176] Lewis R. Aiken, "Ability and Creativity in Mathematics," Review of Educational Research 43 (No. 4, Fall 1973): 425.

[177] Guilford, Intelligence, Creativity, and Their Educational Implications, p. 82.

[178] Ibid., p. 95.

To generalize Guilford, a reasonably high score on intelligence tests is a necessary condition for creativity, but it is not a sufficient condition.[179]

Getzels and Jackson report a similar positive but low correlation between measures of intelligence and creativity using their creativity test.[180] In 1973 in a group with below average intelligence, Schubert concluded there was a significant positive correlation between creativity and intelligence. On the other hand, for a group with above average intelligence there was no significant relationship between creativity and intelligence.[181]

Torrance found that when highly creative students were compared to highly intelligent students, the highly creative ranked in the upper 20 percent on creative thinking but not on intelligence. The highly intelligent ranked in the upper 20 percent on intelligence but not on creativity. In fact, if students were identified as gifted solely on the basis of intelligence tests, 70 percent of the most creative were eliminated.[182] This generalization was based on testing school populations in 1958 and 1959. A more recent check of school populations in the 1970's indicates that this still holds true.[183]

---

[179] Ibid., p. 136.

[180] Getzels and Jackson, Creativity and Intelligence, p. 20.

[181] Daniel S. P. Schubert, "Boredom as an Antagonist of Creativity," Journal of Creative Behavior 11 (No. 4, Fourth Quarter 1977): 233.

[182] Torrance, Guiding Creative Talent, pp. 4-5.

[183] E. Paul Torrance, "Creativity in the Classroom: What Research Says to the Teacher" (Bethesda, Md.: ERIC Reproduction Service, ED 132 593, 1977), p. 13.

The consensus is that although some basic level of intelligence is necessary for creative ability to occur, high intelligence is no guarantee for creativity. Indeed, above a certain level, there is no clear correlation between measures of intelligence and creativity. Sometimes that which is judged to be high intelligence may militate against the development of creativity. In the words of L. L. Thurstone:

> Students with high intelligence are not necessarily the ones who produce the most original ideas. The Quiz Kids are often referred to as geniuses. They would undoubtedly score high in memory functions. . . . But it is doubtful whether they are also fluent in producing ideas.[184]

Irving Taylor states that intelligence tests are an invention of Western culture and reflect our values. They are concerned with how fast relatively unimportant problems can be solved without making errors.[185] According to Calvin Taylor, the nature of traditional creativity tests does not directly involve the ability to create new ideas or things.[186]

Trachtman, in comparing intelligence and creativity, asserts that the intelligent mind converges upon a predetermined goal and is not distracted. The creative mind diverges, seeing beyond the task it was called on to perform.[187] Calvin W. Taylor, at the Second Minnesota Conference on Gifted Children, voiced his criticism of the traditional

---

[184] Osborn, Applied Imagination, p. 22.

[185] Taylor, "The Nature of the Creative Process," p. 54.

[186] Taylor, "A Tentative Description of the Creative Individual," p. 174.

[187] Leon E. Trachtman, "Creative People, Creative Times," Journal of Creative Behavior 9 (No. 1, First Quarter 1975): 37.

intelligence test:

> To me it is highly inconsistent to conceive of the mind as being represented by a single score or even by only the handful of scores or dimensions present in our current intelligence tests. The brain which underlies the mind is far, far too complex for us to hope that all of its intellectual activities can be represented by only a single score or by a handful of dimensions. To seriously utilize such an over-simplified picture might be considered an insult to the brain, to the human mind, and to the human being.[188]

Creativity and Age

Torrance is one researcher who has studied the creative development of various age-level students. He concludes that a decrement in creative thinking ability occurs approximately at ages five, nine, and twelve.[189] From the eighth grade until the end of high school, there is steady growth of creativity. At the end of high school there is a leveling off or slight decline.[190] Yamamoto also produced scales which showed a decline in creative productivity after high school.[191] Jackson's findings (using Guilford's test of divergent thinking) did not agree with Yamamoto. His findings indicated that the level of creative productivity is neither inhibited nor promoted during the four years of college.[192]

Lehman did a classic study regarding the peak age for creative achievements in a variety of fields. Among chemists he found the greatest contributions were made between the ages of twenty-six and thirty;

---

[188]Torrance, Guiding Creative Talent, p. 20.

[189]Ibid., p. 103. [190]Ibid., p. 98.

[191]Leon Jackson, "Creative Growth Curves of University Students" (Bethesda, Md.: ERIC Document Reproduction Service, ED 039 600, 1970), p. 4.

[192]Ibid., p. 4.

among mathematicians, between the ages of thirty and thirty-four; among musicians, between the ages of thirty and forty; among authors, under the age of forty-five; among philosophers, between the ages of thirty-five and thirty-nine. Lehman concluded that superior creativity rose to its highest point in the thirties age range and declined thereafter.[193] In 1960, Lehman confirmed his earlier findings.[194]

In his book, Age and Achievement, Lehman was careful to point out that it is not age itself, but the factors which accompany age that bring about a reduction in creative productivity. Lehman cited sixteen reasons for this decline--among them, decline in physical vigor, illness, diminution in sensory capacity, and complacency as a result of earlier creative works.[195] Osborn also discusses the fact that age sometimes lessens creativity. He hypothesizes that as a result of education and experience, the individual becomes a victim to habit. This, in turn, rigidifies his thinking and causes him to function less creatively.[196] Alpaugh, Renner, and Birren state that older individuals have a fear of being wrong and, therefore, tend to be more cautious than younger individuals. This ultimately results in decreasing creativity.[197]

---

[193] Harvey C. Lehman, Age and Achievement (Princeton: Princeton University Press, 1953), pp. 324-325.

[194] Harvey C. Lehman, "The Age Decrement in Scientific Creativity," American Psychologist 15 (February 1960): 128-134.

[195] Lehman, Age and Achievement, pp. 328-329.

[196] Osborn, Applied Imagination, p. 43.

[197] Patricia K. Alpaugh, V. Jayne Renner, and James E. Birren, "Age and Creativity: Implications for Educators and Teachers," Educational Gerontology 1 (No. 1, January-March 1976): 29.

Rossman's study of inventors found that their creativity occurred at extremely young ages. Of the 710 inventors, 61 percent made their first invention before age twenty-five. The average age at the time of this invention was 21.3 years. The age range in which the greatest number of patents occurred was from twenty-five to twenty-nine.[198]

The age for creative production in mathematics appears to be even lower than that for creative contributors in other fields. Hardy, writing in A Mathematician's Apology, comments on this anomaly:

> I had better say something here about this question of age, since it is particularly important for mathematicians. No man should ever allow himself to forget that mathematics, more than any other art or science, is a young man's game. . . . Newton gave up mathematics at fifty and had lost his enthusiasm long before; he had recognized by the time he was forty that his great creative days were over. Galois died at twenty-one, Abel at twenty-seven, Ramanujan at thirty-three, Reimann at forty. I do not know an instance of a major mathematical advance initiated by a man past fifty.[199]

While Hardy's statement is true, in almost every other field, there are examples of men making great contributions in their later years. Thomas Edison continued to invent until his mid-eighties, Galileo's Dialoghi delle nuove scienza was published when he was in his mid-seventies, and Jean-Paul Sartre didn't stop writing until age seventy.[200] Milton wrote Paradise Lost at age fifty-seven and Paradise Regained at age sixty-two. George Bernard Shaw won the Nobel Prize when he was almost seventy. Goethe, Voltaire, and Longfellow all continued to be

---

[198] J. Rossman, The Psychology of the Inventor, rev. ed. (Washington, D. C.: Inventors Publishing Co., 1931).

[199] G. H. Hardy, A Mathematician's Apology (Cambridge: Cambridge University Press, 1941), pp. 10-12.

[200] William E. Roweton, "Creativity: Machines Then Us!" Journal of Creative Behavior 11 (No. 4, Fourth Quarter 1977): 244.

creative in later life.[201] Lehman himself admits:

> In like manner one should not accept the findings with reference to man's most creative years as inevitable in regard to one's self merely because of statistical averages. Individual variations at each and every age level are so large and so numerous that careful study of the individual himself should be the court of last appeal.[202]

Relative Creativity of the Sexes

Osborn claims that scientific research on the relative creativity of the sexes has been inconclusive.[203] Cobb believes that sex does not play any role in creativity and states that "talent is neutral to sex."[204] Maslow feels that there is no gender difference in creativeness. Nevertheless, he acknowledges that creativity of the conventional production type is generally regarded as a more masculine role.[205]

Torrance points out that creativity, by its very nature, requires both sensitivity and independence. In our culture, sensitivity is a feminine virtue and independence is a masculine virtue. Hence, one might expect the highly creative girl to be more masculine than her peers and the highly creative boy to be more effeminate than his peers. In longitudinal studies, Torrance found examples of children who sacrificed their creativity in order to maintain their masculinity or femininity.[206] One might hypothesize that sex will influence creativity less in the

---

[202] Lehman, Age and Achievement, p. 220.

[203] Osborn, Applied Imagination, p. 22.

[204] Cobb, The Importance of Creativity, p. 32.

[205] Maslow, "Creativity in Self-Actualizing People," pp. 95-96.

[206] Torrance, Guiding Creative Talent, pp. 111-112.

future due to changing sex roles. Today women are being given more opportunities to compete in "a man's world" and to fulfill their creative potential.

One Creativity Project in Mathematics Education

One of the few projects dealing with structuring for creativity in mathematics education was done in January 1970 by Rochelle Meyer. It was done under the auspices of the Wisconsin Research and Development Center for Cognitive Learning. The program was designed to determine if participation in a mathematics creativity program would increase mathematical creativity in first-grade students.[207]

The mathematical situation was rather open-ended, working with geometric problems using concrete materials. The only mathematical skills which were prerequisite were counting and comparing objects to twenty-five.[208] The research was done at Prospect Street Elementary School with a group of six students. There were fifteen lessons, each lasting twenty minutes.[209] Some of the activities were:

1. Make as many triangles as you can using six straws and as many pipe cleaners as necessary to fasten straws together.[210]

2. Trace this 1½ inch equilateral triangle on this paper (4¼ by 7¼ inch) as many times as possible so that the triangles can be cut out.[211]

---

[207] Meyer, Identification and Encouragement of Mathematical Creativity in First Grade Students, Part I, Chapters I-IV, p. 1.

[208] Ibid., p. 33. [209] Ibid., pp. 40-43. [210] Ibid., p. 47.

[211] Ibid., p. 53.

3. Given equilateral triangles, squares, (both figures 1½ inches per side) and tape, make as many imaginative closed surfaces as possible.[212]

The effect in the program on mathematical creativity was judged by watching the actions of a student while he worked on a mathematics problem, in addition to evaluating the results he achieved. The students were observed by videotape and measured every minute on mathematical creativity by scorers using six criteria. These six criteria describe overt behaviors that were face validated by seven professors at the University of Wisconsin.[213]

1. Introducing a goal--In the absence of a specifically stated mathematical goal, the student verbally suggests or exhibits goal-directed behavior.

2. Identifying a property--The student states an appropriate unstated property.

3. Seeking a relationship--The student conjectures or investigates a possible relationship between some property of the task he is currently pursuing and a previous task or property.

4. Seeking a generalization--The student states or demonstrates a suitable generalization.

5. Reaching a mathematically elegant product--The student achieves a mathematically elegant and appropriate product.

---

[212]Ibid., p. 58.

[213]Rochelle Meyer, Identification and Encouragement of Mathematical Creativity in First Grade Students, Part II, Chapters V to Conclusion (Bethesda, Md.: ERIC Document Reproduction Service, ED 038 293, 1970), pp. 81-88.

6. Modifying the task--After having attempted a task outlined by the teacher, the student either verbally suggests or begins a modification of the task.[214]

Unfortunately, the null hypothesis was ultimately accepted. Participation in the program had no significant effect on mathematical creativity.[215] Meyer, in an attempt to find an explanation for this failure, stated that creative behavior could be elicited rather easily from first-grade students. From this she reasoned that any effort to increase the likelihood of these behaviors is comparable to an attempt to increase the scores of people who consistently score high. Such an increase is possible only with a mammoth amount of time and energy.[216] One could hypothesize that the lack of structure to the program, the inadequate amount of time spent with the program, the small experimental group, and perhaps teacher effectiveness could be extraneous variables which influenced the failure.

Creativity and the Schools

There are numerous writers in the area of creativity whose conclusions are all the same concerning the amount of creativity found in the schools today. Moustakas sees the ultimate end of schooling as "uniformity of behavior, uniformity of expression, death of individuality, docility, passivity, and conformity."[217] Rogers and Stoddard also

---

[214]Ibid., p. 143. [215]Ibid., p. 151. [216]Ibid., p. 155.

[217]Clark Moustakas, "Creativity and Conformity in Education," in Explorations in Creativity, p. 177.

assert that schools mold conformists.[218]

Although divergent thinking has long been recognized as an important component in creativity, convergent thinking is venerated in the schools today. Getzels and Jackson observe that other than in the arts, divergent thinking is generally discouraged in schools.[219] A study was done in which 4,562 items were selected from seventy-four randomly selected tests in sixty-three high schools in Southern California. When analyzed with respect to Bloom's taxonomy, approximately 98 percent of those items could be classified in the knowledge category and 75 percent of the total items came under one subcategory of knowledge--knowledge of specific facts. The 2 percent of the remaining items were classified in only two of the upper five categories, comprehension and application. The top two categories which particularly relate to creativity and divergent thinking had no items.[220]

One indication that schools do not value creativity is the lack of correlation between grades and creativity, or grades and later success in fields where creativity is demanded. A study was initiated by Gluskinos in an effort to relate creativity scores and the grade point averages of engineering students. To increase the validity of the results, the researcher utilized a variety of methods to measure

---

[218] Carl R. Rogers, "Toward a Theory of Creativity," p. 69; George D. Stoddard, "Creativity in Education," in Creativity and Its Cultivation, p. 181.

[219] Gowan and Demos, The Education and Guidance of the Ablest, (Springfield, Illinois: Charles C. Thomas, 1964), p. 84.

[220] Parnes, "Creativity: Developing Human Potential," p. 32.

creativity. One approach was divergent production problems devised by engineering instructors who were familiar with Guilford's Structure-of-the-Intellect. Other methods included the AC Test for Creative Ability, and Guilford's divergent production tests. The conclusion was that creativity and grade point average were definitely unrelated.[221] The viewpoint that creativity has not been sufficiently reinforced in the classroom later received support at a national conference on creative engineering education:

> . . . in most engineering schools grading practices do not encourage novel departure from, or challenges to what has been absorbed in the class or through study. Feedback is expected and the closer the student adheres to the script, the better the grades. In short, the grading system customarily employed in engineering education tends to measure retention rather than creativity.[222]

Industry, government, and universities use grade point average of college students as a means for identifying those students having the aptitude to become research scientists. Unfortunately, evidence does not indicate any relationship between undergraduate grades and success as a research scientist.[223] Wight also insists that there are many research studies showing virtually no relationship between grades and performance on any other aspect of life outside academia. Grades predict

---

[221]Ury Gluskinos, "Criteria for Student Engineering Creativity and Their Relationship to College Grades," Journal of Educational Measurement 8 (Fall 1971): 189-194.

[222]Ibid., pp. 194-195.

[223]Calvin W. Taylor, William R. Smith, and Brewster Ghiselin, "The Creative and Other Contributions of One Sample of Research Scientists" in Scientific Creativity: Its Recognition and Development, p. 72.

future grades and maybe I.Q.[224] Dr. John Holland, research director of the National Merit Scholarship Corporation, believes that much of the $100,000,000 available annually for college scholarships has been going to the wrong students--those having high grades but lacking creative talent. He asserts that good grades in high school are moderately accurate for predicting college grades, but have little relationship to after-college accomplishments.[225]

Creative students do not flourish in a college or university setting. Paul Heist, author of The Creative College Student: An Unmet Challenge, discovered a dropout rate of approximately 50 to 80 percent for college students identified as creative. (The study was conducted in seven dissimilar colleges using the Allport, Vernon, and Lindzey Study of Values to measure creativity.) In five out of seven colleges, a significantly higher percentage of creative students left college than did noncreative students.[226] Osborn confirms that scientific testing has revealed that college graduates do not rate higher than non-college graduates on creative aptitude.[227]

Creative students who did graduate from college, although less critical than creative dropouts, still reacted rather strongly against the system. One of the most frequent reactions dealt with the rigidity

---

[224] Albert R. Wight, "Participative Education and the Inevitable Revolution," Journal of Creative Behavior 4 (No. 4, Fall 1970): 260.

[225] Osborn, Applied Imagination, p. 361.

[226] Paul Heist, "Creative Students: College Transients," in The Creative College Student: An Unmet Challenge, p. 54.

[227] Osborn, Applied Imagination, p. 64.

or flexibility of colleges. Creative students resented the trivial regulations and established curricula that seemed to resist change. The general quality of instruction was rated as mediocre and uninspired. Subject matter was given superficial treatment in many classrooms. Several students indicated that there were few opportunities to be involved in the excitement of learning things of personal interest. To them, college was a detour which kept them from experiencing essential intellectual and emotional satisfactions.[228]

D. N. E. Whitaker (1967) did a study of 151 people in Berkeley's underground subculture for his dissertation at the University of California. (They were not enrolled at Berkeley.) These young people were identified as creative by using the Allport, Vernon, and Lindzey scale. Although apparently attracted to the university as a source of cultural stimulation, they had given up hope that established education could meet their needs.[229]

Teachers at every educational level complain about students' unwillingness to think for themselves. It is the teacher, however, who is often partially responsible for creating this situation. One could conclude from the studies that if schools are to assist in the development of creative thinkers, they must change from a "closed system" to an "open system" approach. Harold Anderson applies the phrase

---

[228]Paul Heist, "Creative Students: College Transients," pp. 52-53.

[229]E. Paul Torrance "Creativity Research and Higher Education" (Bethesda, Md.: ERIC Document Reproduction Service, ED 037 160, 1969), p. 8.

"open system" to any environment which allows the individual to be himself and to explore the unknown. He defines a "closed system" as the antithesis of the "open system" or as an environment which restricts this freedom.[230] Most classrooms today are closed systems; the major activity in the classroom is acquiring a body of knowledge or memorizing facts. Since there is little opportunity for exploration, there is little opportunity for independent, creative thinking. There is a definite need for a shifting of emphasis from acquiring to inquiring in classrooms today.

Creativity is not highly valued by the general public. To many people, creativity is considered a garnish to the curriculum, rather than the core of it. It is something "nice" and "fun" to do after everything important has been done. Torrance states that schools reflect the values of the home and community and are unlikely to stimulate creativity to any greater extent than valued by the community.[231]

Since the creative teacher is a divergent thinker, she may express ideas which differ from those of administration. This causes her to be regarded as a threat to many insecure administrators. Research shows that the creative teacher is not valued by her superiors. In 1957, Jex did a study involving fifty-four mathematics and science teachers from various secondary schools throughout the United States.

---

[230] Harold Anderson, "Creativity in Perspective," in Creativity and Its Cultivation, pp. 252-253.

[231] E. Paul Torrance, Education and the Creative Potential, p. 55.

Each teacher's creativity was measured by Flanagan's Ingenuity Test. It was found that the overall creativity scores correlated negatively with the supervisors' and principals' ratings of teacher effectiveness.[232]

Teachers are besieged with administrative trivia and overcrowded classrooms which tend to create discipline problems. Margaret Mead explains that even the most dedicated teacher cannot risk bringing out any creativity that might disrupt her overcrowded classroom.[233] Kneller states that many of the discipline problems in school come about as a result of creative energy which is not allowed to express itself constructively.

> In the schools this energy is frustrated by regulations designed to keep masses of young people in order by making them behave in unison. It is frustrated, too, by tired, overworked teachers, who cannot spare the time to nurture the creativity of the individual student because they must struggle amid the impersonal web of administrative detail and mass guidance and counseling procedures to instill into their swollen classes the basic requirements of a stereotyped syllabus.[234]

Summary

A review of the literature gives various definitions and perspectives on creativity by leading writers in the field. Both earlier and present theories of creativity were examined. Traits of the creative individual, levels of creativity, and creativity evaluation instruments

---

[232] Frank B. Jex, "Negative Validities for Two Different Ingenuity Tests" in Scientific Creativity: Its Recognition and Development, p. 299.

[233] Margaret Mead, "Where Education Fits In" in Explorations in Creativity, p. 169.

[234] George F. Kneller, The Art and Science of Creativity, p. 99.

were identified. Creativity and its relationship to the variables of intelligence, age, and sex was discussed. The review concluded with assessment of the dearth of creativity in the schools and reasons propounded for this situation.

CHAPTER III

PHILOSOPHICAL BASIS FOR THE MODEL

Creativity is perhaps one of the most nebulous terms in the English language--it means something different to everyone. The word "creativity" is sometimes vulgarized by educators to mean any fun and nonacademic activity, whether it be making papier-maché or playing Indians. Kneller, author of The Art and Science of Creativity, bemoans the fact that to many people, creativity means simply relaxing impulses or tensions. When this type of thinking prevails, creativity becomes, in the words of Jacques Barzun, "a device by which we give ourselves easy satisfactions while avoiding necessary judgments."[1]

Margaret Mead regards this as a repercussion of Freudian thinking and of the general educational outlook of progressivism. During the progressive movement, creativity was seen as something natural to childhood, which if only given freedom would grow. The first grader was called creative merely because he produced a fingerpainting that was little different from that of his classmates. Such a misuse of the term did a great deal of harm, since it deluded the child into believing that creativity could be obtained with little effort. The absurdity of the situation was summarized by Mead:

---

[1]George F. Kneller, The Art and Science of Creativity (New York: Holt, Rinehart and Winston, Inc., 1965), p. 2.

> We were then confronted with the spectacle of the gifted five-year-old weeping bitter tears over her failure to draw a human face: "What is the use of being called 'the best artist in nursery school' if I can't draw what I want to draw!"[2]

Another misconception is that unconventional or even bizarre behavior accompanies creativity. Crutchfield does not classify the counter-conformist who indiscriminately rejects what the group believes and strives for "difference for difference's sake" as a true creative. Instead, the counter-conformist's efforts are lessened since they are directed toward superficial outer appearances.[3] MacKinnon insists that the creative individual "does not do the off-beat thing narcissistically, that is, to call attention to himself."[4] L. S. Kubie, author of Neurotic Distortion of the Creative Process, maintains that social deviancy is often motivated by sick minds and should not be regarded as constructive creativity.[5] Extreme factions or bands of individuals who do not conform to society's expectations are, in many cases, mistaken for creative individuals. What must be remembered is that many

---

[2]Margaret Mead, "Creativity in Cross-Cultural Perspective," in Creativity and Its Cultivation, ed. Harold H. Anderson (New York: Harper and Brothers Publishers, 1959), p. 225.

[3]Richard S. Crutchfield, "Conformity and Creative Thinking," in Contemporary Approaches to Creative Thinking, eds. Howard E. Gruber, Glenn Terrell, and Michael Wertheimer (New York: Atherton Press, 1962), pp. 137-138.

[4]Daniel S. P. Schubert and Angelo M. Biondi, "Creativity and Mental Health: Part III--Creativity and Adjustment," Journal of Creative Behavior 11 (No. 3, Third Quarter 1977): 188.

[5]L. S. Kubie, Neurotic Distortion of the Creative Process (New York: The Noonday Press, A Division of Farrar, Straus, and Giroux, 1961).

radical leaders demand rigid unquestioning conformity to a closed doctrine or belief.

Some researchers take another extreme position. They are interested in the fractional percentage of the population who have the potential to become creative geniuses--the Mozarts, Poincarés, Wordsworths, or Van Goghs. To them, creativity is attainable only for a chosen few.

The writer does not accept any of the above ideas. For purposes of this study, creativity has been defined as an ability to go beyond the commonplace and ordinary, an ability to combine information and/or experience in a unique, insightful, and useful way. The commonly accepted definition in the Western world which incorporates product-centeredness is not compatible with the definition used in this study. Rather, the definition in this study is more attuned with the Eastern world's process-centered perspective. Although it is sometimes desirable and even necessary for the creative individual to produce a visible product, the ultimate concern must be for the person and the process, not the product.

A question which confronts any researcher in the area of creativity is whether creativity is a generalized trait or whether there are different forms and types of creativity. Thurstone remarked in 1952 that this was an unresolved question.[6] Today, there is still

---

[6] L. L. Thurstone, "The Scientific Study of Inventive Talent," in A Source Book for Creative Thinking, eds. Sidney J. Parnes and Harold F. Harding (New York: Charles Scribner's Sons, 1962), p. 61.

disagreement among the scholars as to the answer. MacKinnon specifies that there are two types of creativity, artistic creativity and scientific creativity. Artistic creativity is described as being predominately perceptive.[7] Artists, writers, and poets all have a greater preference for the feeling judgment.[8] On the other hand, he regards scientific creativity as more evaluative and judgmental.[9] The scientifically creative person has a greater proficiency in analytical thinking.[10] White similarly delineates two categories of creative people, those with an artistic orientation and those with a problem-solving orientation.[11]

The opposing viewpoint is expressed by Hadamard who adheres to the belief that mathematical creativity relates to creativity in general. He contends that it rarely happens in high school that the student who is brightest in mathematics is slowest in other areas of learning.[12]

---

[7]Donald W. MacKinnon, "The Highly Effective Individual," in Explorations in Creativity, eds. Ross L. Mooney and Taher A. Razik (New York: Harper and Row Publishers, 1967), p. 67.

[8]Donald J. MacKinnon et al., "A Dialogue on Creativity," in The Creative College Student: An Unmet Challenge (San Francisco: Jossey-Bass Inc., Publishers, 1968), p. 9.

[9]MacKinnon, "The Highly Effective Individual," in Explorations in Creativity, p. 67.

[10]MacKinnon, "A Dialogue on Creativity," p. 9.

[11]Schubert and Biondi, "Creativity and Mental Health: Part III, Creativity and Adjustment," Journal of Creative Behavior, p. 193.

[12]Jacques Hadamard, The Psychology of Invention in the Mathematical Field (Princeton: Princeton University Press, 1949), p. 5.

Keyser agrees that the person who is mathematically endowed is also well-endowed in other areas.[13] Myron Allen asserts that there is a single set of tools used by creative thinkers regardless of their line of work.[14] This could partially explain why men such as Leonardo da Vinci and Francis Bacon were creative in both scientific and artistic fields. In addition, the creative individual who is knowledgeable in many fields has a definite advantage. Many accomplishments have come about as a result of an idea or technique in one field being applied to another.[15] The writer concurs with the interpretation of creativity as described by Hadamard, Allen, and Keyser. Hence, those who are creative in mathematics have the potential for being creative in other areas.

Since mathematical creativity and general creativity are related, mathematical creativity is defined by using the basic definition of creativity and inserting the word "mathematics" at appropriate points. The definition of mathematical creativity then becomes an ability to go beyond the commonplace and ordinary in mathematics, an ability to combine mathematical information and/or experience in a unique, insightful and useful way.

In developing a theoretical base for the model presented in this study, a list of traits considered essential to mathematical creativity

---

[13]Cassius J. Keyser, The Human Worth of Rigorous Thinking (New York: Columbia University Press, 1916), p. 290.

[14]Myron S. Allen, Morphological Creativity (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962), p. 61.

[15]E. Paul Torrance, "Developing Creative Thinking Through School Experiences," in A Source Book for Creative Thinking, p. 45.

have been identified. The list is applicable to creativity in any given area by making minor modifications such as inserting the word "information" in the place of "problem."

Traits of Mathematical Creativity

1. Ability to grasp parameters of the problem--The creative person must possess a total understanding of the problem. This includes an ability to detect unstated assumptions within the problem. Through isolating independent variables which influence the problem, he can accurately analyze and assess the situation.

2. Sensitivity to problems and needs within the environment and information which can be used to solve these problems or satisfy needs--This is an openness to stimuli which causes the individual to be "totally alive" and perceptive to information around him. His senses are acute; he is keenly aware of everything within the environment.

3. Mathematical fluency--Mathematical fluency includes both an ability to find a variety of methods to solve a given problem and an ability to generate a large number of solutions in open-ended problems.

4. Ability to break from conventional methods of solutions in dealing with problems--The person who examines old problems from new angles or the person who finds some rather unique shortcuts in solving a problem is exhibiting this trait.

5. Understanding of the "whole of mathematics and how mathematics relates to other disciplines--The creative individual must possess an understanding of mathematics and what distinguishes it from other disciplines, such as science or history. Through this understanding, he

will be able to visualize the various areas of mathematics (arithmetic, geometry, algebra, calculus, etc.) working together as a unified entity. He must also be able to relate mathematics to other disciplines in the total structure of knowledge.

6. Synthesis ability--The individual with this quality can apply that which he has learned in one situation to another. He can see useful and unique relationships among seemingly unrelated information or elements. Because of an inexhaustible number of possible combinations, he must possess the ability to choose what to combine.

7. Sufficient background of mathematical concepts and skills--No one can be creative in mathematics or any other discipline without having some prerequisite skills and knowledge. The theory of gravity originated only when an apple fell on a well-prepared mind.

Summary

This chapter has identified and refuted some commonly accepted myths regarding the nature of creativity. The relationship between mathematical creativity and general creativity was discussed. A definition of mathematical creativity was elaborated by listing traits of mathematical creativity. An understanding of the concepts in this chapter provides a philosophical basis for the model of a creative mathematics classroom.

CHAPTER IV

MODEL FOR A CREATIVE MATHEMATICS CLASSROOM

Introduction

Creativity must be thought of as existing along a continuum. There is no classroom which can be classified as either totally creative or totally uncreative. Instead, creativity occurs in degrees. Just as every individual possesses some degree of creativeness, every classroom has some degree of creativity. Unfortunately, this creativity is usually unplanned and sporadic. Teachers are tried by problems of the moment and confronted by many interest groups which impose various demands. These demands make it difficult at times to distinguish between day-to-day routine and worthwhile purposes, such as creativity. As education becomes more demanding and more complex, teachers begin to content themselves with merely keeping the system from falling apart.

The model presented here is a conscious effort to plan for creativity in a secondary mathematics college-preparatory classroom. It represents an ideal; the model is a goal but will possibly never be fully attained. Within the model, there are three components which interact to produce the creative secondary mathematics classroom: creative course content, creative strategies, and flexible classroom organization. Each of these components is in turn influenced by several criteria. The outline of the model is listed. Explanation and validation of the criteria follow the outline.

I. Creative Course Content

A. A large supply of information is essential.

B. The mathematics curriculum reveals the essential nature of mathematics.

C. There is a "holistic" approach toward learning.

1. Within the mathematics curriculum itself, ideas have a definite relationship.

2. Through interdisciplinary learning, the mathematics curriculum relates to other subject areas.

D. Students are exposed to problems with many "right" answers.

E. Everything taught in mathematics is not relevant to the here and now.

F. Within the mathematics curriculum there are alternatives; students are allowed to choose individual studies or projects to pursue.

II. Creative Strategies

A. The teacher is creative.

1. The teacher's behavior creates a psychologically safe classroom atmosphere.

2. The teacher sees his/her role as being that of a learning facilitator.

B. The learning technique is an inquiry-discovery approach.

C. The teacher attempts to make students more aware of mathematical problems within the environment.

D. Students are encouraged to develop analytical abilities.

E. Students acquire the ability to synthesize through selecting and organizing ideas.

F. Students are encouraged to take many different approaches in solving problems.

G. The teacher allows the opportunity for inquiry in depth rather than superficially covering material.

III. Flexible Classroom Organization

A. Provisions are made for both active (exploratory) and quiet (reflective) periods.

B. Various grouping arrangements are employed--large, small, individual.

C. Modular scheduling is used as a more flexible way of approaching learning.

D. Students are allowed input in classroom organization, procedures, and topics.

E. Some testing is open-ended.

Presentation of Model

A large amount of information is essential for mathematics creativity. Practically all writers in the field of creativity agree on this point. Osborn and Guilford attest to the fact that having a good supply of information is necessary for creative production.[1] Ghiselin asserts that "mastering accumulated knowledge" is a prerequisite for creativity. In his words, "Even the most energetic and original mind, in order to reorganize or extend human insight in any valuable way, must have attained more than ordinary mastery of the field in which he is to act. . . ." Passow writes in his article, "Fostering Creativity in the Gifted Child": "To exercise creativity the individual must have a sound base upon which to build knowledge."[3]

---

[1]Alex F. Osborn, Applied Imagination (New York: Charles Scribner's Sons, 1963), p. 64; J. P. Guilford, Intelligence, Creativity, and Their Educational Implications (San Diego, California: Robert R. Knapp, 1968), p. 134.

[2]Brewster Ghiselin, The Creative Process (New York: Mentor, New American Library, 1952), pp. 28-29.

[3]A. Harry Passow, "Fostering Creativity in the Gifted Child," in Readings in Gifted and Talented Education, ed. Herbert Goldstein (Guilford, Conn.: Special Learning Corporation, 1978), p. 73.

Bloom's taxonomy for the cognitive domain rather vividly shows the importance of having and being able to use a large supply of information. The cognitive domain deals with the development of intellectual abilities and skills and is broken down into six hierarchical classes: knowledge, comprehension, application, analysis, synthesis, and evaluation. They are classified as hierarchical since in order to be at any particular stage of development, one must have mastered the preceding stages.[4] Whereas creative production is recognized as occurring primarily at the three higher stages, an individual must have first gone through the stages of knowledge, comprehension and application. As Charlie Mingus, a renowned jazz musician, once reflected: "What you have to do [to be creative] is to know where you're coming from, to be able to do what's gone before, but go from there in your own way."[5]

Mathematics particularly seems to be one subject area where having sufficient background is extremely important. One can observe students in high school mathematics classrooms who appear to possess general creative ability, but lack the necessary mathematical background to approach mathematics creatively.

The mathematics curriculum reveals the essential nature of mathematics. Many of our "back-to-basics" proponents would reduce mathematics to little more than the ability to add, subtract, multiply, and

---

[4]Benjamin S. Bloom, et al., eds., Taxonomy of Educational Objectives: Classification of Educational Goals Handbook, Cognitive Domain (New York: David McKay Co., Inc., 1956), p. 6. The writer acknowledges that Bloom in a later work expressed uncertainty as to whether his cognitive domain was of a hierarchical nature or merely a classification scheme.

[5]"Creativity," Mainliner, July 1977, p. 25.

divide. This results in a false notion of mathematics in its entirety. The NACOME report, examining the current state of mathematics education, viewed with dismay the increasing portion of time devoted to computational skills.[6] Nevertheless, mathematics education appears destined to repeat its past mistakes. Earlier critics of mathematics denounced an operation-oriented, uncreative discipline. Oliver Wendell Holmes likened mathematical thought to the operations of a calculating machine.[7] Huxley interpreted mathematics as "that study which knows nothing of experiment, nothing of causation."[8] Finally, according to a Scottish philosopher, Sir William Hamilton:

> Mathematics, regarded as a discipline, as a builder of mind is inferior. Devotion to it is fatal to the development of the sensibilities and the imagination. Continued pursuit of the study leaves the mind narrow and dry, meagre and lean, disqualifying it both for the practical affairs and those large and liberal studies where moral questions intervene and judgment depends, <u>not on nice calculation by rule</u>, but on a wide survey and a balancing of probabilities.[9] (Emphasis the writer's.)

Mathematicians themselves disagree with the above conceptions of mathematics. Whitehead succinctly defines mathematics as "the development of all types of necessary deductive reasoning"[10] While Bertrand Russell refers to the deducible character of mathematics.[11] Keyser, writing in <u>Mathematics as a Cultural Clue</u>, associates mathematical thinking

---

[6]Shirley Hill, "Issues from the NACOME Report," <u>The Mathematics Teacher</u> 69 (October 1976): 443.

[7]Cassius J. Keyser, <u>The Human Worth of Rigorous Thinking</u> (New York: Columbia University Press, 1916), p. 289.

[8]Ibid. [9]Ibid.

[10]Robert Edouard Moritz, <u>Memorabilia Mathematica: The Philomath's Quotation-Book</u> (New York: The Macmillan Company, 1914), p. 6.

[11]Ibid., p. 7.

with postulational thinking and lists the following steps:

1. There are certain primitive terms (undefined terms).

2. All the important terms (except the primitive ones) are defined by means of primitive terms.

3. There is a set of compatible primitive statements or assumptions (axioms or postulates).

4. There is a set of compatible statements (theorems) that the mathematician has logically deduced from the axioms.[12]

H. S. Wall, in the forward to his book Creative Mathematics, gives one of the best explanations of the nature of mathematics:

> Mathematics is a creation of the mind. To begin with, there is a collection of things, which exist only in the mind, assumed to be distinguishable from one another; and then there is a collection of statements about these things, which are taken for granted. Starting with the assumed statements concerning these invented or imagined things, the mathematician discovers other statements, called theorems, and proves them as necessary consequences. This, in brief, is the pattern of mathematics. The mathematician is an artist whose medium is the mind and whose creations are ideas.[13] (Emphasis the writer's.)

Hardy, author of A Mathematician's Apology, classifies mathematics as a "creative subject" and remarks that mathematics can offer little consolation when one has lost the desire or ability to create.[14] The essence of mathematics, if it is to be a meaningful discipline, must be both creative and postulational. Great contributions that have been made to the world in the area of mathematics have not been primarily of a computational nature. Instead, they have reflected the creative

---

[12]Cassius J. Keyser, Mathematics as a Cultural Clue and Other Essays Volume I (New York: Scripta Mathematica, Yeshiva University, 1947), p. 7.

[13]H. S. Wall, Creative Mathematics (Austin, Texas: University of Texas Press, 1967).

[14]G. H. Hardy, A Mathematician's Apology (Cambridge: Cambridge University Press, 1941), p. 83.

character of mathematics.

One might seriously question if high school students are aware of the creative or postulational nature of mathematics. If asked to define mathematics, most students respond in terms of "calculations" or "numbers." Professor H. R. Pitt insists that mathematics students ". . . are not fully aware of the axiomatic and deductive nature of mathematical reasoning. . . ."[15] This ignorance might be expected as a result of the method of teaching. Students are given few opportunities to engage in postulational thinking. Even in Euclidean geometry, where this pattern of thinking is most apparent, students are commonly told to examine what someone else has generated rather than being allowed to generate various theorems themselves. One type of useful activity might be to give the students an arbitrary mathematical system with certain definitions and postulates, such as the four-point geometry system,[16] and ask them to find as many theorems as possible.

There is a "holistic" approach toward learning in the creative mathematics classroom. Many writers in the area of creativity and curriculum attest to the need for a more unified curriculum. Taba points up the fact that as the number of specialized fields increases, the pursuit of specialized subjects becomes more difficult. This results in the need for more emphasis on the integration of knowledge.[17] In order to

---

[15] H. R. Pitt, "Priorities in the Reform of Mathematics Teaching," The Mathematical Gazette 47 (October 1963): 229.

[16] R. L. Wilder discusses axiomatic method and mentions four-point geometry problem, Chapter II in The Foundations of Mathematics (New York: John Wiley and Sons, Inc., 1952).

[17] Hilda Taba, Curriculum Development: Theory and Practice (New York: Harcourt, Brace and World, Inc., 1962), pp. 189-190.

achieve this integration, Taba subscribes to a Gestalt or field theory model. Following Taba's model, specific facts are used to produce understandings rather than to serve as ends in themselves and curriculum units are conceived in large organized wholes.[18]

Getzels and Jackson concur with Taba when they state that possessing isolated facts is not the same as being "broadly educated."[19] Research shows that 80 percent of all disconnected facts are forgotten in two years.[20] Because of this, attention must be focused on the essential principles and ideas which give structure to thinking. Judd verified this as early as 1908 when he demonstrated that the generalizations underlying specific facts and skills, rather than those specific facts and skills themselves, transferred to new situations. His research received very little attention for many years since associationists, like Thorndike, and conditioning psychologists, such as Watson, dominated American psychology.[21] Another curriculum writer, Jerome Bruner, comments: "The structure of knowledge--its connectiveness and the derivations that make one idea follow from another--is the proper emphasis in education."[22] Goodlad believes that the curriculum should select a

---

[18]Ibid., p. 84.

[19]Jacob W. Getzels and Philip W. Jackson, Creativity and Intelligence (New York: John Wiley and Sons, Inc., 1962), p. 127

[20]Taba, Curriculum Development, p. 212.

[21]Alexander Frazier, ed., New Dimensions in Learning: A Multidisciplinary Approach (Washington, D. C.: Association for Supervision and Curriculum Development, 1962), p. 70.

[22]Jerome Bruner, On Knowing (Cambridge, Mass.: Belknap Press, 1962), p. 120.

few major principles, ideas, or generalizations and organize relevant content around them.[23] Whitehead summarizes the holistic approach when he notes that an important part of education is ". . . the stage of shedding details in favour of the active application of principles."[24] In any creative curriculum, the content must stress relationships and overall unity.

Within the mathematics curriculum itself, ideas have a definite relationship. Many writers throughout history have regarded the unity of mathematics as a significant characteristic of the discipline. Poincaré, a mathematician highly acclaimed in the area of creativity, discusses how important it is for mathematics to possess ". . . a kind of unity, enabling us to see more than the juxtaposition of its elements."[25] John Locke states that man should ". . . exercise his mind in observing the connection between ideas, and following them in train. Nothing does this better than mathematics which therefore, I think should be taught to all those who have the time and opportunity, not so much to make them mathematicians as to make them reasonable creatures."[26] Locke's statement is only partially true. Mathematics allows one to see this "connection between ideas" only if it is properly taught and the overall unity is clarified. Keyser in Mathematical Philosophy reflects on the wholeness of mathematics: ". . . no literature surpasses the literature of

---

[23] John I. Goodlad, School, Curriculum, and the Individual (Waltham, Mass.: Blaisdell Publishing Co., 1966), p. 135.

[24] A. N. Whitehead, The Aims of Education and Other Essays (London: William and Norgate Ltd., 1950), p. 58.

[25] Henri Poincaré, Science and Hypothesis, p. 15.

[26] Moritz, Memorabilia Mathematica, p. 56.

mathematics. . . . , for it is the unity of a whole owing its integrity to the inner bond of implication."[27]

The need for unity in the mathematics curriculum was recognized at the onset of "new math." A great deal was heard from mathematics educators about the importance of unifying ideas and the "structure" of mathematics. Too often in reality, attempts at unification--through such things as "sets" and properties, such as commutative and associative, merely complicated rather than unified ideas. Simplistic solutions were offered for complex problems. One writer discusses a "new math" project: "We now see the most satisfactory way of integrating school mathematics is a fundamental one, through sets."[28] It appears ludicrous to suggest that any single concept be used to integrate all mathematics. With "new math" came "new math" jargon, repeatedly misunderstood and misapplied. The term "structure" became overused to the point that Morris Kline confessed that he really had no idea what the term meant: "It seems to be just a fashionable word."[29]

Through the thoughtless introduction of a hodgepodge of new topics into many "new math" curricula, an already fragmented curriculum became even more fragmented. Fletcher decries the "new math" practice of introducing topics such as modular arithmetic, matrices, and sets in a superficial manner:

---

[27]Cassius J. Keyser, Mathematical Philosophy (New York: E. P. Dalton and Company, 1922), p. 171.

[28]R. S. Heritage, "The Shopshire Math Experiment," The Mathematical Gazette 49 (May 1965): 133.

[29]Morris Kline, "NACOME: Implications for Curriculum Design," The Mathematics Teacher 69 (October 1976): 450.

> Properly handled these ideas have a contribution to make to the mathematical education of nearly all secondary students, but it is necessary to teach them with sound progression and understanding of their purposes, to show that they can solve problems which are important and to make plain their unifying power. Today too many students are meeting an indigestible, unprogressive miscellany of topics. . . . We need to be more certain about the underlying unity of mathematics.[30]

The mathematics curriculum should be organized in such a way that each student is encouraged to assume the role of a mathematician in searching for relationships among various topics and ideas. Bruner suggests that the mathematician's job is to find the deepest properties of puzzles so that he may recognize that a particular puzzle is an example of a family of puzzles. He is also a student of the kinship existing among families of puzzles.[31] Poincaré in Science and Hypothesis speaks of finding relationships ". . . between objects which seemed destined to remain for ever unconnected."[32] In the 1953 Yearbook of the National Council of Teachers of Mathematics, Fehr points out the importance of relating ideas in mathematics:

> Always consider the whole in responding. It is not how much you know about a situation . . . but how much relatedness in all possible ways there is between the facts and the whole of a situation.[33]

All of these statements should apply not only to the mathematician, but

---

[30]T. J. Fletcher, "Secondary Mathematics Today," Trends in Education No. 35 (October 1974): 16.

[31]Bruner, On Knowing, p. 98.

[32]Henri Poincaré, Science and Hypothesis (New York: Dover Publications, Inc., 1952), p. 173.

[33]Howard F. Fehr, "Theories of Learning Related to the Field of Mathematics" in The Learning of Mathematics: Its Theory and Practice, Twenty-First Yearbook (Washington, D. C.: National Council of Teachers of Mathematics, 1953), p. 19.

also to the student of mathematics.

Through interdisciplinary learning, the mathematics curriculum relates to other subject areas. The need for a more interdisciplinary curriculum has been underscored by many curriculum writers. Phenix discusses the necessity for understanding relationships among the various disciplines. He believes that studies should reveal similarities and contrasts with other disciplines.[34] The North Carolina State Superintendent's Task Force on Secondary Education also mentions the need for more understanding of the interrelationships among fields of knowledge.[35]

Taba states that the subject organization, conventionally pursued in high schools, is a deterrent to integrated learning.[36] In high schools each subject is studied at a different time and taught by a different teacher who is often only interested in his/her subject area. This almost forces students into regarding disciplines as unrelated. Observation in high schools would tend to lead one to believe that students carefully compartmentalize learning. They are so accustomed to a disunified curriculum that they believe each subject should be pursued in isolation. Each subject then becomes a dead-end track, and fragmentation decreases the possibility of transfer.

---

[34] Philip H. Phenix, Realms of Meaning (New York: McGraw-Hill Book Company, 1964), p. 4.

[35] Channels for Changing Secondary Schools: A Report from the State Superintendent's Task Force on Secondary Education (Raleigh, N. C.: North Carolina Department of Public Instruction, 1974), p. 47.

[36] Taba, Curriculum Development, p. 392.

It is significant to note at this point that many mathematics teachers claim that mathematics "teaches students to reason." As early as 1938, Fawcett showed that the transfer of mathematical learning out of the domain does not occur unless specific provision is made for it.[37] Postman reflects upon the "dead-endedness" of the subject organization with his Vaccination Theory of Education:

> English is not History and History is not Science and Science is not Art and Art is not Music . . . a subject is something you "take" and when you have taken it, you have "had" it, and if you have "had" it, you are immune and need not take it again.[38]

One alternative to the subject curriculum which allows more for interdisciplinary learning is the broad fields organization. Here integration occurs through correlating two subjects such as mathematics-science or English-social studies. There are, however, several dangers implicit in this organization. One danger is that the areas would be broad in name only--that integration would be superficial. Another danger is that of overgeneralization, resulting in a lack of depth in the curriculum.[39]

Another type of organization designed to facilitate interdisciplinary learning is the core curriculum. In the core curriculum design, a concept is focused upon from many different subject areas. Tookey's article, "Developing Creative Thinking Through an

---

[37]Harold P. Fawcett, The Nature of Proof, Thirteenth Yearbook (New York: National Council of Teachers of Mathematics, 1938).

[38]Neil Postman and Charles Weingartner, Teaching as a Subversive Activity (New York: Delacorte Press, 1969), p. 21

[39]Taba, Curriculum Development, pp. 393-395.

Interdisciplinary Curriculum" gave four detailed examples of core curricula "Staten Island," "the Eighteenth Century," "Biking down Coastal Maine," and "Beachiness."[40] It was interesting that when Tookey illustrated how the various disciplines could be used to study these topics, mathematics was one of the few disciplines totally ignored. This often happens since somehow English, history, art, music, science--all seem easier to relate to a given concept.

There are several other problems with both the core and broad fields organizations in high school. All administrative arrangements, including accounting of credits and requirements for college, are in terms of separate subjects. Secondary teachers have specialized training in content areas and do not in many cases have sufficient understanding of other disciplines to be able to relate their discipline to others. Kaufman, one mathematics educator, explains some of the difficulty:

> I agree with the idea of integrating mathematics and science , but I don't know how to go about getting science people and mathematics people to sit down and plan a program together. I think it will take a lot more understanding of the needs of each subject.[41]

One of the methods that Tookey suggested for structuring an interdisciplinary curriculum was to explore two seemingly unrelated subjects. She used the example of poetry and mathematics; each was investigated in terms of initial assumptions, and then they were placed

---

[40]Mary Enda Tookey, "Developing Creative Thinking Through an Interdisciplinary Curriculum," Journal for Creative Behavior 9 (No. 4, Fourth Quarter 1975): 268.

[41]Marilyn Suydam, "Continuing the Math Revolution," American Education 6 (No. 1, Jan.-Feb. 1970): 29.

side by side to discover relationships and distinctions.[42] This illustration is related to mathematical philosophy, a part of mathematics almost totally ignored at the secondary level. A project of this type would be feasible in a secondary mathematics classroom. Each student would choose another subject area which he would attempt to associate with mathematics. An extended period of time would be given for individual exploration. This type of interdisciplinary project would allow the student to make choices, to understand the nature of mathematics, and to discover for himself relatedness among disciplines. Hence, this type of activity relates to other criteria in the model. (See I F, I B, II B).

The history of invention and discovery shows that many creative thinkers have been scholars in many areas. Leonardo da Vinci is just one example of a man who was outstanding as a painter, sculptor, musician, scientist, inventor, and engineer. Many accomplishments have come about as a result of an idea or technique from one field being applied to another.[43] This presents one case for interdisciplinary learning--a hope that through a more thorough understanding of the relationships among various fields men might come to apply information or techniques to create knowledge in other disciplines. It is an error to believe as some educators do that interdisciplinary studies, while fine at grades

---

[42] Tookey, "Developing Creative Thinking Through an Interdisciplinary Curriculum," pp. 272-274.

[43] E. Paul Torrance, "Creative Thinking Through School Experiences," in A Source Book for Creative Thinking, eds. Sidney J. Parnes and Harold F. Harding (New York: Charles Scribner's Sons, 1962), p. 45.

K-8, are not desirable or possible at the secondary level. Through a more interdisciplinary approach in mathematics education, high school students can become more aware of how mathematics fits into the totality of learning.

Students are exposed to problems with many "right" answers. Divergent thinking, an important ingredient in creativity, is defined by Guilford as thinking in different directions and arriving at many alternatives. Convergent thinking, on the other hand, leads to a single acceptable or correct answer.[44] Several critics of education have discussed the school's preoccupation with convergent thinking or what might be called the "right answer syndrome." Neil Postman, author of Teaching as a Subversive Activity, states one of the prevalent ideas in schools today: "There is always a single unambiguous Right Answer to a question."[45] Glasser echoes this thought in Schools Without Failure. He views almost all schools as being dominated by a certainty principle--there is a right and wrong answer to every question. The function of education is to see that students know the right answer to questions that educators have decided are important.[46]

Current practices in schools are entrenched in transmitting rather than creating knowledge. Because of this, teachers and students are overly concerned with the "right answer." In one study, Gallagher

---

[44]Guilford, Intelligence, Creativity, and Their Educational Implications, p. 54.

[45]Postman and Weingartner, Teaching as a Subversive Activity, p. 21.

[46]William Glasser, Schools Without Failure (New York: Harper and Row, Publishers, 1969), p. 36.

and Aschner classified the types of questions asked by teachers. It was found that very few teachers asked even a small number of questions leading to divergent thinking.[47] Questions asked in most classrooms are structured so that the main intellectual activity of the student is guessing what answer the teacher wants.

The curriculum organization and the types of textbooks available intensify this conception of learning. The curriculum, especially at the high school level, consists of a fairly fixed body of information. This, in turn, forces a more uniform interpretation of knowledge than is desirable. Textbooks tend to be unimaginative. The assumption made is that learning is retaining information and the function of the book is to supply information to be retained. Handlin expresses this dilemma very accurately:

> The publisher is constrained by the market to turn out books for existing courses; the author writes what will be published; and the teacher shapes his course by the available texts. The result is endless imitation.[48]

Mathematics is one subject area in which the "fixed answer syndrome" particularly dominates. Many students make the claim that "everything in math is either right or wrong." The organization of the mathematics curriculum is partially responsible for this false notion. Harold Anderson, discussing "fixed answer" problems, states:

> This is a kind of learning, common to arithmetic, chemistry, physics, and mathematics courses. . . . The answers, determined in advance,

---

[47] John C. Gowan and George D. Demos, Education and Guidance of the Ablest (Springfield, Illinois: Charles C. Thomas, 1964), p. 89.

[48] O. Handlin, "Textbooks That Don't Teach," Atlantic Monthly 200 (December 1957): 112.

are found in the back of the book or in the experimenter's head. The predetermined answer is the external criterion of evaluation of this kind of learning. Such a criterion, however, makes the problem a kind of closed system, with originality of the subject restricted to methods of approach to the "solution" and not permitted in form or content of the solution.[49]

Perhaps one of the best cases for teaching mathematics as something more than "correct" answers would be an historical one. Actual mathematicians today are concerned with consistency; the axioms themselves are quite arbitrary.[50] At one time, mathematicians re-examined the existing body of mathematics with the idea of purging it of the false. These mathematicians believed in the existence of self-evident propositions or axioms. What they finally realized was that an axiom of a given set could be replaced by its contradictory axiom and that the results of the new set stood all the tests of truth just as well as the results of the old set. This was a deadening blow to the belief in the self-evidence of axioms. Mathematicians then abandoned their search for "the truth"; instead, they aimed at being consistent.[51]

This principle must be imparted to high school mathematics students. The study of the development of non-Euclidean geometry might be one method to expose the arbitrariness of postulates to students. By

---

[49]Harold Anderson, "Creativity in Perspective" in Creativity and Its Cultivation, ed. Harold Anderson (New York: Harper and Brothers Publishers, 1959), p. 260.

[50]Edna E. Kramer, "Einstein vs. Heisenberg--Shall We Discuss Current Mathematics?" in Emerging Practices in Mathematics Education, Twenty-Second Yearbook (Washington, D. C.: National Council of Teachers of Mathematics, 1954), p. 305.

[51]Cassius J. Keyser, The Human Worth of Rigorous Thinking, pp. 220-221.

changing one postulate, totally new types of geometries having significant implications came into being. More open-ended types of problems also need to be used in mathematics classes. The example in which the students were given an arbitrary mathematical system and asked to generate as many theorems as possible would be one suggestion. Another suggestion is that students be given a paragraph containing a great deal of mathematical information and asked to write as many mathematical problems as possible which can be solved using this information.

Everything taught in mathematics is not relevant to the here and now. Henri Poincaré, long recognized as one of the most creative scientists and mathematicians, presents his case for "irrelevancy":

> The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. . . . Of course, I do not here speak of that beauty that strikes the senses, the beauty of qualities and of appearances; . . . I mean that profounder beauty which comes from the harmonious order of the parts, and which a pure intelligence can grasp. . . . intellectual beauty is sufficient unto itself, and it is for its sake, more perhaps than for the future good of humanity, that the scientist devotes himself to long and difficult labors.[52]

In other words, the scientist dedicates himself to science, not because of the possibility of discovering something of practical value, but because of a desire for aesthetic perfection.

One of the delusions under which many educators operate is that everything taught in schools should be "relevant." In developing this model, one assumption is that everything in mathematics education need not be relevant to the here and now. In the article, "In Praise of

---

[52]Edwin E. Slosson, Major Prophets of Today (Boston: Little, Brown, and Company, 1920), p. 104.

Irrelevance and Other Unpopular Notions," Marilyn Whiteside maintains that when students complain that something is irrelevant, they usually mean that it has no pragmatic value for them at the present time. This does not mean that the material will always be insignificant. As Whiteside concluded: "Irrelevance, like beauty, lies in the eye of the beholder, and data generally lack pertinence only when the eye lacks foresight."[53]

Even though many pure mathematicians, like Poincaré, are not motivated by the idea that their research will have practical value, this is frequently the result--sometimes after a lapse of centuries. The history of mathematics shows numerous instances of mathematical discoveries which were originally motivated by an aesthetic appreciation or a desire to extend mathematical knowledge--suddenly receiving in physics, mechanics, or astronomy, practical applications which their originators would not have imagined.[54] The laws of induction between currents and magnets were discovered by Michael Faraday in 1831-32. At that time, Faraday was asked: "What is the use of this discovery?" His succinct reply was: "What is the use of a child--it grows to be a man." Faraday's "child" did mature until it is now the basis of all the modern applications of electricity.[55] Apollonius did his work on conic sections around 200 B.C. but it was not until the sixteenth or seventeenth century

---

[53]Marilyn Whiteside, "In Praise of Irrelevance and Other Unpopular Notions," Journal of Creative Behavior 11 (No. 3, Third Quarter 1977): 155.

[54]Herbert Schubert, Mathematical Essays and Recreations (Chicago: The Open Court Printing Company, 1910), pp. 33-34.

[55]A. N. Whitehead, An Introduction to Mathematics (London: Oxford University Press, 1948), p. 21.

that Newton and Kepler applied these principles to exploring and calculating the motions of the planets about the sun.[56]

Claparède classifies all inventions as one of two types: (1) A goal is given and one must find a means to reach it. In this type of invention, the mind goes from the question to the solution. (2) A fact is discovered and the discoverer must imagine how it can be utilized. In this case, the answer appears before the question. This second type of invention, Claparède designates as the most general type.[57] It allows us to study mathematics for its own sake or for aesthetic perfection. The entire progress of civilization is dependent upon the invention and beginning of ideas that, at one time, were regarded as "impractical" and "useless." In mathematics classrooms, through studying "impractical" pure mathematics, some very practical results are likely to accrue.

Within the mathematics curriculum there are alternatives--students are allowed to choose individual studies or projects to pursue. More flexibility can be provided within the mathematics curriculum by allowing some degree of "open goals," in which students are given the freedom to make some choices. According to Carl Weinberg, freedom of choice is a moral right and even responsibility of every individual.[58] Too much of the material which students are to learn is dictated by the teacher.

---

[56]Schubert, Mathematical Essays and Recreations, p. 34.

[57]Hadamard, The Psychology of Invention in the Mathematical Field, p. 124.

[58]Carl Weinberg, "The Meaning of Alternatives," in The Conventional and Alternative in Education by John I. Goodlad, et al. (Berkeley, California: McCutchan Publishing Company, 1975), p. 66.

While there may be a need for some degree of commonality in the mathematics curriculum, there is definitely a place for individual studies and projects. Through granting more of this type of choice, students are led into the kind of growth that is unavailable in a more closed or controlled environment.

One of the reasons for this is that choice facilitates intrinsic motivation--long recognized to be important in creative development. Intrinsic motivation is that element of personal satisfaction which comes from doing something because it is personally meaningful, not because of any extrinsic reward or punishment. Polya stresses the importance of intrinsic motivation: "For efficient learning, the learner should be interested in the material to be learnt. . . ."[59] Gross states, "The most important learning is, and should be personal, voluntary, and concomitant with living."[60]

Every student is an individual and, as such, has his own unique interests in mathematics just as in other areas. Teachers can extend and enrich the mathematics curriculum through giving each student alternatives in the form of individual projects or topics. In this manner, teachers increase the possibility that learning will occur because of genuine interest rather than the threat of failure.

The teacher is a creative individual. The teacher must serve

---

[59] George Polya, "On Learning, Teaching, and Learning Teaching," American Mathematical Monthly 70 (June-July 1963): 608.

[60] Ronald Gross, "After Deschooling, Free Learning," in After Deschooling, What? eds. Alan Gartner, Colin Greer, and Frank Riessman (New York: Harper and Row, 1973) p. 151.

as the creative model. There is a difference between teaching "about creativity" and teaching creatively. Only through teaching creatively can the teacher demonstrate the true meaning of creativity. This reflects his/her personality and attitudes. Teachers influence creativity through actions, values, and classroom atmosphere. If the teacher is a creative individual, two results will occur.

1. The teacher's behavior creates a psychologically safe classroom atmosphere. Carl Rogers uses the term "psychological safety" to describe acceptance of the individual and his spontaneous thoughts.[61] Gowan also discusses the necessity of a warm, safe, permissive classroom atmosphere. He believes that initial, unrefined efforts at creativity must be praised and encouraged to grow.[62] Creativity cannot occur unless the student feels completely free to express his ideas and thoughts. He must be able to disagree with or question the teacher without fear of ridicule from either the teacher or his peers. Creativity, even under the best of conditions, involves some degree of risk for the individual. Only through a psychologically safe classroom atmosphere will risk be minimized and the opportunity for creativity be maximized.

2. The teacher sees his/her role as being more of a learning facilitator. Many teachers assume an authoritarian role in teaching, that of purveyor of information. This role greatly restrains the intellectual activity of students. Research studies show that in the

---

[61] Carl Rogers, "Toward a Theory of Creativity," in The Creativity Questions, eds. Albert Rothenberg and Carl R. Hausman (Durham, N. C.: Duke University Press, 1976), p. 303.

[62] Gowan and Demos, Education and Guidance of the Ablest, p. 86.

majority of classrooms controlling functions such as selecting problems, what to learn about them, how to go about learning, and what answers to reach constitute over 40 percent of all teacher acts.[63] By assuming the role of learning facilitator, the teacher grants students the freedom to inquire and manipulate ideas and materials. This is referred to by Torrance as learning creatively. Learning by authority is learning that which one is told to learn and accepting it on the authority of someone else.[64] It is the antithesis of learning creatively. The teacher who abandons the omnipotent purveyor of information role for a more creative facilitator role must be secure in his/her self-concept, willing to experiment and even, at times, to fail.

The importance of the teacher as the key to a creative classroom can be demonstrated by an example. In one study, when students were asked to write essays in their best and worst mathematics classes, 68 percent of their remarks were concerned with the teacher's personal and unique manner of teaching and 29 percent of the remarks dealt with the teacher's personal traits and qualities. Only 16 percent were impersonal comments or evaluations of overall class organization, testing, grading, homework, or instructional materials.[65] The students concluded that the teacher--his/her style and his/her personal traits--is the element which distinguishes the "good" from the "bad" class. The teacher is also the significant element which determines the creative or noncreative class.

---

[63] Taba, Curriculum Development, p. 150

[64] E. Paul Torrance, Education and the Creative Potential (Minneapolis: The University of Minnesota Press, 1962), p. 46.

[65] Charles Cooper, "Secondary Students' Perceptions of Mathematics Teachers and Mathematics Classes," The Mathematics Teacher 69 (March 1976): 228.

The learning technique is an inquiry-discovery approach. The inquiry-discovery approach is sometimes called the heuristic method (from the Greek "I find"). It is dominated by the thought that the student is an active participant, not a passive recipient of knowledge.[66] G. C. Lichtenberg, an eighteenth century German physicist, explained one of the best reasons for actively involving students in the discovery process: "What you have been obliged to discover by yourself leaves a path in your mind which you can use again when the need arises."[67]

Intuition plays an integral part in discovery learning. Bruner defines intuition as the act of grasping meaning or significance; it precedes proof and does not insist on right ideas at all times.[68] According to Bruner, teachers need not teach intuitive thinking. Instead, they must end their practice of inhibiting intuitive thinking.[69] Morris Kline affirms that the importance of intuitive thinking rests not just on the fact that historically this is how mathematics developed. Rather, intuitive thinking is the way the human mind understands any ideas. To repeat Aristotle, there is nothing in the human mind that was not first in the senses.[70] Immanuel Kant underscores the importance of intuition is his Critique of Pure Reason: "Thus all human cognition begins with intuitions, proceeds from thence to conceptions, and ends with ideas."[71]

---

[66] J. W. A. Young, "The Teaching of Mathematics," The Mathematics Teacher 61 (March 1968): 290.

[67] Polya, "On Learning, Teaching, and Learning Teaching," p. 605.

[68] Bruner, On Knowing, p. 102. [69] Ibid., p. 105.

[70] Kline, "NACOME: Implications for Curriculum Design," p. 452.

[71] Polya, "On Learning, Teaching, and Learning Teaching," p. 605.

It is generally accepted that lower mental processes--knowledge and comprehension--can be learned equally well using a variety of experiences and teaching styles. It is also generally acknowledged that achievement of complex types of critical thinking or higher mental processes is unlikely to be gained by lecture methods. The significance of these findings is that the more complex and higher categories of the cognitive domain require more sophisticated types of learning experiences. Much more activity and participation on the part of the learner are necessary. Since creativity is generally found within the complex and higher categories of the cognitive domain, it could be deduced that the nurture of creative thinking demands an active, involved learning style--one similar to that of discovery. Taba verifies that in order to achieve productive thinking, the learner must be given more inquiry, discovery, and experimentation experiences.[72]

The discovery technique is inherently related to other components in the proposed model for a creative mathematics classroom. Inquiry-discovery teaching is a strategy in which the teacher assumes the role of a facilitator. Bruner states that emphasis on discovery leads the learner to organize what he is encountering in a manner that reveals relatedness and to transform information for better use. It also assists the student in distinguishing between relevant and irrelevant information.[73] Hence, within the proposed model, the inquiry-discovery approach is associated with analysis and synthesis.

---

[72]Taba, Curriculum Development, p. 71. The writer interprets productive thinking to be the same as creative thinking.

[73]Bruner, On Knowing, p. 87.

Some teachers incorrectly think that discovery techniques require little effort; one merely tells the student to "figure out things for hinself." Nothing could be further from the truth. Instead, the teacher must be astute in knowing when and how to ask questions, give hints, outline a line of attack, or begin a solution. He or she must be careful to give neither too much nor too little help. One teacher and mathematician who has reflected upon the discovery technique in detail is George Polya. In his book, How to Solve It, the teacher guides the student by asking such questions as: Could you change the unknown (conclusion) or data (hypothesis) so that the new unknown and data are closer to each other? Have you seen a problem like this before? Can you solve a special case? Would it help if you dropped part of the condition for a while and worked with the rest? Have you used all the data? Do you know of a more general problem? Guess an answer.[74] Socrates is considered one of the earliest teachers well-versed in the discovery technique. His dialogue with the slave boy leading to the discovery of the Pythagorean Theorem gives the reader an excellent paradigm of the discovery method in mathematics, employed on a one-to-one basis.[75]

"Discovery" was a very popular term when "new math" came into vogue. While discovery techniques may have influenced elementary school

---

[74] George Polya, How to Solve It, 2d ed. (Garden City, N. Y.: Doubleday and Company, Inc., Doubleday Anchor Books, 1957), pp. 37-126.

[75] See "The Socratic Method: Dialogue as Direct Teaching," in Ways of Teaching, 2d ed., edited by Ronald T. Hyman (Philadelphia: J. B. Lippincott Company, 1974), pp. 91-102.

mathematics classrooms, very few applications of discovery can be observed at the high school level. Kline disagrees with the NACOME report: "The report said new math espoused discovery at the secondary level. I fail to see much, if any, of this in the new math curricula."[76]

Today, with knowledge expanding at a rapid rate, it is increasingly important how a student learns. The discovery process, once mastered, is an invaluable tool to the student in later situations with mathematics. Bruner, writing in Toward a Theory of Instruction, reasons:

> We teach a subject not to produce little living libraries on that subject but rather to get the student to think mathematically for himself, . . . to take part in the process of knowledge-getting. Knowing is a process not a product.[77]

Realistically, discovery learning is not an appropriate learning technique for all mathematical topics at all times in all classrooms. It is, however, a very effective method which is often unused in secondary mathematics.

The teacher attempts to make students more aware of mathematical problems within the environment. Getzels remarks that although there is a great deal written in the area of problem solving, problem finding is one area almost ignored.[78] This is a very important key in the total creative thinking process and as such should not be forgotten. Wertheimer explains the significance of problem finding:

> The function of thinking is not just solving an actual problem, but discovering, envisaging, going into deeper questions. Often

---

[76]Kline, "NACOME: Implications for Curriculum Design," p. 450.

[77]Jerome S. Bruner, Toward a Theory of Instruction (New York: W. W. Norton and Company Inc., 1966), p. 72.

[78]J. W. Getzels, "Problem Finding and the Inventiveness of Solutions," Journal of Creative Behavior 9 (No. 1, First Quarter 1975): 12.

> in great discoveries the most important thing is that a certain question is found.[79]

One of the traits of the creative individual listed by Torrance is sensitivity to environmental stimuli.[80]

In most mathematics classrooms, students are not given the opportunity to develop this trait. Instead of being asked to pose problems, they are told to solve given problems. They are unaware of problems within their environment which might be solved by the application of their mathematical knowledge. It is the responsibility of the mathematics teacher to correct this situation and to heighten students' environmental perceptiveness. As one example of an activity which could be used, students studying trigonometry could be asked to write as many word problems as possible in which trigonometry is used to discover some fact within their environment.

Students are taught to develop analysis abilities. Analysis is the fourth level of Bloom's taxonomy and is designated by John Arnold as the first state in the creative process. Analysis concerns a breakdown of material into constituent parts and the detection of the relationships of the parts and the way they are organized. It is a seeking, questioning stage in the creative process, where the creator is becoming aware of the total problem and what it entails.[81] Inherent in analysis is the ability to recognize unstated assumptions.

---

[79] Max Wertheimer, Productive Thinking, ed. Michael Wertheimer, enl. ed. (New York: Harper and Brothers Publishers, 1959), p. 121.

[80] Torrance, "Creative Thinking Through School Experiences," p. 46.

[81] John E. Arnold, "Creativity in Engineering," in Creativity, ed. Paul Smith (Freeport, New York: Books for Libraries Press, 1959), pp. 38-40.

For the creative mathematics student, analysis is particularly important. Analysis in mathematics implies having a total understanding of the problem, breaking the problem into subproblems, and being careful to avoid tacit assumptions. Through analysis, mathematics students are able to find relationships and generalizations among problems which, at first glance, seem unrelated. Analysis techniques similar to those enumerated by Polya, are generally not taught in mathematics classrooms. Unfortunately, many mathematics teachers are guilty of giving students the same types of problems that are solved in the textbook. For good students these problems can be solved almost immediately upon inspection and present no challenge whatsoever. The knowledge and insight that might be gained from analysis is lost.

Synthesis is provided through requiring the student to select and organize. Creation, regardless of whether it is in mathematics or any other field, takes place by combining ideas. Synthesis, considered by many as the essence of creativity, consists of searching for unifying concepts and putting together pieces in order to form a pattern or structure (whole) not clearly there before.[82] Poincaré expounds on creation: "To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority. Invention is discernment, choice."[83] Paul Valéry reflects this idea when he concludes that the genius is not the man who makes up combinations, but the man who is able to choose. This type of individual

---

[82]Bloom, Taxonomy of Educational Objectives, p. 162.

[83]Henri Poincaré, "Mathematical Creation," in The Creative Process, ed. Brewster Ghiselin (New York: Mentor, New American Library, 1952), p. 35.

finds what is important in a mass of information that is imparted to him.[84]

The importance of synthesis has implications for the mathematics teacher. Students should be taught to associate seemingly unrelated past learnings in problem solving. After analyzing the problem, they should be encouraged to experiment freely and even wildly, attempting to build a new whole. Poincaré supports this type of free association:

> Among chosen combinations the most fertile will often be those formed of elements drawn from domains which are far apart . . . most combinations so formed would be entirely sterile. But certain among them, very rare, are the most fruitful of all.[85]

Situations and problems should be conceived with the idea of forcing students to select and organize. In the Twenty-Second Yearbook of the National Council of Teachers of Mathematics, Ullsvik and Lewis list one critical-thinking trait as an ability to distinguish between evidence that is relevant and evidence that is irrelevant to the problem at hand--in other words, the ability to choose what information to use.[86]

There are many differences between those mathematical problems presented in school and those arising in life outside school. School problems usually have the exact amount of information needed to solve them. Many out-of-school problems require that the individual decide

---

[84] Hadamard, The Psychology of Invention in the Mathematical Field, p. 30.

[85] Poincaré, "Mathematical Creation," pp. 35-36.

[86] Bjarne R. Ullsvik and Harry Lewis, "Evaluation of the Application of Mathematical Reasoning Standards to Nonmathematical Situations," in Emerging Practices in Mathematics Education, Twenty-Second Yearbook (Washington, D. C.: The National Council of Teachers of Mathematics, 1954), p. 370. The writer interprets critical thinking to be the same as creative thinking.

what information is needed and where and how to get it. This skill of selecting pertinent data is highly desired and needs to be cultivated in the classroom. Buswell found that high school and college students had difficulty in identifying which facts were relevant or irrelevant to solving problems.[87] Another investigator discovered that when problems containing excessive data were presented in a first-year algebra course, a large percentage of students used all of the information. This type of rigidity is almost guaranteed to prevent the student from being successful with problems requiring creativeness or selecting from alternatives.[88]

It is important, therefore, that students be given experience with problems having both abundant and deficient data. Students should be taught to ask such questions as: Do we have any inconsistent data and, if so, why? Do we have sufficient data to solve the problem? Is all of the data pertinent to the solution?[89] Problems should be given to students which are somewhat misleading. As an illustration, the following problem appears to have insufficient information at first glance:

---

[87] G. T. Buswell and B. Y. Hersh, Patterns of Thinking in Solving Problems (Berkeley: University of California Press, 1956), pp. 133-134.

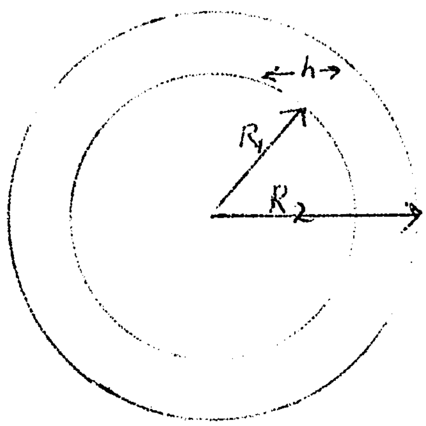
[88] John J. Kinsella, "Problem Solving" in The Teaching of Secondary School Mathematics, Thirty-Third Yearbook (Washington, D. C.: National Council of Teachers of Mathematics, 1970), p. 252.

[89] Richard L. Francis, "Word Problems: Abundant and Deficient Data," The Mathematics Teacher 61 (January 1978): 9.

FIG. 1.

A rope is wrapped around the earth at its equator. Suppose the rope length is increased by 50 meters and the resulting rope made into a circle concentric with the equator. What is the height of the rope above the ground?[90]

Solution:



$$C_1 = 2\pi R_1 \qquad C_2 = 2\pi R_2$$

$$\frac{C_1}{2\pi} = R_1 \qquad \frac{C_2}{2\pi} = R_2$$

$$h = R_2 - R_1$$

$$h = \frac{C_2}{2\pi} - \frac{C_1}{2\pi}$$

Since $C_2 = C_1 + 50$

$$h = \frac{C_1 + 50}{2\pi} - \frac{C_1}{2\pi}$$

$$h = \frac{50}{2\pi} \doteq 8 \text{ meters}$$

[90]Ibid., p. 10. Note that the size of the sphere is independent of the solution and is, therefore, unnecessary to know.

Students are encouraged to take many different approaches in solving problems. Mathematical fluency is an important aspect of creativity in mathematics. It includes not only the ability to generate a large number of solutions in open-ended problems, but also the ability to find a variety of methods to solve a given problem. Too many mathematics students solve problems in a rote, mechanistic manner. Buswell found that students used formalized procedures in problem solving as though following a recipe.[91] Bruner observes that students who tend to be early over-achievers are especially likely to seek "the right way to do it." These students depend upon their ability to "give back" that which they receive. In Bruner's words: "Their learning is not their own."[92] Nowhere do Bruner's or Buswell's statements hold as true as in mathematics classrooms. Many students become frustrated when confronted with mathematics problems that do not fit into a certain category. They are unwilling to try different strategies. Instead, they expect the teacher to give them a simple step-to-step form to follow for every problem.

These students' attitudes, however, do not just happen. They come about as a result of teaching strategies and/or the types of mathematics problems students have encountered in their mathematics courses through the years. Many teachers actively discourage students from finding their own methods of solving problems. This is sometimes done

---

[91]Buswell and Hersh, Patterns of Thinking in Solving Problems, pp. 133-139.

[92]Jerome Bruner, "The Act of Discovery," Harvard Educational Review 31 (Winter 1961): 26.

by the teacher telling the student "how to do it" before the student has a chance to explore and find his own method. Some teachers are guilty of insisting that a problem be solved by using a particular method even when another method is equally valid.

Creativity can be stifled also by the kinds of problems given to students. Typical "textbook" problems can be solved by employing the same stereotyped processes. Kuhn claims that this creates "mental sets" or "Einstellungen."[93] These are terms employed by psychologists to describe the phenomena whereby individuals develop inhibitions that rigidize their thinking. The inhibitions cause the individual to have difficulty in attacking new problems with imaginative approaches.[94] As an alternative to textbook problems, teachers should ask students who have the prerequisite background and skills to solve problems closely resembling those solved by professionals.

The teacher allows the opportunity for following through on ideas rather than superficially covering material. Today, many mathematics teachers, who claim to value creativity, insist that they don't have time for creativity; they are too busy trying to "cover" all of the material. One of the regrettable outcomes of "new math" was the introduction of more topics into an already crowded mathematics curriculum. Trimble urged mathematics educators to stop trying to cover so many topics and reminded them that it was better to do a few things well than many things badly.[95]

---

[93]Thomas McGannon, "Creativity and Mathematics Education," School Science and Mathematics 72 (January 1972): 12.

[94]Ibid.

[95]Harold Trimble, "NACOME: Implications for Teacher Education," The Mathematics Teacher 69 (October 1976): 467.

This is by no means a new idea. As early as 1932, Whitehead, writing in Aims of Education, warns mathematics educators to stop cramming so many topics into the mathematics curriculum. By eliminating the "pointless accumulation of details," students would have plenty of time to concentrate their attention on important topics.[96]

How did our curriculum become obsessed with "covering" material? The oldest and prevailing type of curriculum organization at the secondary level is the subject organization. When a curriculum is structured in terms of subjects, there often is an excessive concern with acquiring specific facts of covering material. College board and accountability testing particularly intensify this situation in mathematics. In addition, the teacher feels compelled to cover the necessary amount to enable the students to be well-prepared for the subsequent mathematics courses.

One of the basic creative abilities listed by Torrance is elaboration, the ability to work out details of an idea and implement it.[97] It is considered by some writers in the area of creativity as one of the final steps in creative production.[98] However, the "ground-covering fetish" works against elaboration. In the words of Torrance: "In many respects the organization of our curricula and the pressure to 'cover' standard bodies of content serve as obstacles to working out the implications of ideas."[99]

---

[96]Whitehead, The Aims of Education, pp. 122-126

[97]Torrance, Education and the Creative Potential, p. 46

[98]J. P. Guilford, Creativity, Intelligence, and Their Educational Implications, p. 211.

[99]E. Paul Torrance, "Developing Creative Thinking Through School Experiences," p. 44.

It has been estimated that the average student is exposed to one-billionth of the world's knowledge in his twelve years of schooling.[100] It is ridiculous to be so specific as to the exact material the one-billionth must contain.

Provisions are made in the creative mathematics classroom for both active (exploratory) and quiet (reflective) periods. Torrance states that both active and quiet periods are important in stimulating creativity.[101] Wallas, writing in The Art of Thought, specified four stages in the creative process: preparation, incubation, illumination, and verification.[102] The first stage, which Wallas calls preparatory, could be thought of as exploratory. He defines this stage as one in which raw data are collected and reorganized. During the exploratory phase, the student could be doing a number of things--analyzing, searching for patterns, clarifying the problem, synthesizing. What is important is that the student is actively involved, not passively absorbing information from the teacher.

One approach to engender creativity in mathematics would be more long-term assignments with the teacher supervising and guiding the student. Another suggestion is that students be given problems or situations in mathematics which require exploration. The Cambridge Conference in 1963 advocated this idea:

---

[100] Jack Frymier, speech at the State Mathematics Conference, Pinehurst, North Carolina, Spring 1977.

[101] E. Paul Torrance, "Developing Creative Thinking Through School Experiences," p. 43.

[102] Graham Wallas, The Art of Thought (New York: Harcourt, Brace and Company, 1926).

> Both the practioner of applied mathematics and the creator of pure mathematics spend much of their time and effort on "here's a situation, explore it," not only on "here's a problem, solve it" or "here's a theorem, prove it." It is good to admit this to the students, and to let them work on mathematics in this manner themselves.[103]

The value of exploration in mathematics could be historically documented by the experiences gained with the three insolvable problems of antiquity--duplication of the cube, trisection of an angle, and squaring of a circle. In attempting to solve these problems, many mathematicians discovered new properties and theories. To quote Herman Schubert: "Thus is the struggle after truth more fruitful then the actual discovery of truth."[104] Many unanticipated benefits can be acquired through exploration.

According to Wallas, the second stage in the creative process is incubation. During this phase, experiences began to mill around and flow together although there is no apparent activity on the part of the individual. The length of incubation may be minutes, days, months, or years. Numerous creative people attest to the benefits of incubation if not its absolute necessity. Poincaré discusses how his discovery of Fuchsian functions came about:

> Most striking at first is this appearance of sudden illumination, a manifest sign of long, unconscious prior work. The role of this unconscious work in mathematical invention appears to me incontestable.[105]

Quiet, reflective periods in which there are no outward signs of

---

[103]Max A. Sobel, "Skills" in <u>The Teaching of Secondary School Mathematics</u>, p. 307.

[104]Schubert, <u>Mathematical Essays and Recreations</u>, p. 30.

[105]Poincaré, "Mathematical Creation," p. 38.

activity are conducive to incubation. There are very few opportunities, particularly in most mathematics classrooms, for incubation to occur. Problems are posed and if responses are not immediately forthcoming, the teacher supplies the answers. A study at Pennsylvania State College found that during a class period, the forty questions used were both asked and answered by the teacher. The average time allowed for an answer was four seconds.[106] It is important that teachers allow sufficient time after a question is asked for students to think and formulate responses. Silence--whether it be seconds, minutes, or hours--can be an effective aid to incubation. Creativity takes time and reflection; it does not happen immediately upon demand.

Various grouping arrangements are employed--large, small, and individual. In many traditional high school classrooms, the only grouping method employed is twenty-five to thirty students doing exactly the same assignments at all times. The teacher directs his/her efforts toward the average student in the group, boring the more able or creative student. The continuous use of only large group instruction results in several problems explained by Taba:

> Questions arise also regarding the amount of ego suppression that occurs in school, because of a necessity of managing large groups. . . . The observation that personality, creativeness, and spontaneity are "flattened out" from primary school upwards is common, . . . in the process of learning the conduct that is appropriate to school, children also learn to deny their unique individuality and hence suffer an ego-hurt.[107]

---

[106] U. S. Chaudhari, "Questioning and Creative Thinking: A Research Perspective," Journal of Creative Behavior 9 (No. 1, First Quarter 1975): 31.

[107] Taba, Curriculum Development, p. 73.

Getzels and Jackson also assert that there is too much emphasis in the classroom today on "group dynamics" and "enforced interactions of one with all."[108] While the exclusive use of large groups is detrimental to learning, some interaction with a large group structure can be beneficial. Large groups can promote stimulating discussions or questions if each member of the group feels free to express himself.

Brainstorming is one creative technique that can be used as an idea starter. It enables the sharing of uncommon experiences without the threat of censure from the group. Because of varying backgrounds of group members the thinking of all is prompted.[109] In general, a small number of group members is preferred in order to achieve maximum involvement of each participant. In mathematics, a problem could be propounded and students could suggest, in a brainstorming session, procedures and techniques for dealing with the problem.

The need for the individual to work alone has long been recognized as vital to creativity. While groups are useful for stimulating initial creative ideas, the final refined creative product comes from an individual. Unfortunately, there are very few provisions made in mathematics classrooms or any other classrooms for a student to work independently on problems or projects of his choice. Taba states: "Curriculum patterns, expectations, and standards often fail to account, still less to provide, for idiosyncrasies in thought or conduct."[110] Getzels and

---

[108] Getzels and Jackson, Creativity and Intelligence, pp. 125-126.

[109] Carl E. Gregory, The Management of Intelligence (New York: McGraw-Hill Book Company, 1967), pp. 194-196.

[110] Taba, Curriculum Development, p. 72.

Jackson underscore the importance of working alone:

> . . . it is certain that some kinds of creative performance require permitting the person to set his own problem, to proceed at his own pace, to cogitate on the issues in his own way, to play with his own ideas in his own fashion.[111]

Large group sessions, small group interactions, and individual work are all important in bringing about creativity. One writer in the area of mathematics curriculum summarizes the need for varying grouping arrangements:

> As students have individual learning styles, teachers have individual teaching styles; to prescribe one style for all teachers is as mistaken as to affirm a single learning style best for all students. . . . Teachers should be eclectic pragmatists, selecting those methods and materials which seem to work best at a particular time for a particular student or group of students working with a particular concept. There are times and situations for which large groups instruction is still appropriate, just as there are situations, teachers, and students best suited to small group or independent work.[112]

Modular scheduling is used as a more flexible way of approaching learning. The six-period day of fifty-five minutes each period is inflexible and unconducive to a creative learning situation. A 1974 North Carolina Task Force on Secondary Education admitted that rigidity in schedules was a problem in secondary schools.[113] One extremely vocal critic of the prevailing high school scheduling organization is Arthur Foshay:

> Ideally, children thus at work should be allowed to continue at their own pace until the work is completed. In practice, we violate this with bell schedules, irrelevant demands, or sheer pressure to "get on with it." . . . School, as we conduct it, does not favor

---

[111] Getzels and Jackson, Creativity and Intelligence, p. 126.

[112] Hill, "Issues from NACOME Report," pp. 444-445.

[113] Channels for Changing Secondary Schools, p. 43.

> the kind of unremitting work that a creative person must learn to carry on. . . . If we really believed unremitting work to be desirable as a part of the creative process, we would greatly increase our provision for independent, individual study. As things stand, the school requires of the student that he flit from one field of activity to another--in high school, every forty minutes or so--so that he can cover many subjects. Such scheduling amounts to an institutional conspiracy to prevent creative behavior.[114]

In order to nurture creativity, it is imperative that educators find an alternative to the present deplorable scheduling structure. Modular scheduling, if properly implemented, could assist in creative growth of the individual in the high school. Silberman, author of Crisis in the Classroom, regards modular scheduling as a mechanism by which schools could gain greater freedom. Modular scheduling allows flexibility through the use of shorter time modules, typically sixteen to twenty minutes. By combining modules, class periods can be organized for varying lengths. This is significant since some learning situations may demand more time to achieve objectives. For example, a lecture or demonstration may use forty minutes or two time modules, whereas a seminar or small group instruction might use sixty to eighty minutes.[115] It is easier through the framework of modular scheduling to accommodate both independent study and small and large group instruction. These elements have already been established within the model as criteria contributing to creativity. Through modular scheduling, a teacher may adapt his/her teaching style to the purpose at hand.

---

[114] Arthur W. Foshay, "The Creative Process Described," in Creativity in Teaching: Innovations and Instances, ed. Alice Miel (Belmont, Calif.: Wadsworth Publishing Company, Inc., 1961), pp. 37-38.

[115] Charles E. Silberman, Crisis in the Classroom (New York: Random House, 1970), p. 341.

One asset of modular scheduling is that it places more responsibility on the student and gives him more opportunities to make choices. (Choice is a part of the proposed model.) One common practice is to arrange programs in order for scheduled lectures, discussions, and classes to occupy only a small portion of a student's week, with a considerable percentage of his time--30 to 40 percent--left unscheduled. In some schools, students are free to do anything they want during unscheduled time. In others, students are technically free but are expected to use the time to complete assignments or probe more deeply into some aspect of a course.[116] One basic theoretical principle of modular scheduling is that it attempts to insure optimal use of school time and resources. Modular scheduling is an administrative technique that makes it possible, but in no way guarantees, a freer and less restrictive atmosphere. Too often it is a gimmick in which nothing changes but the name.

Students are allowed input in classroom organization, procedures, and topics. In most classrooms, too much of the responsibility for the educational process is retained by the teacher. He/she determines the goals, decides on content to be learned, identifies problems to be solved, and evaluates the student's performance against the teacher's (not the student's) standards. The student is obviously included very little in these activities.

Feldhusen and Treffinger suggest that in order to promote creative thinking, the student should have more choices and be a more meaningful part of the decision-making process. Learning experiences, as well

---

[116]Ibid., pp. 342-343.

as the student's total education, should be more within his control.[117] Through allowing more student input in various aspects of the classroom, the teacher is facilitating individual responsibility and (ultimately) creative growth.

Higher levels of the cognitive domain are measured by more open-ended testing. Much of the testing, in mathematics as well as in other classrooms, is done on the knowledge or comprehension level of the cognitive domain. The National Council of Teachers of Mathematics Twenty-Sixth Yearbook states that creativity is one valid objective in mathematics classrooms and, as such, should be tested.[118] They recognize that teacher-made tests do not effectively evaluate productive thinking.[119] The NACOME report, reviewing "new math" and the state of the present mathematics curriculum, questions the quality, validity, and appropriateness of testing in classrooms today. This weakness was especially noticeable in an assessment of higher order mathematical abilities such as problem-solving.[120]

There is a tendency in schools to evaluate those objectives that are not necessarily the most important, but the easiest to measure--

---

[117] John F. Feldhusen and Donald J. Treffinger, Teaching Creative Thinking and Problem Solving (Dubuque, Iowa: Kendall/Hunt Publishing Company, 1977), p. 14.

[118] Max Sobel and Donovan Johnson, "Analysis of Illustrative Test Items," in Evaluation in Mathematics, Twenty-Sixth Yearbook (Washington, D. C.: National Council of Teachers of Mathematics, 1961), pp. 72-73. The writer interprets productive thinking to be the same as creative thinking.

[119] Robert Fouch, "Overview and Practical Interpretations," in Evaluation in Mathematics, p. 178.

[120] Hill, "Issues from NACOME Report," p. 445.

remembering information rather than thinking with it. It is difficult to defend the "frills," such as creativity, from attack as long as there are no provisions made for testing them. To evaluate creativity, mathematics tests must be more subjective and open-ended. Students should be given divergent questions in which they arrive at many "correct" answers. They must also be tested on abilities to analyze and synthesize data. Guilford reminds teachers that *if they are to educate for creativity*: "It almost goes without saying that the kinds of assessment of achievement should be different from those provided by most current marking practices."[121]

The model which has been developed and explained is presented on the following two pages.

---

[121]Getzels and Jackson, Creativity and Intelligence, p. 130.

FIG. 2. MODEL FOR A CREATIVE SECONDARY MATHEMATICS CLASSROOM

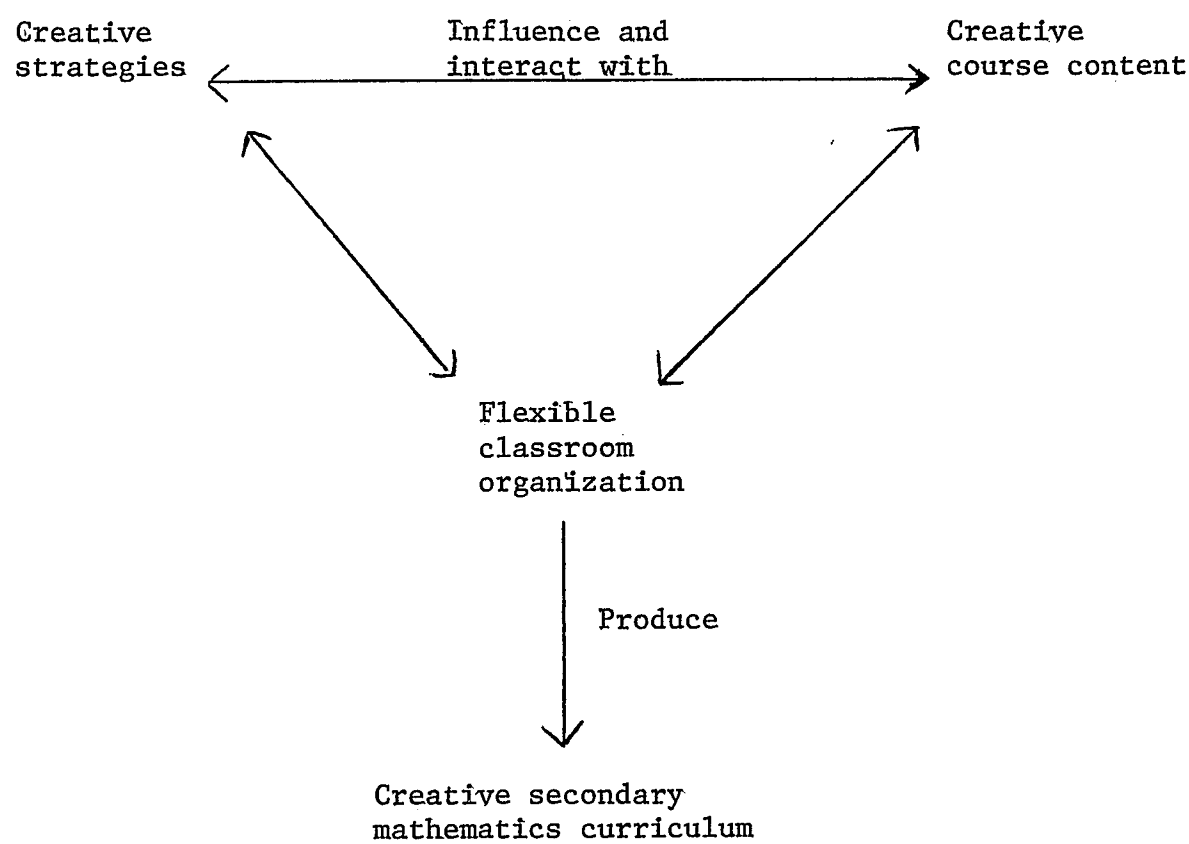
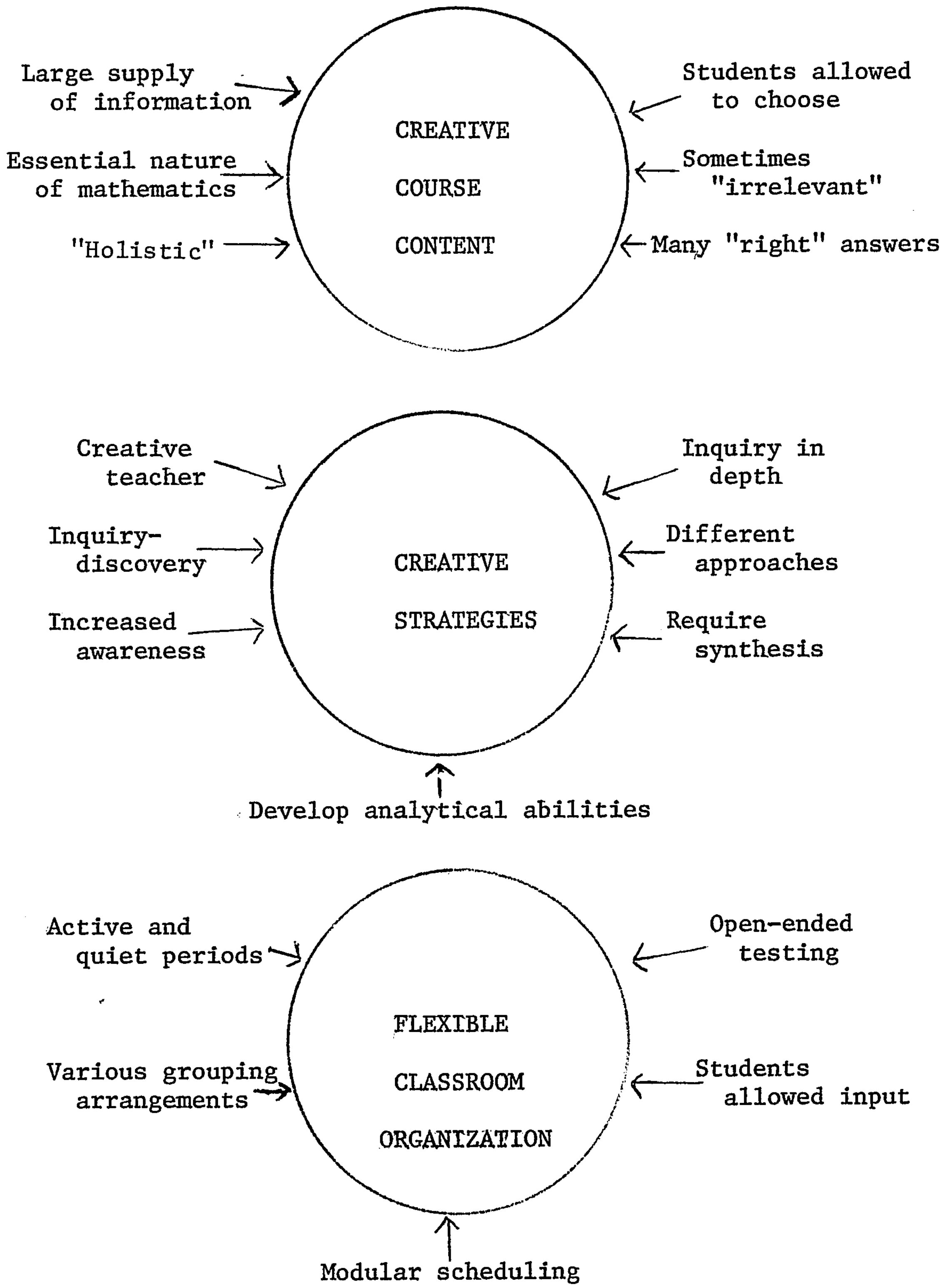


FIG. 3. FURTHER ELABORATION OF COMPONENTS OF MODEL



CHAPTER V

SUMMARY AND CONCLUSIONS

Since 1950, a great deal of research has been done in the area of creativity. Despite this, it is generally agreed that schools today are no more creative than they were fifty years ago. There are several reasons for this situation. Creativity is not valued by the general public. To many people, creativity is a "extra" to the curriculum rather than the crux of it. Too often it is relegated to a nonessential position by school officials, teachers, and the general public.

Nowhere is the lack of creativity any more evident than in secondary mathematics. Very few studies of creative behavior have dealt directly with mathematics education. Much of mathematics teaching is mechanistic and skill-oriented. Mathematics is viewed in general as consisting of little more than computational ability. This trend appears destined to accelerate, primarily because of the efforts of the "back-to-basics" proponents.

Creativity should be thought of as existing along an uninterrupted sequence. Every individual possesses some degree of creativeness; every classroom has some degree of creativity. Unfortunately, much of this creativity is unplanned and inconsistent. The model developed in this study is an effort to plan for creativity in the secondary college preparatory mathematics classroom. It represents an ideal; the model is an objective which will probably never be totally achieved.

The theoretical basis for the model is drawn from findings in the literature on creativity, mathematics, curriculum, and mathematics education. The model consists of three basic components: creative course content, creative strategies, and flexible classroom organization. Each of the components is influenced by several criteria.

Creative course content should reflect a large background of information, reveal the essential nature of mathematics, be holistic, contain problems with many correct answers, sometimes be irrelevant, and allow student choice. Creative strategies should be influenced by the creative teacher's behavior and role, the inquiry-discovery approach, the need for requiring synthesis, encouraging different approaches in problem solving, and allowing inquiry in depth. Flexible classroom organization should allow for active (exploratory) and quiet (reflective) periods, various grouping arrangements, modular scheduling, student input, and measurement of higher levels of the cognitive domain through more open-ended testing.

Implications and Topics for Study

The model provides a framework for further studies in the area of creativity. Some of the implications of the model and possibilities for future study are listed and discussed.

Continued Study of Creativity in Secondary Mathematics Education

This model should serve as a stimulus to other mathematics educators who value creativity. Through careful and thoughtful examination of various criteria in the model, more creative materials and activities could be developed. The model provides a means for evaluating the degree of creativity in present mathematics classrooms.

Pragmatic Extension of the Model

Each criterion of the model should be carefully examined on a more practical level. As an illustration, how can the interdisciplinary concept be best implemented in a high school mathematics classroom?

Structure of the Secondary College Preparatory Mathematics Curriculum

The existing structure of the secondary college preparatory mathematics curriculum needs to be reviewed. In accordance with this model, are the traditional courses of Algebra I, Geometry, Algebra II, and Advanced Mathematics the most effective way of organizing mathematical learning? Is there an alternate organization that could better facilitate creativity in the mathematics curriculum?

Topics Currently Included in Secondary Mathematics Courses

There is a definite need that both high school and college mathematics teachers re-examine those topics which are included in the existing secondary college preparatory mathematics curriculum . Those topics which are nonessential should be eliminated. This would provide additional time for a more creative exploration of mathematics.

Modifications to Other Subject Areas or Levels

The model dealt with only a small part of the total curriculum--secondary college preparatory mathematics. Implications of the model should be found for other subject areas, age levels, and ability levels.

If creativity is a generalized trait, the model should be particularly adaptable to other subject areas.

Implications for Administrators

If creativity is ever to occur in the schools in any meaningful manner, administrators must be involved. While the teacher has the power to effect many changes, there are still those changes which cannot be brought about without the assistance and cooperation of administrators. Administrators should be knowledgeable in the area of creativity and its importance in regard to the classroom.

Teacher Training

The teacher should be able to identify creative talent; he/she should guide and nurture its development. Before any degree of success can be realized in the classroom in this area, the teacher's preparation and training must be revamped. Training in the area of creativity must have a prominent place in the overall preparation for the classroom teacher.

BIBLIOGRAPHY

Aiken, Lewis R. "Ability and Creativity in Mathematics." Review of Educational Research 43 (No. 4, Fall 1973): 405-432.

Allen, Myron S. Morphological Creativity. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962.

Alpaugh, Patricia K.; Renner, V. Jayne; and Birren, James E. "Age and Creativity: Implications for Educators and Teachers." Educational Gerontology 1 (No. 1, January-March 1976): 17-39.

Anderson, Harold H. "Creativity in Perspective." In Creativity and Its Cultivation, pp. 236-267. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Armstrong, Frank Alexander. Idea Tracking. New York: Criterion Books, 1960.

Arnold, John E. "Creativity in Engineering." In Creativity: An Examination of the Creative Process, pp. 33-46. Edited by Paul Smith. Freeport, New York: Books for Libraries Press, 1959.

Baird, Leonard L. "Torrance Tests of Creative Thinking." In The Seventh Mental Measurement Yearbook, Volume I, pp. 836-838. Edited by Oscar Buros. Highland Park, N. J.: The Gryphon Press, 1972.

Barron, Frank. "The Needs for Order and for Disorder as Motives in Creative Activity." In Scientific Creativity: Its Recognition and Development, pp. 153-160. Edited by Calvin W. Taylor and Frank Barron. New York: John Wiley and Sons, Inc., 1963.

Barron, Frank. "The Psychology of Creativity." In The Creativity Question, pp. 189-200. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Barron, Frank et al. "Process Versus Product in Creativity: A Spontaneous Discussion of the Conference Participants." In Widening Horizons in Creativity: The Proceedings of the Fifth Utah Research Conference, pp. 112-121. Edited by Calvin W. Taylor. New York: John Wiley and Sons, Inc., 1964.

Bass, Saul. "Creativity in Visual Communications." In Creativity: An Examination of the Creative Process, pp. 121-142. Edited by Paul Smith. Freeport, New York: Books for Libraries Press, 1959.

Begle, E. G. "SMSG: The First Decade." The Mathematics Teacher 61 (March 1968): 239-245.

Belcher, Terence L. and Davis, Gary A. Interrelationships Among Three Standardized Creativity Tests and IQ. Bethesda, Md.: ERIC Document Reproduction Service, ED 046 982, 1971.

Blakeslee, Alton. "Math Takes the Guesswork Out of Life." The High Point Enterprise, 7 May 1978, sec. 18C.

Bloom, Benjamin S.; Engelhart, Max D.; Furst, Edward J.; Hill, Walker H.; and Krathwohl, David R.; eds. Taxonomy of Educational Objectives: Classification of Educational Goals Handbook, Cognitive Domain. New York: David McKay Co., Inc., 1956.

Bruner, Jerome, On Knowing. Cambridge, Mass.: Belknap Press, 1962.

Bruner, Jerome. "The Act of Discovery." Harvard Educational Review 31 (Winter 1961): 21-32.

Bruner, Jerome. "The Conditions of Creativity." In Contemporary Approaches to Creative Thinking, pp. 1-30. Edited by Howard Gruber, Glenn Terrell, and Michael Wertheimer. New York: Atherton Press, 1967.

Bruner, Jerome S. Toward a Theory of Instruction. New York: W. W. Norton and Company, Inc., 1966.

Buswell, G. T. and Hersh, B. Y. Patterns of Thinking in Solving Problems. Berkeley: University of California Press, 1956.

Chaudhari, U. S. "Questioning and Creative Thinking: A Research Perspective." Journal of Creative Behavior 9 (No. 1, First Quarter 1975): 30-34.

Clary, Robert; Eason, Margaret; Harris, Bryce; and Ridgeway, Jane. A Guide to Curriculum Study: High School Mathematics. Raleigh, N. C.: State Board of Education, 1959.

Cobb, Stanwood. The Importance of Creativity. Metuchen, N. J.: The Scarecrow Press, Inc., 1967.

Cooper, Charles. "Secondary Students' Perceptions of Mathematics Teachers and Mathematics Classes." The Mathematics Teacher 69 (March 1976): 226-232.

"Creativity." Mainliner, July 1977, pp. 25-31.

Crutchfield, Richard S. "Conformity and Creative Thinking." In Contemporary Approaches to Creative Thinking, pp. 120-140. Edited by Howard E. Gruber, Glenn Terrell, and Michael Wertheimer. New York: Atherton Press, 1962.

Davis, Gary A. "In Frumious Pursuit of the Creative Person." Journal of Creative Behavior 9 (No. 2, Second Quarter 1975): 78-87.

Davis, Gary A. "Training Creativity in Adolescence: A Discussion of Strategy." Journal of Creative Behavior 3 (No. 2, Spring 1969): 95-104.

DeVito, Alfred. "Survival Through Creative Education." Journal of Creative Behavior 10 (No. 1, First Quarter 1976): 45-51.

Dirkes, Ann. "Intellectual Development through Interdisciplinary Problem-Solving." School Science and Mathematics 75 (April 1975): 318-322.

Douglas, John H. "The Genius of Everyman." Science News, 23 April 1977, pp. 268-270.

Dunn, James A. "Tests of Creativity in Mathematics." International Journal of Mathematical Education in Science and Technology 6 (No. 3 1975): 327-331.

Fawcett, Harold P. The Nature of Proof, Thirteenth Yearbook. New York: National Council of Teachers of Mathematics, 1938.

Fehr, Howard F. "Theories of Learning Related to the Field of Mathematics." In The Learning of Mathematics: Its Theory and Practice, Twenty-First Yearbook, pp. 1-41. Washington, D. C.: National Council of Teachers of Mathematics, 1953.

Feldhusen, John F. and Treffinger, Donald J. Teaching Creative Thinking and Problem Solving. Dubuque, Iowa: Kendall/Hunt Publishing Company, 1977.

Fitzgerald, William M. "The Role of Mathematics in a Comprehensive Problem-Solving Curriculum in Secondary Schools." School Science and Mathematics 75 (January 1975): 39-47.

Fletcher, T. J. "Secondary Mathematics Today." Trends in Education No. 35 (October 1974): 11-17.

Foshay, Arthur W. "The Creative Process Described." In Creativity in Teaching: Innovations and Instances, pp. 22-40. Edited by Alice Miel. Belmont, Calif.: Wadsworth Publishing Company, Inc., 1961.

Fouch, Robert. "Overview and Practical Interpretations." In _Evaluation in Mathematics_, Twenty-Sixth Yearbook, pp. 167-180. Washington, D. C.: National Council of Teachers of Mathematics, 1961.

Francis, Richard L. "Word Problems: Abundant and Deficient Data." _The Mathematics Teacher_ 61 (January 1978): 6-11.

Frazier, Alexander, ed. _New Dimensions in Learning: A Multidisciplinary Approach_. Washington, D. C.: Association for Supervision and Curriculum Development, 1962.

Friess, Walter J. "A Case History on Creativity in Industry." In _Creativity: An Examination of the Creative Process_, pp. 179-192. Edited by Paul Smith. Freeport, New York: Books for Libraries Press, 1959.

Fromm, Erich. "The Creative Attitude." In _Creativity and Its Cultivation_, pp. 44-54. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Frymier, Jack. State Mathematics Conference, Pinehurst, North Carolina. Speech, Spring 1977.

Galton, Francis. _Hereditary Genius: An Inquiry Into Its Laws and Consequences_. 1976 facsimile, 1892 rpt. New York: Horizon Press, 1952.

Gerard, R. W. "The Biological Basis of Imagination." In _The Creative Process_, pp. 226-251. Edited by Brewster Ghiselin. New York: Mentor, New American Library, 1952.

Getzels, J. W. "Problem-Finding and the Inventiveness of Solutions." _Journal of Creative Behavior_ 9 (No. 1, First Quarter 1975): 12-18.

Getzels, Jacob W. and Jackson, Philip W. _Creativity and Intelligence_. New York: John Wiley and Sons, Inc., 1962.

Ghiselin, Brewster. "Introduction." In _The Creative Process_, pp. 11-31. Edited by Brewster Ghiselin. New York: Mentor, New American Library, 1952.

Gibb, E. Glenadine. _Creative Problem Solving_. Bethesda, Md.: ERIC Document Reproduction Service, ED 037 367, 1970.

Glasser, William. _Schools Without Failure._ New York: Harper and Row, Publishers, 1969.

Gluskinos, Ury. "Criteria for Student Engineering Creativity and Their Relationship to College Grades." Journal of Educational Measurement 8 (Fall 1971): 189-195.

Goodlad, John I. School, Curriculum, and the Individual. Waltham, Mass.: Blaisdell Publishing Co., 1966.

Gordan, W. J. J. "Metaphor and Invention." In The Creativity Question, pp. 250-255. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Gowan, John C. and Demos, George D. Education and Guidance of the Ablest. Springfield, Illinois: Charles C. Thomas, 1964.

Gregory, Carl E. The Management of Intelligence. New York: McGraw-Hill Book Company, 1967.

Gross, Ronald. "After Deschooling, Free Learning." In After Deschooling, What? pp. 151-165. Edited by Alan Gartner, Colin Greer, and Frank Riessman. New York: Harper and Row, 1973.

Guilford, J. P. "Creativity: Its Measurement and Development." In A Source Book for Creative Thinking, pp. 151-168. Edited by Sidney J. Parnes and Harold F. Harding. New York: Charles Scribner's Sons, 1962.

Guilford, J. P. Intelligence, Creativity, and Their Educational Implications. San Diego, California: Robert R. Knapp, 1968.

Guilford, J. P. The Nature of Human Intelligence. New York: McGraw-Hill Book Company, 1967.

Guilford, J. P. "Traits of Creativity." In Creativity and Its Cultivation, pp. 142-161. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Hadamard, Jacques. An Essay on the Psychology of Invention in the Mathematical Field. Princeton, N. J.: Princeton University Press, 1949.

Handlin, Oscar. "Textbooks That Don't Teach." Atlantic Monthly 200 (December 1957): 110-113.

Hardy, G. H. A Mathematician's Apology. Cambridge: Cambridge University Press, 1941.

Heist, Paul. "Considerations in the Assessment of Creativity." In The Creative College Student: An Unmet Challenge, pp. 208-223. Edited by Paul Heist. San Francisco: Jossey-Bass Inc., Publishers, 1968.

Heist, Paul. "Creative Students: College Transients." In The Creative College Student: An Unmet Challenge, pp. 35-55. Edited by Paul Heist. San Francisco: Jossey-Bass, Inc., Publishers, 1968.

Henle, Mary. "The Birth and Death of Ideas." In Contemporary Approaches to Creative Thinking, pp. 31-62. Edited by Howard Gruber, Glenn Terrell, and Michael Wertheimer. New York: Atherton Press, 1967.

Heritage, R. S. "The Shopshire Math Experiment." The Mathematical Gazette 49 (May 1965): 132-135.

Hill, Shirley. "Issues from the NACOME Report." The Mathematics Teacher 69 (October 1976): 440-447.

Hughes, Helen E. "Creativity in Women." American Association of University Women Bulletin, November 1976, pp. 6-9.

Hyman, Ronald T., ed. Ways of Teaching. Philadelphia: J. B. Lippincott Company, 1974.

Jackson, Leon. Creative Growth Curves of University Students. Bethesda, Md.: ERIC Document Reproduction Service, ED 039 600, 1970.

Jex, Frank B. "Negative Validities for Two Different Ingenuity Tests." In Scientific Creativity: Its Recognition and Development, pp. 299-301. Edited by Calvin W. Taylor and Frank Barron. New York: John Wiley and Sons, Inc., 1963.

Keyser, Cassius J. Mathematical Philosophy. New York: E. P. Dalton and Company, 1922.

Keyser, Cassius J. Mathematics as a Cultural Clue and Other Essays, Volume I. New York: Scripta Mathematica, Yeshiva University, 1947.

Keyser, Cassius J. The Human Worth of Rigorous Thinking. New York: Columbia University Press, 1916.

Khatena, Joe. Measurement and Identification of the Creative Potential. Bethesda, Md.: ERIC Document Reproduction Service, ED 116 431, 1973.

Kilpatrick, Jeremy. "Problem Solving and Creative Behavior in Mathematics." In Studies in Mathematics, XIX, pp. 153-180. Edited by School Mathematics Study Group. Leland Stanford Junior University, 1969.

Kinsella, John J. "Problem Solving." In The Teaching of Secondary School Mathematics, Thirty-Third Yearbook, pp. 241-266. Washington, D. C.: The National Council of Teachers of Mathematics, 1970.

Kline, Morris. "NACOME: Implications for Curriculum Design." The Mathematics Teacher 69 (October 1976): 449-454.

Kneller, George F. The Art and Science of Creativity. New York: Holt, Rinehart and Winston, Inc., 1967.

Koestler, Arthur. The Act of Creation. London: Hutchinson and Company, 1964.

Kramer, Edna E. "Einstein vs. Heisenberg--Shall We Discuss Current Mathematics?" In Emerging Practices in Mathematics Education, Twenty-Second Yearbook, pp. 303-323. Washington, D. C.: National Council of Teachers of Mathematics, 1954.

Krippner, Stanley and Arons, Myron. "Creativity: Person, Process, or Product?" Gifted Child Quarterly 17 (No. 2, Summer 1973): 116-123.

Kubie, Lawrence S. "Blocks to Creativity." In Explorations in Creativity, pp. 33-42. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

Kubie, Lawrence S. "Creation and Neurosis." In The Creativity Question. pp. 143-148. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Kubie, L. S. Neurotic Distortion of the Creative Process. New York: The Noonday Press, A Division of Farrar, Straus, and Giroux, 1961.

Lehman, Harvey C. Age and Achievement. Princeton: Princeton University Press, 1953.

Lehman, Harvey C. "The Age Decrement in Scientific Creativity." American Psychologist 15 (February 1960): 128-134.

Leonard, George. Education and Ecstasy. New York: Dell Publishing Company, 1968.

Lieber, Lillian R. The Education of T. C. Mits. New York: W. W. Norton and Company, Inc., 1942.

Luthe, Wolfgang. Creativity Mobilization Technique. New York: Grune and Stratton, 1976.

MacKinnon, Donald J. "The Highly Effective Individual." In Explorations in Creativity, pp. 55-68. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

MacKinnon, Donald J.; Giannini, Vittorio; Gleason, Ralph; Trent, James; and Webster, Harold. "A Dialogue on Creativity." In The Creative College Student: An Unmet Challenge, pp. 3-17. Edited by Paul Heist. San Francisco: Jossey-Bass Inc., Publishers, 1968.

McGannon, Thomas, "Creativity and Mathematics Education." School Science and Mathematics 72 (January 1972): 7-12.

McPherson, J. H. "Environment and Training for Creativity." In Creativity: Progress and Potential, pp. 130-153. Edited by Calvin W. Taylor. New York: McGraw-Hill Book Company, 1964.

Marian, James F. and Rogan, Donald V. Synectics: An Explanation of the Process and Some Comments on Its Application in the Secondary School. Bethesda, Md.: ERIC Document Reproduction Service, ED 061 140, 1966.

Maslow, Abraham H. "Creativity in Self-Actualizing People." In Creativity and Its Cultivation, pp. 83-95. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

May, Rollo. "The Nature of Creativity." In Creativity and Its Cultivation, pp. 55-68. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Mead, Margaret. "Creativity in Cross-Cultural Perspective." In Creativity and Its Cultivation, pp. 222-235. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Mead, Margaret. "Where Education Fits In." In Explorations in Creativity, pp. 165-172. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

Mednick, Sarnoff. "The Associative Basis of the Creative Process." In The Creativity Question, pp. 227-237. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Meyer, Rochelle. Identification and Encouragement of Mathematical Creativity in First Grade Students, Part I, Chapters I-IV. Bethesda, Md: ERIC Document Reproduction Service, ED 038 292, 1970.

Meyer, Rochelle. Identification and Encouragement of Mathematical Creativity in First Grade Students, Part II, Chapters V to Conclusion. Bethesda, Md.: ERIC Document Reproduction Service, ED 038 293, 1970.

Moritz, Robert Edouard. Memorabilia Mathematica: The Philomath's Quotation-Book. New York: The Macmillan Company, 1914.

Moustakas, Clark. "Creativity and Conformity in Education." In Explorations in Creativity, pp. 173-184. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

Murray, Henry A. "Vicissitudes of Creativity." In Creativity and Its Cultivation, pp. 96-118. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

National Council of Teachers of Mathematics, Advertisement, 1978.

North Carolina Mathematics Advisory Council. Mathematics Curriculum Guide: Grades 7-12. Raleigh, N. C.: State Department of Public Instruction, 1976.

Osborn, Alex F. Applied Imagination. 3d rev. ed. New York: Charles Scribner's Sons, 1963.

Parnes, Sidney J. "Creativity: Developing Human Potential." Journal of Creative Behavior 5 (No. 1, First Quarter 1971): 19-35.

Parnes, Sidney J. and Biondi, Angelo M. "Creative Behavior: A Delicate Balance." Journal of Creative Behavior 9 (No. 3, Third Quarter 1975): 149-158.

Passow, A. Harry. "Fostering Creativity in the Gifted Child." In Readings in Gifted and Talented Education, pp. 69-74. Edited by Herbert Goldstein. Guilford, Conn.: Special Learning Corporation, 1978.

Peter, Lawrence. "The Peter Principle: We're All Incompetent." Phi Delta Kappan 48 (March 1967): 339-341.

Phenix, Philip H. Realms of Meaning. New York: McGraw-Hill Book Company, 1964.

Pietschmann, Richard. "The Rewards of Creativity." Mainliner, July 1977, pp. 32-34.

Pitt, H. R. "Priorities in the Reform of Mathematics Teaching." The Mathematical Gazette 47 (October 1963): 228-232.

Pleuthner, Bill; Smith, Paul; Bass, Saul; Freiss, Walter; and Upjohn, W. John. "Brainstorming and Testing for Creativity." In Creativity: An Examination of the Creative Process, pp. 193-206. Edited by Paul Smith. Freeport, New York: Books for Libraries Press, 1959.

Poincaré, Henri. "Mathematical Creation." In The Creative Process, pp. 33-42. Edited by Brewster Ghiselin. New York: Mentor, New American Library, 1952.

Poincaré, Henri. Science and Hypothesis. New York: Dover Publications, Inc., 1952.

Polya, George. How to Solve It, 2d ed. Garden City, N. Y.: Doubleday and Company, Inc., Doubleday Anchor Books, 1957.

Polya, George. "On Learning, Teaching, and Learning Teaching." American Mathematical Monthly 70 (June-July 1963): 605-619.

Postman, Neil and Weingartner, Charles. Teaching as a Subversive Activity. New York: Delacorte Press, 1969.

Prince, George M. "The Operational Mechanism of Synectics." Journal of Creative Behavior 2 (No. 1, Winter 1967): 1-13.

Ribot, Theodule Armand. Essay on the Creative Imagination. New York: Arno Press, 1973.

Ridley, Dennis. Definitions and Criteria of Creativity: A Literature Review. Bethesda, Md.: ERIC Document Reproduction Service, ED 108 235, 1969.

Rogers, Carl R. "Toward a Theory of Creativity." In Creativity and Its Cultivation, pp. 69-82. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Rogers, Carl R. "Toward a Theory of Creativity." In The Creativity Question, pp. 296-305. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Rossman, J. The Psychology of the Inventor. Washington, D. C.: Inventors Publishing Co., 1931.

Roweton, William E. Creativity: Idea Quantity and Idea Quality. Bethesda, Md.: ERIC Document Reproduction Service, ED 038 665, 1970.

Roweton, William E. "Creativity: Machines Then Us!" Journal of Creative Behavior 11 (No. 4, Fourth Quarter 1977): 241-245.

Roweton, William E.; Farless, James W.; and Spencer, Herbert L. "Notes on Creativity Research: Little Hope for Classroom Teachers." Contemporary Education 44 (February 1973): 225-228.

Schubert, Daniel S. P. "Boredom as an Antagonist of Creativity." Journal of Creative Behavior 11 (No. 4, Fourth Quarter 1977): 233-239.

Schubert, Daniel S. P. and Biondi, Angelo M. "Creativity and Mental Health: Part III--Creativity and Adjustment." Journal of Creative Behavior 11 (No. 3, Third Quarter 1977): 186-197.

Schubert, Herbert. Mathematical Essays and Recreations. Chicago: The Open Court Printing Company, 1910.

Seidel, George J. The Crisis of Creativity. London: University of Notre Dame Press, 1966.

Silberman, Charles E. Crisis in the Classroom. New York: Random House, 1970.

Slosson, Edwin E. Major Prophets of Today. Boston: Little, Brown, and Company, 1920.

Sobel, Max A. "Skills." In The Teaching of Secondary School Mathematics, Thirty-Third Yearbook, pp. 291-308. Washington, D. C.: National Council of Teachers of Mathematics, 1970.

Sobel, Max and Johnson, Donovan. "Analysis of Illustrative Test Items." In Evaluation in Mathematics, Twenty-Sixth Yearbook, pp. 71-91. Washington, D. C.: National Council of Teachers of Mathematics, 1961.

State Superintendent's Task Force on Secondary Education. Channels for Changing Secondary Schools. Raleigh, N. C.: North Carolina Department of Public Instruction, 1974.

Stein, Morris I. "Creativity and Culture." In Explorations in Creativity, pp. 109-119. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

Stoddard, George D. "Creativity in Education." In Creativity and Its Cultivation, pp. 181-202. Edited by Harold H. Anderson. New York: Harper and Brothers Publishers, 1959.

Suydam, Marilyn. "Continuing the Math Revolution." American Education 6 (No. 1, January-February 1970): 26-30.

Taba, Hilda. Curriculum Development: Theory and Practice. New York: Harcourt, Brace and World, Inc., 1962.

Taylor, Calvin W. "A Tentative Description of the Creative Individual." In A Source Book for Creative Thinking, pp. 169-184. Edited by Sidney J. Parnes and Harold F. Harding. New York: Charles Scribner's Sons, 1962.

Taylor, Calvin W. and Holland, John L. "Development and Application of Tests of Creativity." In Explorations in Creativity, pp. 219-228. Edited by Ross L. Mooney and Taher A. Razik. New York: Harper and Row Publishers, 1967.

Taylor, Calvin W.; Smith, William R.; and Ghiselin, Brewster. "The Creative and Other Contributions of One Sample of Research Scientists." In Scientific Creativity: Its Recognition and Development, pp. 53-76. Edited by Calvin W. Taylor and Frank Barron. New York: John Wiley and Sons, Inc., 1963.

Taylor, Irving A. "Psychological Sources of Creativity." Journal of Creative Behavior 10 (No. 3, Third Quarter 1976): 193-201.

Taylor, Irving A. "The Nature of the Creative Process." In Creativity: An Examination of the Creative Process, pp. 51-82. Edited by Paul Smith. Freeport, New York: Books for Libraries Press, 1959.

Thurstone, L. L. "The Scientific Study of Inventive Talent." In A Source Book for Creative Thinking. Edited by Sidney J. Parnes and Harold F. Harding. New York: Charles Scribner's Sons, 1962.

Tookey, Mary Enda. "Developing Creative Thinking Through an Interdisciplinary Curriculum." Journal of Creative Behavior 9 (No. 4, Fourth Quarter 1975): 267-276.

Torrance, E. Paul. Creativity in the Classroom: What Research Says to the Teacher. Bethesda, Md.: ERIC Reproduction Service, ED 132 593, 1977.

Torrance, E. Paul. Creativity Research and Higher Education. Bethesda, Md.: ERIC Document Reproduction Service, ED 037 160, 1969.

Torrance, E. Paul. "Developing Creative Thinking Through School Experiences." In A Source Book for Creative Thinking, pp. 31-47. Edited by Sidney J. Parnes and Harold F. Harding. New York: Charles Scribner's Sons, 1962.

Torrance, E. Paul. "Education and Creativity." In The Creativity Question, pp. 217-227. Edited by Albert Rothenberg and Carl R. Hausman. Durham, N. C.: Duke University Press, 1976.

Torrance, E. Paul. Education and the Creative Potential. Minneapolis: The University of Minnesota Press, 1963.

Torrance, E. Paul. Encouraging Creativity in the Classroom. Dubuque, Iowa: William C. Brown, 1970.

Torrance E. Paul. Guiding Creative Talent. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962.

Trachtman, Leon E. "Creative People, Creative Times." Journal of Creative Behavior 9 (No. 1, First Quarter 1975): 35-50.

Treffinger, Donald. Problems in Assessment of Creative Problem Solving. Bethesda, Md.: ERIC Document Reproduction Service, ED 038 663, 1970.

Trimble, Harold. "NACOME: Implications for Teacher Education." The Mathematics Teacher 69 (October 1976): 465-468.

Ullsvik, Bjarne R. and Lewis, Harry. "Evaluation of the Application of Mathematical Reasoning Standards to Nonmathematical Situations." In Emerging Practices in Mathematics Education, Twenty-Second Yearbook, pp. 370-383. Washington, D. C.: The National Council of Teachers of Mathematics, 1954.

Wall, H. S. Creative Mathematics. Austin Texas: University of Texas Press, 1967.

Wallas, Graham. The Art of Thought. New York: Harcourt, Brace and Company, 1926.

Wallas, Graham. "The Art of Thought." In Creativity, pp. 91-97. Edited by P. E. Vernon. Middlesex, England: Penguin Books, 1970.

Weinberg, Carl. "The Meaning of Alternatives." In The Conventional and Alternative in Education, pp. 49-75. By John I. Goodlad, Gary D. Fenstermacher, Thomas J. La Belle, Val D. Rust, Rodney Skager, and Carl Weinberg. Berkeley, California: McCutchan Publishing Company, 1975.

Wertheimer, Max. Productive Thinking. Edited by Michael Wertheimer, enl. ed. New York: Harper and Brothers Publishers, 1959.

Wescott, Alvin M. and Smith, James A. Creative Teaching of Mathematics in the Elementary School. Boston: Allyn and Bacon, 1968.

Whitehead, A. N. An Introduction to Mathematics. London: Oxford University Press, 1948.

Whitehead, A. N. The Aims of Education and Other Essays. London: William and Norgate Ltd., 1950.

Whiteside, Marilyn. "In Praise of Irrelevance and Other Unpopular Notions." Journal of Creative Behavior 11 (No. 3, Third Quarter 1977): 153-157.

Wight, Albert R. "Participative Education and the Inevitable Revolution." Journal of Creative Behavior 4 (No. 4, Fall 1970): 234-282.

Wilder, R. L. The Foundations of Mathematics. New York: John Wiley and Sons, Inc., 1952.

Young, J. W. A. "The Teaching of Mathematics." The Mathematics Teacher 61 (March 1968): 287-295.