A STUDY OF THE DIVERGENT AND CONVERGENT THOUGHT PROCESSES IN RELATION TO SCIENCE LEARNING

by

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B.A.(Hons.), Simon Fraser University, 1969

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS (EDUCATION)

in the Department

of

Behavioural Science

SIMON FRASER UNIVERSITY

August 1971

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ABSTRACT

This study was designed to explore the relationships between "creativity" and science learning with the use of divergent materials (kits) currently being used in British Columbia schools.

The initial stage of this research involves a historical review of some of the leading educational theorists and their contributions which are relevant to this research. These include Pestalozzi, Herbart, Froebel, Montessori, Dewey, and Piaget.

The second stage of this research is a discussion of creativity and divergent and convergent thought processes. Authors reviewed are Beveridge, Cropley, Ghiselin, Hudson, Torrance, Taylor, Thomson, Wartofsky and Wooldridge. The studies of Bradley, Cline, Richards and Needham, Cropley and Field, Field and Cropley, and Holland, link the creative nature of scientists and of "doing science" with the teaching of science using a divergent approach.

The empirical portion of this research includes a description of the experiment, its rationale and design. It was hypothesized that the more divergent approach to science learning (i.e., via the kits) would result in greater science knowledge based upon objective testing. It was further hypothesized that the pupils who tested to be most creative would have more significant gains with the kit method than those who tested to be less creative. The hypotheses were not supported as the results did not consistently favor either method with statistically significant data.

The concluding chapter contains a discussion of the implications of the results of the study, the biases realized by the writer, as well as suggestions for further research.

To Marian and Lisa,

who have done without too much

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A STUDY OF THE DIVERGENT AND CONVERGENT THOUGHT PROCESSES IN RELATION TO SCIENCE LEARNING

CHAPTER I

INTRODUCTION

In 1969, the British Columbia Provincial Department of Education issued a revised curriculum guide for elementary school science. In it was outlined a new approach to the teaching of science which involved the use of instructional materials in the form of kits. These kits allow the pupils to experiment with their own equipment as issued from the materials provided. The new approach is to be in full use throughout the province by 1972.

The kits are expensive, relative to the former methods used, and the expendable items, of which there are many, must be replaced after each use. The cost of the new program is borne by each individual school board, and the implementation of the program is the responsibility of the teachers. The question of values arose. Are the kits worth the money and the extra effort of the teachers?

The method of the new program is to capitalize upon the creative aspects of children's play and thereby maximize the learning potential in the school situation. The emphasis is on conceptual rather than factual learning; or in other words, general notions about the natural laws of science and of classification systems, rather than specific details. The question raised in this area is: can all children gain more from the new method than from the old? It is this question which prompted this research.

It was hypothesized that the more divergent approach to science learning (i.e., via the kits) will result in greater science knowledge based upon objective testing. It was further hypothesized that the pupils who tested to be the most "creative" would have more significant gains with the kit method than those who tested to be less creative.

Chapter II outlines the historical background for the development of the kits. Some influential educational theorists are examined with regard to their contributions which are relevant to this research. They include Johann Pestalozzi, Johann Herbart, Friedrich Froebel, Maria Montessori, John Dewey, and Jean Piaget. The section on each theorist contains, where pertinent, a summary of their educational philosophy, psychology, pedagogy, and educational program.

Chapter III deals first with "creativity," its definitions and some of the research in this area. The authors reviewed include some of the leading researchers and theorists of the last fifteen years. The research dealing with the relationship of creativity and science includes that of Bradley (1965), Cline, Richards and Needham (1963), Cropley and Field (1969), Field and Cropley (1969) and Holland (1961).

Chapter IV presents a description of the experimental portion of this research, the rationale and design.

Chapter V presents the analyses of the data gathered during the empirical portion of this research. Included are the hypotheses and conclusions suggested within each phase of the analysis.

Chapter VI contains the conclusions of the study, the biases contained therein, and suggestions for further research.

CHAPTER II

REVIEW OF LITERATURE: IMPLICATIONS FOR SCIENCE TEACHING

The meaningfulness of the investigation of the creative aspects of learning and of the convergent versus divergent thought processes of science students to which this study is devoted, may be enhanced by setting it in the appropriate context. Science programs and programs in other subject matter areas have been influenced by many educational theorists, and the most influential are those who exemplified their theories by practical application and demonstrated how the learning process can be facilitated. Among these are Johann Pestalozzi (1746-1827), Johann Herbart (1776-1841), Friedrich Froebel (1782-1852), Maria Montessori (1870-1952), John Dewey (1859-1952) and Jean Piaget (1896-).

The contributions of each of these as well as some others who were influenced by them or whose work is related will be considered. But, as this study is neither specifically concerned with their contributions, nor a history of educational thought, the treatment will be brief. Note must also be made that some of these theorists were chiefly concerned with kindergarten or early childhood education. Consequently, an inference drawn for elementary science education in higher grades and with older children needs to be viewed as an extrapolation and subject to the limitations of such.

A. Johann Heinrich Pestalozzi

1. Educational Philosophy

Owing to an economically prosperous time in Zurich, Pestalozzi lived under an apparently liberal government which was attempting to educate people of all social classes. He saw education as a means of social reform through which his ideal of equal opportunity could be realized. He felt that it was the duty of society to develop each man's abilities to his maximal potential. This could best be accomplished through what he termed "natural education."

His view was that the multitude of objects which constitute environment exist independent of man's knowledge of them. However, man is able to know them through sensation, reflection, and organization of sense-data experienced. All nature is chaotic and brutal, and without discipline; this includes man.

Pestalozzi wanted, through education, to establish an order for chaotic sense impressions, and to develop a God-centered, moral society in which all primitive impulses were controlled. Although he held a genetic conception of man's physical nature, he agreed with Locke's _tabula rasa_ conception of the mind upon which life's experiences are written. However, Pestalozzi held that sense experience must be organized before being entered into the mind (written on the slate). This organization is called contemplation. He contended that if the learning process followed a child's natural curiosities, there would be a pattern of development from near to far and from simple to complex. Each succeeding step in educating could be based upon existing knowledge.

He used the terms "natural education" and "psychology of learning"[1] synonymously. In so doing, his reference was to man's mind following the natural laws and order of nature. The development of "mind" was the basis for his theory of organic development. A plant absorbs basic elements from its immediate environment and transforms them into a harmonious whole of balanced parts. A child, likewise, develops as a result of contact with his immediate environment. Both grow and unfold from within. A farmer tends his plants so as to provide a controlled environment to aid a balanced growth and avoid tropisms. Similarly, a teacher must control the environment of a pupil to avoid an imbalance in development.

Moral and religious growth was looked upon as the basis for a sense of social responsibility. Although morality and religion were not overtly taught, their values were evident in the personal relationships derived from the school situation. Such things, he felt, could only be learned circumstantially. The teacher then must provide the best conditions for the child's maturational process and guide him to achieve a balanced development through conscious effort.

2. Pedagogy

Pestalozzi believed that sensation (apprehension of sense-data) is the basis for learning and consequently that sound educational practice

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[1]Gerald Lee Gutek, Pestalozzi and Education (New York: Random House, 1968), p. 86.

implies the provision of experiences with tangible materials.

> For Pestalozzi sensation was clearly the basis for acquiring knowledge. Instruction in effective sense impression had to be related to natural laws and to the active process of Anschauung. Pestalozzi aimed at obtaining clear ideas from the confused mass of chaotic sensations. To proceed from perceptual experience to clear and distinct ideas or concepts necessitated the functioning of numerous mental abilities, such as memory, imagination, thought, understanding, judgement, and reasoning. . . .[2]

This point of view or assumption led Pestalozzi to postulate the object lesson based on number, form, and language in which the learner acquired the ability to recognize the number of objects, their appearances, form, structure or outline, and then to learn the name and to express it both orally and in written language.

Pestalozzi's theory of child development makes explicit what is implicit in the foregoing--that a person develops from near to far. By this he means that children move from knowledge or awareness of their own bodies and immediate surroundings to knowledge or awareness of other persons, objects and places. The function of the school is to facilitate the efforts of children to expand their area of awareness. To do this the school must not only be a child's world that would gain and sustain the interests of the child, but also provide adequately for expression of these interests.

He believed existing schools to be, in content and form, based upon adult interests, or at best on interests which adults perceived as being the interests of children. Additionally, he saw these adult

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[2] Ibid., p. 92.

interests being presented to the child in an abstract manner which precluded the child from enjoying and benefiting from the sensory experience that provides a naturally graduated continuum of learning.

Pestalozzi, in basing his teaching on sensory experience, allowed "form" to be the primary consideration. Under this heading he reduced form to simpler components such as lines, perpendiculars, horizontals, circles, squares, and more complex combinations of these; always from the simple to the complex. He would have the child recognize the geometrical forms, copy them, measure them, and break them up into their components again, thus leading to formation of a concept regarding any shape. Number was dealt with by giving pupils the numbers from one to ten, and relating them to actual objects which were subsequently represented by a series of lines and dots. In this manner, concrete objects were abstracted into representations on paper and the concept of number was removed from the concrete. This led to the abstraction of the concrete into the form of language. He applied the same principle to language learning by reducing words to their component sounds and presenting them first orally, then in written form.

3. Educational Program

Pestalozzi was critical of traditional educational programs. He believed that they imposed adult abstractions of adult experience upon a child's interests, and left untutored crucial phases of his development.

A child was given five years at home to enjoy the security and loving warmth of a mother's attention. For Pestalozzi, that this should cease upon entering a school was unthinkable. A teacher must love and must be able to receive love from pupils. The love relationship between teacher and pupil would be the basis for a sense of duty and obligation, ergo a basis for moral and social development. Education, to him, was an harmonious development of heart (love), body (physically), and mind (thought processes), therefore his daily routine with pupils contained physical exercise to condition the body.

Intellectual development was based upon his concept of number, form and language. Having been thoroughly researched by the teacher, a subject would be presented to a class. The presentation would be in either the form of representative specimen or series of specimens, or the form of photographs, if the former was not possible. The teacher then proceeded to guide the observations of the specimen and give names, first to the whole, then to the parts and their properties.

> The teacher encourages the pupil in the development of language, observation, and the mental skills . . . of making sounds, forming images, and imagining concepts, powers on which Pestalozzi bases his whole educational practice.[3]

He postulated that the mind tends to sort out and categorize the mass of objects presented by the environment. In so doing the common properties of form and number are applied, and these in conjunction with shape and other sense impressions, when related through the mind to previous experience, lead to an attempt at naming. Thus the natural progression of his educational continuum of number, form, and language, of simple to complex:

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[3] S. J. Curtis and M. E. A. Boultwood, A Short History of Educational Ideas (London: University Tutorial Press Ltd., 1961), p. 343.

> Constant exercise in describing verbally what he sees, feels, and hears, and what he has seen, has felt and has heard, will give a child increasing command over language both in vocabulary and construction. Pestalozzi accepted as a fundamental that a whole sentence is simpler than its component parts, yet when he planned the teaching of spelling and reading he started from syllables--he assumed that the 'natural' process was the formation of single sounds into words, and words into speech.[4]

The teaching of "form" was an attempt to combine measuring, drawing and writing. Thus, natural shapes were categorized, geometrical shapes conceptualized, and a firm basis for writing the letters of the alphabet was established.

In this approach to teaching number, real and common objects were utilized. Peas, beans, stones and the like, were used to give the concept of many or few, and to teach counting along with addition and subtraction.

> Pestalozzi began his number teaching by giving the students the conceptions of numbers from one to ten, first with the help of actual objects and then later by lines and dots on tables. Only when the children had been thoroughly exercised in the counting of objects, such as peas and pebbles, did the instruction proceed to figures, which were regarded as abbreviations of the specific relations of more or less that had been developed by the counting exercises.[5]

To summarize Pestalozzi's theory, a teacher must love the pupils, who will reciprocate the love and experience emotional security, while demonstrating a respect and desire to please. At this point the teaching of the basics of "form, number and language" can begin. All instruction is based upon sensory experience and leads from the simple to the complex, from near to far, from concrete to conceptual.

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[4]Ibid., pp. 344-345.

[5]Gutek, op. cit., p. 121.

B. Johann Friedrich Herbart

1. Educational Philosophy

To Herbart, the aim of education was morality. In order to achieve this end there are three main categories to be considered: logic, metaphysics and aesthetics. Logic was presented in a straightforward, traditional manner, and although he had no particular interest in it _per se_, he felt it was necessary for the development of his system. Each of the others, metaphysics and aesthetics, were broken into subdivisions for consideration. These parts form an all-inclusive system, based upon the organization of nature.

An individual's perceptions of nature or the external world give rise to a multiplicity of concepts in his mind. The mind itself is a thing amidst the apparently chaotic existence of things. These things have independent natures and realities. When they interact, they cause disturbances. When the mind interacts with environment, the disturbances are sensations which in turn lead to ideas or concepts about the "real" world. One can never get to know the essence of things; one can only receive sensations and know the external realities.

A teacher can educate by the presentation of things to interest the mind in a logical order. Such an order or series of steps include clarity, association, system, and method.

> In order to create many-sided interests in the pupil, prepare and present the material at hand--the specific facts--as clearly as possible. Remember that many-sided interests and many-sided self-activities are one and the same process; that self-activity in itself

> is not educative, much depending upon the direction it is given; . . . that to arouse attention you should present your material concretely (pictorially) rather than descriptively, and gradually and logically . . .[6]

The assimilation or abstraction and generalization take place in conjunction with ideas already existing in the pupil. It is also necessary for the teacher to envisage these steps as being logical modes within the same process.

The many-sided interests fall into the two basic categories of empirical and social. The former is concerned with the reason for things and with causes and effects. The latter is concerned with human beings and their relationships, with religion, and ultimately with sympathy. If a moral individual is to be the object of education, then all these interests and their connected side issues must be developed in a balanced program so as not to produce a one-sidedness similar to the "tropism" which concerned Pestalozzi.

2. Psychology

Herbart believed that the mind was developed by the experience of an individual and that its structure and content was a result of the soul's encounter with other real things. This encounter was by way of sensations. External realities impinge upon the senses of the individual, adapt themselves to past experiences, and become a part of the mind's system of ideas or knowledge. He attempted to make psychology a

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[6]Mehdi Nakosteen, The History and Philosophy of Education (New York: The Ronald Press Company, 1965), p. 348.

science, and in Newtonian terms this meant dealing with forces which then could be measured and reduced to mathematics. If the soul is confronted with an encounter of two things which are similar, they will reinforce each other. If the encounter is between two dissimilar things, they will form closely-knit combinations. If the encounter is between two contrary things, the stronger would dominate the weaker in proportion to the extent it is stronger.

Herbart did not undertake to devise methods of measurement for all variables in encounters. He did use examples of sound being measured in decibels, hot and cold being measured in degrees, colour fusing or showing dominance, and choral work producing a "stronger" presentation than a single voice. When the soul (or mind) is confronted with external reals through the senses, it is continually being altered according to the relative similarity, strength or weakness of the thing presented. Some will reinforce what is recorded in the mind if they are similar, some will form combinations of "complexions" if they are dissimilar and some will either dominate or be rejected, depending on their relative strength if they are contrary.

> A lesson (i.e., a new presentation or mass of presentations) appearing in mind would simply sink below the threshold of consciousness unless united to other similar presentational masses. . . . this is where the famous "steps" come into play. They were to link each item of subject matter to existing masses in mind by explicitly showing their relatedness. New learning had to be related to old. Otherwise the teacher would waste his time by merely dropping into mind, so to speak, material that would immediately sink below the threshold of consciousness and lie inert. The development of great apperceptive masses was also the means of achieving the great aim of education, moral strength of character, for only large, stable apperceptive masses could produce consistent and persistent states of character.[7]

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[7] Ibid., pp. 61-62.

In summary, Herbart was not a major influence upon the educational system of his own day. He did not agree with his contemporaries in either the philosophical or educational fields, nor in his support of psychology as an exact science. The philosophers Kante, Fichte, Schelling and Hegel were extremely popular. His educational system was one more suited to a system of private tutors than the popular education for the masses. His psychology dealt with the building of a mind and personality through experience rather than the more favoured dualistic and traditionally religious doctrines. His fame and popularity came posthumously because of a group who expounded doctrines in his name. Herbartianism, as it is known, came forth with Herbart's ideas greatly modified. His system of pedagogy did not offer any simple solution to those wishing to deal with numbers of people which are not well known to their teachers. Herbartianism compensated and is best known for the five steps to be followed by educators. The steps are:

a) Preparation: where the teacher recalls particular material with which the pupils are familiar and which is relevant to the lesson to be taught;
b) Presentation: where the new material is introduced to the class in as interesting and dramatic a way as possible to gain interest;
c) Association: where the new material is related to that which is already familiar;
d) Generalization: closely related to step three, and where generalities regarding the subject matter are pointed out to pupils;

e) Application: where the pupil has an opportunity to use the new material in practice.

Herbart paid tribute to Pestalozzi but did not believe his theories went far enough. Pestalozzi was not nearly as systematic as Herbart, and the former was too fragmentary and restricted to elementary schools to be of benefit to an educational whole whereas Herbart's aim was to present a more rounded system leading to the university level of academic achievement.

C. Friedrich Froebel

1. Educational Philosophy

Froebel came from a very religious background, so it is no wonder that he placed such an emphasis on God and God's creative will. The other two important factors in his philosophy are science, particularly biology, and education and the important part it plays in separating man from animals.

He believed that there is a universal pattern of development for human beings; and as for individuals, so for nations. Education had to take a new course and stop the stultifying veneration of the old habits and modes of thought. The past should be viewed as knowledge and this should be a starting point for going to a higher level of development, especially in the areas of science.

> I consider that there is a universal pattern of development. When a certain level has been reached after a period of growth, there is a

> point of culmination. At this stage and in the form it has now reached everything passes through an exactly opposite cycle so that with a clearer, more intense knowledge of it, it comes back to the unity of being. Having assimilated this experience, it then goes forward with energy restored and life renewed for a still higher level of growth. To put it more briefly, I regard this simple pattern of development from the analytical to the synthetical, such as I find in pure thought, as the course of development of all being.[8]

One can see the biological interest showing in that what he describes is analogous to the life of a perennial plant. It grows in seasons, reaches plateaux of development, recedes and grows again with renewed vigour after resting. Man was created in the image of God to experience freely and to use his experiences to uplift himself to higher existence, not to be restricted by predetermined ideals of goodness and perfection.

> . . . it should be borne in mind that the accepted ideal or the perfect life is intended to serve as a model only in its aim and essence, never in its form. It is a profound misconception to take those human beings who exemplify the spiritual life as formal models, for the usual method is to check and restrain rather than to uplift mankind. Throughout his life Jesus himself attacked such clinging to an external standard. . . . The perfect life which we as Christians see in Jesus was a life which was lived in clear and vivid awareness of the original ground of its being, and which came from the eternal creator self-active and self-reliant. Through the pattern of his life Jesus requires each human being to become such a copy of the eternal ideal and, in his turn, such a pattern for himself and others that he advances freely according to eternal law by his own determination and his own choice. This is the function and purpose of all education and should be the only one.[9]

Although Froebel's view of education encompassed every stage from the infant to the university graduate, he did not meet with his greatest

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[8] _Ibid._, p. 42.

[9] _Ibid._, p. 54.

success until he concentrated on infant education as the basis for his system. If each stage of development could evolve from the children started in his kindergarten, a new and better world and a renewal of life for mankind would evolve. He studied the actions and responses of babies from birth onwards and wrote much about his observations. Through the stages of development experienced by the children themselves, Froebel formulated his plans for a continuing educational experience, each phase of which was built upon the previous ones.

2. Pedagogy

Froebel believed that a society is composed of individuals and for society to progress, each individual must do so. He saw education as the means for societal advancement, and kindergartens as a basis for the educational system. Through the experience of group activity, learning, and group living under his system, individuals would emerge with a social conscience, ready to serve the needs of the community. Froebel did not primarily concern himself with national systems of education but was more concerned with community life and the transforming of a people's life style through the family and through education.

To Froebel a child's play was of utmost importance and the key to the whole educational program. This form of activity is all-engrossing and affords maximal potential for creative self-expression by children.

> Play is the highest level of child development. It is the spontaneous expression of thought and feeling--an expression which his inner life requires. This is the meaning of the word "play." It is the purest creation of the child's mind as it is also a pattern and

> copy of the natural life hidden in man and in all things. So it promotes enjoyment, satisfaction, serenity, and constitutes the source of all that can benefit the child. A child who plays well of his own accord, quietly persisting until he is physically tired out, will develop as an efficient and determined person, ever ready to make sacrifices for the good of himself and others.[10]

The purpose of a child's play is to discover the various aspects of his environment and their relation to himself. A system should be utilized where each activity corresponds with the developmental stage of the child; therefore the sequence should be from simple to complex. A number of playthings or "gifts" given to the child comprise the program devised by Froebel. Each is significant in two respects: that it has an emotional and a practical counterpart in adult life. The sequence of gifts is from soft balls, a cube and cylinder, large cubes divisible into smaller cubes to oblongs and to prisms. Later stages involve drawing, clay modelling, and paper in various shapes and forms. Still later stages involve gardening, tending pets, and responsibilities out of doors with direct communion with nature so that the child who is a whole within himself can realize that he is also a part of a whole.

> The purpose and character of these plays may be described as follows: They are a coherent system, starting at each stage from the simplest activity and progressing to the most diverse and complex manifestations of it. The purpose of each one of them is to instruct human beings so that they may progress as individuals and as members of humanity in all its various relationships. Collectively they form a complete whole, like a many-branched tree, whose parts explain and advance each other. Each is self-contained, whole, a seed from which manifold new developments may spring to continue further activity. They cover the whole field of intuitive and sensory instruction and lay the basis for all further teaching. They begin by establishing

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[10] *Ibid.*, p. 84.

> spatial relationships and proceed to sensory and language training so that eventually man comes to see himself as a sentient, intelligent and rational being and as such strives to live. From observation of Nature and life in all its phenomena they lead us to perceive that there is always an inner coherence and that the material and spiritual worlds are one.[11]

In summary, Froebel was impressed by his reading of Pestalozzi's writings and his experience with him at Yverdun. He met with his greatest success in developing kindergartens which were to be the basis for a better, more wholesome humanity. He stressed the religious aspects of education more heavily than Pestalozzi. Although there are similarities in their theories of child development, Froebel believed in the perfect life, as attained by Jesus, to be the will of God and the steps toward it appear as surges upward in both the individual and society. Pestalozzi was more concerned with unfolding of the individual toward the maximum of his own potential.

Froebel's emphasis on the design of playthings for children opened the way for future developments in the programming of educational tasks and toys to capture the interest of pupils as well as broadening their knowledge of relationships.

D. Maria Montessori

1. Educational Philosophy

The basic tenet of Montessori's philosophy is liberty for the child. Other educators saw this need for freedom on the part of the

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[11] _Ibid._, p. 98.

learner, but she devised a system which incorporated it. Her freedom pertained not only to academic, manipulative, and mobility concerns, but also to child-sized furniture which was not fixed in place. Pupils could learn from their environment and with their environment. The role of teachers is basically passive, administering the organization of materials and environment, the regulation of liberty so learning situations are discovered by the child at times appropriately determined by the readiness of the child.

The importance of the Montessori method lies in the effects produced in the classroom. Children are left free to go about their work and all actions which are not disturbing to others are allowed. It is disorder that is eliminated. The restraints used by Montessori are minimal and require infrequent imposition because the child has work organized in such a fashion as to permit an outlet for energies, self-development, and satisfaction.

> It is the perfect organization of work, permitting the possibility of self-development and giving outlet for the energies, which procures for each child the beneficial and calming satisfaction. And it is under such conditions of work that liberty leads to a perfecting of the activities, and to the attainment of a fine discipline which is in itself the result of that new quality of calmness that has been developed in the child.[12]

The individual differences in children must be allowed for. It is not for the teacher to determine what tasks should be done at certain times of the day. A child might wish to do arithmetic instead of

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[12]Maria Montessori, Dr. Montessori's Own Handbook (New York: Schocken Books, 1965), p. 187.

practising writing, and he should have the freedom and materials available to do so. Children progress at different rates and are therefore prepared for similar tasks at varying times. It is the responsibility of the teacher then to observe all children closely and to determine the needs of each, and to arrange for materials to be available so that a continuous development can be realized in each child. The child in turn achieves satisfaction rather than frustration, and is better behaved and eager to achieve greater success in the learning situation.

2. Pedagogy

The technique employed within the Montessori Method follows the physiological and psychological development of children closely and is divided into the three areas of motor, sensory and language education. To accomplish this, Montessori developed educational toys and tasks designed to incorporate the three main areas of concern in gradual stages ranging from simple to complex. To these toys and tasks she gave the name didactic materials.

Didactic materials contain within themselves a control for error, that is, they are self-correcting. Either they fit or they do not; the final result is clearly correct or incorrect. The child is given access to these materials only as playthings, and they are presented in an order which progresses from less to greater in complexity, and from concrete to abstract. Each step must be learned before the next step is allowed into the child's hands. In other words, the child's experiences are organized in such a way that he learns from them what is wanted by the teacher. The child is rewarded by engaging in meaningful tasks and is able to evaluate himself on his own performance because of the self-correcting features of the devices.

The sensory experiences which Montessori arranged for the child are also built into the didactic materials. In performing the task of fitting cylinders into their respective places in a block with holes to contain the cylinders, the child sees them, handles them and becomes thoroughly familiar with them. So it is with the size and shape of other geometric figures and materials of the curriculum. The tactile sense is exercised to a point where the child can recognize objects while blindfolded. Mastery of the "game" gives great satisfaction to the children. Color co-ordination of objects for separation into different groups brings the visual sense into play in yet another way, and is tied into the more abstract concept of categorization.

The auditory sense is exercised in two ways. Where music is concerned, the lessons are obvious. When silence is taught, the lessons are not so obvious. Silence is learned by the listening as a group, for sounds such as clocks ticking, birds outside, or movements in another part of the building. Silence then is really an exercise in self-control as well as an auditory experience.

The more abstract lessons of Montessori involve language and number, and these concepts are linked with sensory development associated with the didactic materials. Words as names, description, placement, number, and color, teach the language of the physical and spatial world. Other more abstract relationships such as temporal, tonal, comparative qualities and gradations of these are taught directly related to the materials in their situational use. Each of the foregoing is integrated into the whole experience of the child at his own pace of development.

> . . . our little ones make the impression of continually 'making discoveries' in the world about them; and in this they find their greatest joy. They take from the world a knowledge which is ordered and inspires them with enthusiasm.[13]

In summary, Montessori became involved with the education of children through different concerns than other educators. She combines the theories of Pestalozzi and Froebel in that the individual pupil is of prime concern in a programmed environment which allows the practice of limited freedoms. She also incorporates the methodical, scientific approach of Herbart and his emphasis on psychology.

3. Psychology

Montessori went further than her predecessors in that she designed a curriculum conjoined with many diverse objects for educational play. She used a practical psychology in designing her classrooms on a scale for the children's use. Equipment such as chairs, cupboards, and tables, were of a size which permitted and encouraged use by the children. She called the objects of play didactic materials, and they were designed to be the bases of lessons which became increasingly difficult and more abstract as the pupil progressed through the series. Each didactic

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[13]Ibid., p. 130.

instrument was in itself a series of lessons dealing with shape, number, color, and language.

Montessori attempted to use all the senses in the learning process, particularly the audio, visual, and tactile senses; hence the use of her didactic materials incorporates these senses vigorously.

The Montessori Method of teaching still enjoys much favour, particularly in the kindergarten and primary areas of education.

E. John Dewey

1. Educational Philosophy

Dewey is known as a pragmatist and therefore one who dealt with personal and purposive thought in inquiry. In so doing the abstracts of absolute truth and reality are validated only by personal emotions and capabilities in practical application. It cannot be assumed that the result of thought was the ultimate for Dewey; the process of inquiry, which involves an adjustment between a person and his environment, was more important. There must be interaction. In experience, there must be a continuity or experiential continuum. The process of inquiry should become habit.

According to Dewey, one of the basic characteristics of habit is the fact that every experience enacted, modifies the one who experiences and the quality of that individual's subsequent experiences. Habit is not merely a fixed way of doing things, it is the attendant intellectual attitudes, which affect and effect our responses to subsequent experiences. Experiences are differentiated by comparison and contrast through reflective thought when viewed in the continuum of experience.

He said that:

> . . . By putting the consequences of different ways and lines of action before the mind, it enables us to know what we are about when we act. It converts action that is merely appetitive, blind and impulsive into intelligent action.[14]

This involves the determination of ends and the selection of the most viable method of achieving them.

In no way does he attempt to reinforce the dualism of mind and matter or mind and body. On the contrary, he advocates a philosophy "which recognizes the origin, place, and function of mind in an activity which controls the environment."[15] Such a conception views intelligence as a purposive reorganization of material experience through action. The purposive reorganizational aspect of experience must come through reflection and the relationships that are established as a result--the connection between past experience, current possibilities and their potentialities.

He points out two conclusions important to education:

> (1) Experience is primarily an active-passive affair; it is not primarily cognitive. But (2) the measure of the value of an experience lies in the perception of relationships or continuities to which it leads up. It includes cognition in the degree in which it is cumulative or amounts to something, or has meaning.[16]

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[14]John Dewey, How We Think (Boston: D. C. Heath and Company, 1933), p. 17.

[15]John Dewey, Democracy and Education (4th printing; New York: The MacMillan Company, 1964), p. 323.

[16]Ibid., p. 140.

There is no room for the spectator theory in his philosophy. The body is a necessary part of the mind; the two cannot be dissociated. If an emphasis is placed upon one without the other, the secondary part becomes a useless and distracting appendage to be disciplined unrealistically. The body is an organic circuitry for the ingress and egress of instructive and meaningful data to be organized and reflected upon so the body may react in a manner which is meaningful to the individual.

Reflection, he points out, is the discernment of the relationships between what we try and the consequences. Such connections between acts and consequences is thought, and this allows foresight, which in turn allows for responsibility in action and for actions taken.

> Thinking is thus equivalent to an explicit rendering of the intelligent elements in our experience. It makes it possible to act with an end in view. It is the condition of our having aims.[17]

2. Pedagogy

In the education system of Dewey, it is the responsibility of the educator to guide the student into conscious articulation of facts and ideas. The educator must strive to lead the student to adopt what is called the "scientific attitude and method." The learning is of intelligent activity which involves the determination of ends, the selection of means, analysis and synthesis to attain those ends.

His pedagogy is based upon three observed impulses of children: first, the social desire to communicate; second, the impulse to make

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[17] Ibid., p. 146.

things, either in emulation or in an artistic and creative sense; third, the impulse to investigate things. The latter two do not necessarily occur in this sequence, but these impulses should be capitalized upon by teachers. Schools must change, he said, to become places where children can learn by experience as opposed to the traditional fact-oriented, listening situations which perpetuate the dualism of mind and body by exercising one and denying the other.

Another of his emphases was the relationship of the school and society. Curricula must be designed to assist students in dealing with a modern and changing society. Intelligence therefore becomes the main factor in dealing with new situations. Intelligent conduct of life, in his view, rests upon a scientific method of problem solving. There are four phases involved in this process;

a) The sensing of a problem which is generated by interest;
b) Observation of the problem and conditions surrounding it;
c) Formulation of plans of action or hypotheses;
d) Testing of the hypotheses actively to validate them.

The utilization of a scientific approach in thinking is the only method by which an individual can avoid traditional beliefs and establish a set of "warranted assertions" regarding current life. Intelligent thought is the main factor in coping with new situations, and the subject matter of schools must always relate to social life.

> The two principles of continuity and interaction are not separate from one another. They intersect and unite. They are, so to speak,

> the longitudinal and lateral aspects of experience. Different situations succeed one another. But because of the principle of continuity something is carried over from the earlier to the later ones. As an individual passes from one situation to another, his work, his environment, expands or contracts. He does not find himself living in another world but a different part or aspect of one and the same world. What he has learned along the way of knowledge and skill in the one situation becomes an instrument of understanding and dealing effectively with the situations which follow. The process goes on as long as life and learning continue.[18]

In the educational sense, the intellectual relationships of new objects and situations to earlier experiences is essential. It is the responsibility of the educator to guide the student into conscious articulation of facts and ideas. The student must become the centre of experiential situations which are of interest to him. He must either possess or be able to obtain the correct information to make observations, and then he must be allowed to assume the responsibility for developing them in an orderly way to the ultimate testing experience.

Dewey's emphasis on relationship of subject matter to social life may be exemplified by the teaching of language as a form of communication which is naturally desirable to a child. If language is taught artificially as many facts, parts of speech, and constructions, it becomes divorced from the social element. If language is taught with respect to the interests and communicative desires of pupils, it becomes at once more meaningful, useful and interesting for them. He said:

> . . . This does not mean, however, that students are to be seduced unaware into preoccupation with lessons. It means that they shall

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[18]Joseph Ratner (ed.), Intelligence in the Modern World (New York: The Modern Library, 1939), p. 670, citing John Dewey, Experience and Education (New York: The MacMillan Company, 1938).

> be occupied with them for real reasons or ends, and not just something to be learned. This is accomplished whenever the pupil perceives the place occupied by the subject matter in the fulfilling of some experience.[19]

In summary, Dewey contends that education is not a preparatory step towards life, but life itself, and should be treated as such. Schools should allow the child to live and become a part of the process rather than an absorbing observer of it. Schools should reflect the community and society at large so that when a pupil leaves school he is already a part of the current stream of society. If this is to be accomplished in a meaningful way then the school and the community must integrate their efforts to the point where each is a resource of the other.

Dewey felt that Froebel contributed much to education by way of recognition of the individual capacities of children and the spurring of interest in the area of educational research. He said by way of criticism that Froebel's ". . . formulation of the notion of development and his organization of devices for promoting it were badly hampered by the fact that he conceived development to be the unfolding of a ready-made latent principle."[20] This is an adoption of an _a priori_ principle unacceptable to Dewey.

Dewey's praise of Pestalozzi is basically that a progressive and enlightened society could be achieved through a democratic educational

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[19] John Dewey, _Democracy and Education_ (4th printing; New York: The MacMillan Company, 1964), p. 169.

[20] _Ibid._, p. 58.

system and that such a desirable end could only be through the support of the state. Pestalozzi saw this and could not gain state support to any degree that would advance his theories in practice.

Dewey supported Herbart's bringing of teaching into focus with regard to both subject material and method.

> Herbart undoubtedly has had a greater influence in bringing to the front questions connected with the material of study than any other educational philosopher. He stated problems of method from the standpoint of their connection with subject matter: method having to do with the manner and sequence of presenting new subject matter to insure its proper interaction with old.[21]

However, Dewey pointed out Herbart's fundamental theoretical defect as ". . . ignoring the existence in a living being of active and specific functions which are developed in redirection and combination which occur as they are combined with their environment."[22]

This point is coincidental with his criticism of Montessori. He claimed that an over-control of possibilities in play and instructional materials was not beneficial to the pupil. A child learns by making mistakes, both in the correctness in doing things and in the extent of his own capabilities. Dewey upheld the use of the senses and active use of things in a meaningful way but not isolated as tasks for the development of dexterity and separate skills. He felt that Montessori's didactic materials and Froebel's playthings were so designed as to incorporate an adult concept of correctness. He said, ". . . it is more

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[21] Ibid., p. 71.

[22] Ibid.

important to keep alive a creative and constructive attitude than to secure an external perfection by engaging the pupil's action in too minute and too closely regulated pieces of work. Accuracy and finish of detail can be insisted upon in such proportions of a complex work as are within the pupil's capacity."[23]

Dewey stated repeatedly that a scientific method of thought is the most intelligent and meaningful way to control new experiences. Information about the world should never become an end in itself; it has to have a relevant meaning for the learner. Such relevance is a result of past experience with current interest by way of involvement with desired ends and available means.

F. Jean Piaget

Piaget is not formally an educator. He is primarily concerned with the psychology and physiology of learning. His research method is to observe closely; to record the activities of a few subjects over an extended period of time; and then to search the material for emerging patterns. He has determined three major stages and four substages of intellectual development, each of which is hierarchically determined and contingent upon physiological development.

> Intelligence, in the Piaget model, is a process of adaptation and organization. Adaptation is seen as an equilibrium in the interaction of the organism and the environment. Organization involves a structural concept called the schema. Piaget defines schemas as

[23] Ibid., p. 197.

> essentially repeatable psychological units of intelligent action. Schemas may best be interpreted as types of "programs" or "strategies" that the individual has at his disposal when interacting with the environment.
>
> Adaptation involves the two invariant processes of assimilation and accommodation. Assimilation is the incorporation of the environment into present patterns of behavior. Accommodation is the change in the intellectual structures (schemas) which is necessary in order for the person to adjust to demands which the external environment makes on the individual.[24]

The parameters of these stages of adaptation are neither firmly fixed chronologically nor parallel in structure. An individual child may reach the next stage either earlier or later than the general observation, or he may be advanced in only certain aspects of his development. The sensorimotor stage has been established as being from 0 to 2 years. The next stage, the preoperational, has two sub-categories: preconceptual thought (2 to 4 years) and intuitive thought (4 to 7 years). The third stage, the operational, has two phases: concrete operational thought (7 to 11 years) and formal operational thought (11 to 16 years).

During the sensorimotor stage the child interacts with the environment basically through reflex action. He has no concept of time, space, causality, intentionality or object permanence. There is no apparent continuity of relationships established and there are no symbolic functions such as language. These begin in the next stage.

Preconceptual thought is the stage during which imitative behaviour becomes apparent. This pertains to physical action and language usage.

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[24]Edmund M. Sullivan, Piaget and the School Curriculum--a Critical Appraisal (Ontario: The Ontario Institute for Studies in Education, Bulletin No. 2, 1967), pp. 2-3.

Memory develops to the point of imitating absent persons or their sounds and actions. The world of the child now begins to expand beyond the horizon of immediate sensory perception of particulars.

During the substage of intuitive thought more than one aspect of a problem can be comprehended at one time. For example, in the conservation of volume experiment like volumes of liquid are poured into containers of various shapes. The four year old child will focus on one aspect such as the comparative height of the liquids and claim the higher level to indicate greater quantity. As he matures towards the operational stage, he will consider both the height and width of the container and also remember that the liquids were measured equal at the start. Handling the three aspects he will consider the amounts to remain the same regardless of the shape of the container.

Between the ages of 7 and 11 there develop four operations which enable the child to become more adept in handling abstract ideas; viz., combinativity, reversibility, associativity and identity.

> a) Combinativity is an operation whereby two classes may be combined into one comprehensive class which embraces them both . . .
>
> b) Reversibility is an operation whereby every logical or mathematical operation can be cancelled by an opposite operation . . . By reversibility division is the converse of multiplication.
>
> c) Associativity is an operation whereby several classes are combined. It makes no difference which will be combined first (e.g., [a+b] + c = a + [b+c]).
>
> d) Identity is an operation whereby a quantity can be nullified by combining it with its opposite.[25]

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[25] *Ibid.*, p. 7.

During the stage of formal operational thought the child breaks away from concrete and action-oriented thought to deal with abstract concepts in a hypothetico-deductive reasoning. Verbally posed problems, at the beginning of this stage, cannot be sorted out and dealt with, but the ability develops as the stage progresses.

There are four factors which Piaget outlined as being important for consideration in conjunction with the foregoing stages. The first is maturation and is based upon the hierarchical progression through the stages of cognitive development. Each stage, beginning with the sensorimotor, is the basis for the next stage and may be influenced by the environment of the individual. Therefore there is no fixed rate of progression.

The second factor is physical experience which is the interaction of the child with his physical environment. Repetition is the keynote and leads to the establishment of object permanence schemas. "The development of concrete operational thought is said to occur through the manipulation of concrete objects and the internalization of these manipulations."[26]

The third factor is social experience and is the result of social interaction. This involves a shift in emphasis from egocentric to sociocentric modes of thought. As the child becomes more aware of his peer groups, rules begin to become flexible in games and respect is both given and sought by participants. The language mode changes from monologue to dialogue with individuals and groups.

The fourth factor is equilibration which is the balancing of assimilation and accommodation. "The concept of equilibration is defined as a progressive interior organization of material in a step-wise fashion."[27]

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[26] Ibid., p. 11.

[27] Ibid., p. 12.

G. Implications for Science Teaching

The foregoing has shown a brief historical background for the current trend in science teaching which has developed in the following manner. When the ideas of the historical persons are juxtaposed it is found that the keyword throughout has been "experience" with emphasis upon a graduation of conceptual material from concrete to abstract. Intrinsic in this process of children's cognitive development is the physical maturing of pupils and the dexterity involving small muscle control.

The manner in which one uses and is used by his environment is the basis for his cognitive processes. The social and existential environments are so intertwined as to be a single conjoint influence. If the association of environment and experiences is a routine adaptation in the framework of habit, or one so familiar as to require no concentrated thought, there is merely recognition of previous experience. If, however, the past experiences are widely varied and numerous, the chances of a synergetic relationship are increased; that is, a relationship which is worth more than merely the sum of the components. If combinations of experiences can be applied to a present situation there is again an increase. It can be realized, then, that in the case of divergent thinking, the permutations and combinations of past experiences with present situations can more readily be expressed as exponential, because in any one thought there are the results of many past experiences, both concrete and abstract. The suitability of action is determined solely on the determination of an end in view, which is itself a means for further inquiry.

When considering the context of science teaching, the obvious approach is via an experimental method. Such a method has been developed by several companies and research groups and is available in the form of "kits" which provide materials for concept learning. Materials are provided for experimentation with a minimum of guidance. Any guidance, theoretically, should be by questioning technique which will lead the pupil on to the desired result by way of a new inquiry. His investigations are limited by virtue of the equipment at his disposal, but the interaction of pupil, material, classmates, and instructor, offer him many opportunities for varied approaches to any one problem. Granted, the problem is superimposed, but the divergency of approaches to a solution are as varied as the pupil makes them. The materials provided are analogous to Froebel's gifts, Montessori's didactic materials, and Dewey's things.

Froebel's gifts were seriated to accommodate the transition from concrete to abstract. They became increasingly difficult and manipulatory as the series progressed. Ultimately they led to activities out of doors for a relationship to be established with the world as a whole.

It was Montessori's contention that a child, given the materials necessary for the discovery of a principle (and only those materials necessary), would through the process of induction, come upon the revelation himself. It is interesting to note that Montessori and Piaget agree implicitly in the respect that Piaget has recorded an apparent timetable of cognitive growth patterns which must be experienced by each child, and Montessori never pushed or hurried a child to learn the lesson held in her didactic materials because they were not ready for it if they did not unlock the secret themselves.

Dewey said that ". . . analysis and rearrangement of facts which is indispensable to the growth, knowledge and power of exploration and right classification cannot be attained purely mentally--just inside the head. Men have to do something to the things . . . ."[28] This doing is in the form of laboratory work where conditions may be altered, and there is a concomitant learning with the doing. Furthermore, Dewey recognized that this "doing" must be at an age young enough for the intellectual aspects of the experience to be significant.

The philosophy of the science program currently being phased into British Columbia schools is as follows. Two elements of learning are of prime concern: the processes and the effective knowledge. The processes in science, of course, should follow the phases of scientific method. These phases include observing, questioning, testing, measuring, forming conclusions and predicting, among others. Children do these things naturally and it is the job of the science teacher to order these, along with "meaningful" experiences. The 1969 issue of the elementary science curriculum guide suggests that definite attention should be paid to allowing pupils to use, and realize by using, the creative processes involved in arriving at scientific knowledge.

There are certain premises which underlie the modern approach to elementary school science.

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[28]John Dewey, Democracy and Education (4th printing; New York: The MacMillan Company, 1964), p. 275.

a) Every pupil learns best when real things . . . are available for him to use. . . . First hand experiences help the pupil to understand relationships, to make applications, to acquire skills and to develop resourcefulness. How the pupil learns things is more important than the things he learns.

b) The experiences of the pupil as he attempts to find things out are often more important than what he discovers. There are many ways of inquiry into the nature of things, and the more opportunity each pupil has of pursuing investigations in diverse ways, the richer his experience will be . . .

c) Pupils will explore both extensively and intensively and unpredictably. They do not normally recognize traditional subject boundaries . . .

Furthermore, the rapidly accelerating pace of the knowledge explosion makes it impractical to insist that the mere learning of facts in some predetermined fashion is an essential part of a science education . . .

d) As far as possible "the interest of individual pupils and groups of pupils should determine science activities." The investigations and discoveries which the pupils will make can then be as exciting as they were to the original scientists . . .

e) The teacher supports with wise planning the pupils' attempts to understand the nature of the world, for "inquiry-centered science necessitates a new role for the teacher that is, in many ways, far more difficult and complex than that of the teacher who wishes simply to impart information."

The teacher provides the materials and organizes the classroom to encourage the pupils working with the materials . . .

The teacher creates a learning situation in which the pupil looks to him for guidance and encouragement, but not for answers.

A good teacher makes maximum use of divergent rather than convergent questions. The former serve as a point of departure for critical thinking. They lead pupils into exploratory activities to test the fruitfulness of their ideas.[29]

It is clearly evident then, that the attempt to create successful science students is via a divergent approach. The material is to be

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[29]Elementary Science, Years 1-7, Province of British Columbia, Department of Education, Division of Curriculum, Victoria, 1969, pp. 3-4.

concrete and the approach is to be divergent. The question remains whether or not the successful pupils handle the situation in a divergent manner.

In order to provide an answer for this question one must look into the area of creativity and its relationship to science learning. The new science program is historically and theoretically soundly based according to the educators and researchers already cited. The next chapter is devoted to creativity and its relationship to science education.

CHAPTER III

CREATIVITY AND STUDIES RELATED TO SCIENCE LEARNING

A. Creativity

The definition of creativity varies from one writer to another, and although all agree upon some characteristics, complete unanimity has not yet been reached. Taylor and Holland[1] give credit to J. P. Guilford for the list of a number of characteristics which are generally accepted by other researchers. These characteristics are listed under the headings of intellectual, motivational and personality characteristics.

Intellectual

Originality - statistical unusualness;
Redefinition - readiness to give up old interpretations of the familiar;
Adaptive Flexibility - unusual solutions when familiar ones fail;
Spontaneous Flexibility - freedom from categorization, movement from one to another readily;
Associational Fluency - many meanings, synonyms readily available;
Word Fluency - ability to produce words containing specific letter combinations;
Ideational Fluency - producing certain idea requirements in limited times;
Elaboration - addition of minor steps;
Evaluation - realizing worth of a solution relative to the situation and its limitations.

Motivational

Curiosity - capacity to be puzzled;

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[1]Calvin W. Taylor, John Holland, "Predictors of Creative Performance," Creativity: Progress and Potential, ed. by Calvin W. Taylor (New York: McGraw-Hill Book Co., 1964), p. 19.

Intellectually persistent - desires closure of a problem;
Tolerant of ambiguity - tenuous relationships tolerated;
Initiative - enterprising;
Cognition - likes reflective and divergent thinking.

. . . He has an inner need for recognition; he needs variety and autonomy; he has a preference for complex order and challenges therein; he has an esthetic and to some extent, religious orientation; he resists premature closure and crystallization of concepts, though he has a strong need for ultimate closure; he desires a mastery of a problem; he finds challenging, the intellectual ordering of the apparently unclassifiable; and he wants to improve upon currently accepted orders and systems. The use of passional sources of energy and kinesthetic cues may be important.[2]

Personality

There is some evidence that creative persons are more self-sufficient, more independent in judgement, more open to the irrational in themselves, more stable, more feminine in interests and characteristics, (especially in awareness of their impulses), more dominant and self-assertive, more complex, more self accepting, more resourceful and adventurous, more radical (Bohemian), more self-controlled, and possibly more emotionally sensitive, and more introverted but bold.[3]

These, and other traits of the creative person, have been assembled into various forms of definitions with regard to the process and the product. Usually creativity is known by the results of a process that is not often evident. This result is recognized as something unique, something imaginative and possessing excellence.

John L. Holland said the creative person is depicted as ". . . independent, complex in outlook, curious, self-assured, intellectual, interested in science and art, and generally effective."[4] He stated further that creative performance ". . . seems to be the outcome of a conscious

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[2]Ibid., p. 19.

[3]Ibid.

[4]John L. Holland, "Creative and Academic Performance Among Talented Adolescents," Journal of Educational Psychology, 1961, Vol. 52, No. 3, p. 137.

conception of being original, active participation in creative hobbies, and reinforcement by parents who possess values and attitudes which appear to be conducive to such performance."[5]

E. Paul Torrance has utilized the following definition as the basis for his research in creativity. It is

> . . . a 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.[6]

Robert Thomson outlined four steps which resulted from creativity research done by C. Patrick. The steps are:

> Preparation. Here the subject makes himself familiar with his situation and materials;
>
> Incubation. The problem begins to be defined. Suggestions occur, and fragments of the final product appear;
>
> Illumination. A specific goal is envisaged and the subject begins to work towards it.
>
> Verification. The results are worked out fully, revised, altered, completed. (Testing--in the case of hypothesis).[7]

Many authors and researchers use the terms divergent and convergent rather than creative and non-creative, but these terms are not

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[5]Ibid., p. 142.

[6]E. Paul Torrance, Torrance Tests of Creative Thinking, Norms-Technical Manual, Research Edition (Princeton, New Jersey: Personnel Press Inc., 1966), p. 6.

[7]Robert Thomson, The Psychology of Thinking (Baltimore: Penguin Books, 1964), p. 189.

completely synonymous. Psychology has generally adopted the use of the term creative. Liam Hudson says, "Whatever the logical connection between convergence or divergence and originality, psychologists are prone to view the topics as one and the same. Many psychologists, particularly American ones, see the diverger as potentially creative and the converger as potentially uncreative."[8] J. P. White[9] argues that the creativity of a girl with crayons and a drawing pad, a boy devising uses for bricks, a child learning mathematics in school and scientists like Einstein and novelists like Dostoevsky have no creativity in common except the word.

> But the meaning of this word is not a mysterious inner process. In fact it has no one meaning in these different examples, but a number of meanings, with just enough in common between them to make it plausible, though confusing, to apply the same word to all four cases.[10]

White continued that creative thinking is not a peculiar type of thinking that has features differing from other types of thinking. "Creative" is merely a label given to the public products and not to the process which is private and not publicly observable. The persons responsible for the products are labelled "creative" by virtue of their achievements.

To find what the creative process is in scientific discovery, one must turn to recognized scientists and their reflections upon the matter, and writers who have investigated the problem in depth.

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[8] Liam Hudson, Contrary Imaginations (New York: Schocken Books, 1966), p. 100.

[9] J. P. White, "Creativity and Education: A Philosophical Analysis," Jane R. Martin (ed.), Readings in the Philosophy of Education: A Study of Curriculum (Boston: Allyn and Bacon Inc., 1970), pp. 122-137.

[10] Ibid., p. 123.

Wartofsky generally agrees with the previous statements that there must be familiarity with the subject matter and the ability to ultimately abstract that which is sensually perceived.

> The 'abstractions' which perception achieves at this level, we may say, are not yet detached from actual perceptual situations themselves, nor are they represented in some explicit symbol apart from direct responses to environmental stimuli. Perceptual 'abstraction' is at best a way of operating within perceptual experience, in actual perceptual situations. Memory and imagination take us a step beyond actual, relatively direct perceptual involvement. In effect, we detach the perceptual image from direct outward sensory or motor activity. Thus imagination and memory provide a kind of isolation from the flux and press of sensory discrimination and response. But both memory and imagination are still tied to the direct imagery of sense perception, even when this imagery appears in fanciful or distorted form. The memory image, or the imagined image, may be vivid or faint, vague and confused, or clear and distinct; but it remains bound to the sensory qualities of colors, shapes, sounds, feels, smells, and so on.[11]

He continued that the level of abstraction of the memory image yields a greater possibility for manipulation of the abstractions and symbols until a desirable conclusion has been reached for explanation and communication. He lists six advantages of this as a method.

a) Conceptual representation in a language is economical;

b) The detachment of the conceptual representation from direct perception and action permits the reflection on ends and means and introduces the possibilities of judgement and rational choice;

c) The conceptual model is time-binding (memory allows stop action review of events for examination);

d) Implicit habits or learned patterns of action become explicated as rules or plans which can come under conscious scrutiny and criticism;

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[11]Marx W. Wartofsky, Conceptual Foundations of Scientific Thought (New York: The MacMillan Company, 1968), pp. 35-36.

e) Explicit rules of contradiction and consistency emerge with the development of rational discourse.

f) Explanation or understanding of the 'why' of things rests on knowledge by means of concepts.[12]

Beveridge went a little further when he said:

> Emotional sensitivity is perhaps a valuable attribute for a scientist to possess. In any event the great scientist must be regarded as a creative artist and it is quite false to think of the scientist as a man who merely follows rules of logic and experiment. Some of the masters of the art of research have displayed artistic talents in other directions.[13]

He then outlined the biography of several scientists and their talents, such as Einstein and Planck who were musicians, Pasteur who was a painter, and Bernard who was a playwright.

Ghiselin[14] has collected the comments on creative style and functioning from many recognized people in various fields ranging from the arts to mathematics. Henri Poincaré described his process of mathematical discovery as containing several distinct steps. First there was a prolonged period of intense involvement with a problem. Then there came a period, either longer or shorter than the original, or relaxation or activity divorced from the problem. During this second stage there would often be sudden insight into the problem worked upon. Then there was the final stage of a second period of concentration to work out and explain the insight gained during the period of relaxation.

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[12] Ibid., pp. 37-38.

[13] W. I. B. Beveridge, The Art of Scientific Investigation (New York: Vintage Books, 1957), p. 102.

[14] Brewster Ghiselin (ed.), The Creative Process (California: Mentor, 1959).

There are slight variations from this pattern in his experience, but the essence is the same. In his own words, he says:

> 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, and traces of it would be found in other cases where it is less evident. Often when one works at a hard question, nothing good is accomplished at the first attack. Then one takes a rest, longer or shorter, and sits down anew at the work. During the first half-hour, as before, nothing is found, and then all of a sudden the dedisive idea presents itself to the mind. It might be said that the conscious work has been more fruitful because it has been interrupted and the rest has given back to the mind its force and freshness. But it is more probable that this rest has been filled out with unconscious work and that the result of this work has afterward revealed itself to the geometer just as in the cases I have cited; only the revelation, instead of coming during a walk or a journey, has happened during a period of conscious work, but independently of this work which plays at most a role of excitant, as if it were the goad stimulating the results already reached during rest, but remaining unconscious, to assume the conscious form.[15]

The period of rest he speaks of is nothing other than a period where the unconscious, as he puts it, is freed to work in a divergent manner. The combinations of ideas seem to go on automatically, the sterile ones are rejected but the useful or synergetic combinations impinge themselves upon the conscious mind to be recognized and worked out.

In response to research being done by Jacques Hadamard on the question of the psychology involved in mathematical invention, Albert Einstein reported the following to be his experience:

> The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs

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[15]<u>Ibid</u>., p. 38.

> and more or less clear images which can 'voluntarily' be reproduced and combined.
>
> There is, of course, a certain connection between those elements and relevant logical concepts. It is also clear that the desire to arrive finally at logically connected concepts is the emotional basis of this rather vague play with the above-mentioned elements. But taken from a psychological viewpoint, this combinatory play seems to be the essential feature in productive thought--before there is any connection with logical construction in words or other kinds of signs which can be communicated to others.[16]

Again the emphasis is on a "combinatory play" or a divergent thought process. For further verification of this phenomenon, the writer interviewed Rand Collins, a student currently completing his Master's thesis on a study of the conformation of proteins using a nuclear magnetic resonance method. His responses indicate that he is a visualizer of images. He began with the experimental stage and recounted that when the results of an experiment were before him he attempted to explain them. In cases where the problem appeared simple and straight-forward, the explanation was worked out immediately. In more difficult cases the criterion appeared to be relaxation in the form of sleep. If he gained a good ten hours of sleep he would often awake with an insight or a solution to the problem. If he gained only seven or so hours of sleep, the resolution of the problem was delayed until during the work of the next day. It would appear that in his case there is a critical period of rest required where the unconscious has the opportunity to manipulate the pertinent data for relevant and meaningful relationships to be established.

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[16]*Ibid.*, p. 43.

D. E. Wooldridge says of the brain function itself:

> The development and employment of complex concepts doubtless is basic to most intellectual activity. This must be especially true of creative thought. In this connection there may be particular significance in the feature of our postulated storage mechanism whereby the activation of one stored memory pattern lowers the threshold of all other patterns containing similar sensory content. An essential ingredient of creative thought is the ability to move quickly and easily from one concept to a related one. It seems possible that the principal difference between the creative and the unimaginative individual is simply that the feedback or other mechanism involved in this threshold-lowering process is more effective for the one than for the other.[17]

B. Studies Related to Science Learning

Some research has been done with relation to the determination of the role that divergent thinking or creativity plays in the learning of science in the school situation.

Cline, Richards and Needham[18] conducted a study to provide evidence respecting the validity of creativity tests as predictors of performance in high school science. Their sample consisted of 114 high school students, 74 males and 40 females, in Salt Lake City, Utah. The battery of tests used by them was more extensive than that used in the present study, but the same and similar tests were included. An I.Q. was established by the California Mental Maturity Inventory. The creativity tests which were selected for emphasis on Ideational Fluency to reduce the factorial

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[17] Dean E. Wooldridge, The Machinery of the Brain (New York: McGraw-Hill Book Co. Inc., 1963), p. 225.

[18] Victor B. Cline, James M. Richards, Walter E. Needham, "Creativity Tests and Achievement in High School Science," Journal of Applied Psychology, 1963, Vol. 47, No. 3, pp. 184-189.

complexity of the battery, were developed by J. P. Guilford. They included Consequences, Word Association, Hidden Figures, Brick Uses and Match Problems.

There were five criteria established as relevant to achievement in high school science. The first was grade point average, based on 4.00 = A, 3.00 = B, 2.00 = C, 1.00 = D. The second criterion was the score obtained on a "Sequential Test for Educational Progress (S.T.E.P.) Science Achievement Test." This was obtained from the student files. The third criterion was a teacher rating of the overall performance of each student as compared to a hundred randomly selected science students. These scores were adjusted so the highest score possible was one hundred. The fourth criterion was the number of science courses taken up to the time the data were collected. The fifth criterion was based upon information obtained from research done by the National Merit Scholarship Corporation, and included student responses to a question on involvement in science.

The results of their study indicated clearly that the creativity battery does have

> . . . considerable predictive validity against each of the criteria for each of the sexes, and that the creativity tests do account for a substantial amount of criterion variance in addition to that accounted for by the I.Q. test. Furthermore, on all five criteria for males and two of the five criteria for females the multiple correlation for the creativity battery is higher than the first order validity tests of the I.Q. test and on the remaining three criteria for females the creativity battery predicts almost as well as the I.Q. test.[19]

[19] Ibid., p. 187.

A study was done by Cropley and Field[20] and was concerned with the question of whether high achievers differed markedly from low achievers in science, in terms of style rather than level of intellect. Their battery of tests was administered to all Fifth and Sixth Form students of two high schools in large country towns in New South Wales, Australia. A total of 178 students included 104 boys and 74 girls.

The series of tests included a standardized test of science achievement designed specifically for Australian students at this level. An I.Q. rating was obtained. Four tests involving intellectual style were then given. They included originality, and flexibility, both designed by E. P. Torrance, category width, designed by T. F. Pettigrew, and a test on the abstractness of intellectual functioning designed by R. P. Tisher after those of Jean Piaget.

The standard tests were scored according to the published specifications, while the originality and flexibility ratings were weighted according to those of the designer and again by Cropley. The Tisher test scores were based upon the students being predominantly concrete, early formal or late formal in their style of responses. The results include product-moment intercorrelations, means, standard deviations for achievement, and I.Q. and style variables.

The main finding was support for the idea that "intellectual style: is of importance in science achievement.

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[20]A. J. Cropley, T. W. Field, "Achievement in Science and Intellectual Style," Journal of Applied Psychology, 1969, Vol. 53, No. 2, pp. 132-135.

> The most successful science students in the present study were characterized by highly abstract and original thinking and by their characteristic ways of relating apparently discrepant data. These findings are consistent with others based on scores of unusually successful undergraduate scientists in an Australian university (Cropley, 1967b). In a longitudinal study covering the 4 years required for an undergraduate honors course in science, it was shown that men graduating with honors came almost exclusively from among those who had been rated highly divergent in their style of thinking on entry to the university 4 years previously.[21]

The data they gathered, however, did not show that the relationship between intellectual style and achievement was peculiar to the area of science.

The same study was reported in another journal[22] with a slightly different emphasis upon the results.

> The processing of science information by pupils in the experimental sample has been shown to be related to a number of specific modes of cognitive functioning which, it is claimed, must be recognized by science teachers and curriculum writers if pupils are to achieve optimum understanding at any given time.[23]

> . . . In particular the conception of a specific science cognitive style appears to have considerable merit. Finally, it is felt that classroom practice could benefit from a more detailed knowledge of each pupil's preference in cognitive functioning.[24]

Another study, by Bradley,[25] examined alternative methods of teaching the physical science program in Michigan State University. No

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[21] Ibid., p. 134.

[22] T. W. Field and A. J. Cropley, "Cognitive Style and Science Achievement," Journal of Research in Science Teaching, Vol. 6, 1969, pp. 2-10.

[23] Ibid., p. 9.

[24] Ibid., p. 10.

[25] Robert L. Bradley, "Lecture Demonstration versus Individual

reference was made to creativity or cognitive style. The two methods were the lecture-demonstration presentation and the individual laboratory method. The lecture-demonstration method was the experimental part of the study where the instructor performed the experiments and lectured to the students. The other method involved the students in doing their own experiments. The criterion of the final examination in the course was based on the assumption that it adequately measured the objectives of the course.

The population sampled was that enrolled in the course at the time of the study and consisted of two groups with unequal numbers which were statistically equated. There was no significant difference in the ability scores of the two groups as measured by the CQT-T scores established at the time of enrollment at the university.

The instructors made no effort to follow the same testing program during the term; one gave weekly ten minute quizzes while the other gave five one hour tests.

> The outstanding result of this study is that the particular methods of teaching differ very little as evidenced by student learning and retention, when the aims and objectives of the General Education Science are examined on the basis of a pencil and paper test. . . . However, in so far as this paper provides evidence, individual laboratory experience for the attainment of general education goals does not appear to be necessary.[26]

Laboratory Work in a General Education Science Course," The Journal of Experimental Education, Vol. 34, No. 1, Fall, 1965, pp. 34-42.

[26] Ibid., p. 39.

In summary, research into creativity and divergent thinking versus convergent thinking indicates that there are various modes of cognitive functioning. The methods for determining these various modes have met with a degree of success.

The studies involving science learning and intellectual style have yielded a lesser degree of success in correlating these two factors. One of the difficulties in this may be the different age groups used in the studies and that the intellectual style of individuals changes with maturity, as suggested by Piaget.

The studies of Cropley and Field involve both intellectual style and science learning, and suggest that a creative approach to the subject matter of science would best suit divergent thinkers.

The study of Cline _et al_. suggests that creativity tests have a predictive value in pre-determining successful science students. This finding is further backed by the longitudinal study referred to by Cropley and Field.

Bradley's study utilized a divergent and a convergent approach to science teaching with the two classes of university students. He found no difference in the results based upon the criterion of final examinations.

The combination of these studies suggests itself as an area for research and this study has combined them in the following manner. It incorporates the use of teaching and learning in both the divergent and convergent methods and establishes degrees of creativity for the grade seven group involved.

CHAPTER IV

DESCRIPTION AND DESIGN OF THE EXPERIMENT

A. Review of Previous Teaching Method

The population used for this research was that comprising the grade seven pupils of an elementary school. During their previous two years of science they had been exposed almost entirely to an investigative approach to science learning. As kits and materials became available, they were utilized in the school with the current "Discovery Method" as outlined in the teacher guide books for the various kits. As the kits were not available in great enough numbers for each school in the district to have them full time, some units were taught by the traditional methods.

In the case of this population, there were five units utilizing kits and three units taught in their grade six year by traditional methods of lecture, reading texts and demonstrations by the teacher. In the latter cases the pupils reacted with resentment at not being allowed to "experiment" in the laboratory.

The nature of the kits is such that each child has equipment either for himself or for a group of three or four. The result is that each child actually manipulates the equipment and conducts experiments in the laboratory setting. The resentment mentioned stemmed from a change of role from "scientist" to "pupil" and was expressed as such by many individuals.

By the end of their grade six year, there were enough kits available to provide the experimental science approach for them on a continuing basis.

When the group entered grade seven, they did not have the same class make-up. However, the same population remained with few exceptions. The first unit of their grade seven science year was relatively traditional due to kit material being unavailable. The unit included warm and cold blooded animals and was based upon text reading, questions on the chapters read, and private research on particular animals of their own interest. They were encouraged to do field work with cameras and to do their own photographic processing. The presentation of their booklets, and projects which resulted from their research, took place during the last week of September. Both classes studied the same unit.

On October 2nd, 1970, both classes were given the series of three divergent thinking tests (see Appendix B). On October 6th, the Educational Testing Service General Science Test, Form A* was given. The following science lessons began the first phase of this research with the introduction of the new units. The two classes, hereinafter referred to as Division I and Division II, were treated as separate and distinct entities. Division I received the experimental approach to learning first while Division II was taught in the traditional manner. Each science period was of eighty minutes duration.

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*Hereinafter referred to as science test A and B.

B. Teaching Procedure (see Appendix D)

The school district in which this research was done has a central office for the storage, replenishment and disbursement of science kits. It proved impossible to obtain the "Gases and Airs" kit at the two times necessary for this research, due to another school having booked it previously. The unit used to replace it was one dealing with the physical states of water, and is described later in more detail.

The teaching methods used must be described at this point. The experimental, or divergent approach, involves an active participation on the part of pupils. Meaningful encounters with representative environmental phenomena are encouraged by the teacher. Children are given the opportunity to experience natural phenomena in a manner which is personally important for them. The problems to be investigated are made salient by the teacher by virtue of apparent contradiction with what is generally observed. The contradictions are not explained to the pupils, but are investigated by the pupils in their own manner and explained by them in their own terms. When sufficient data has been gathered by a class, patterns emerge which can be used as bases for formulating hypotheses and "laws."

Through this method a conceptual framework is gradually built. It is one which directly involves the pupil and therefore is portable to situations outside the classroom. An example of this is when the unit on "Microgardening" (the study of molds) was taken by the grade sevens, many parents complained, in a good natured manner, that their homes were being filled with moldy articles as experiments being conducted there.

Similarly, during the unit of "Kitchen Physics" the home kitchen cupboards were ransacked in search of materials to "experiment" with. Several girls who had previously shown little interest in science, related laboratory work with home chores in that they "discovered" how detergents removed food and grease from dishes. As a final example, some boys realized why a car or bicycle tire is heavier when inflated as a direct result of doing the "Gases and Airs" unit. Although this is not a problem directly involved in the unit, the result was obtained because the boys were encouraged to follow their own line of experimentation during the unit presentation.

The traditional approach to science has been textbook oriented. The result has been both limiting and rigid. Chapters were assigned to be read, questions were given on the reading, and sometimes a demonstration of an experiment or a film was included. Facts were the all important core of the program and if they were memorized by pupils, success was thought to have been achieved. Textbooks are a distillation of hundreds of years of observations, trials and errors, put into print by experts who are not questioned by grade school pupils.

All too often the teacher is not knowledgeable in the science area and is forced to rely upon a textbook. In many such cases the science lesson merely becomes a reading lesson with the possibility of attendant frills such as demonstrations. Pupils learn that science is a school subject and often fail to remove it from that abstract context and relate it to everyday life situations.

The unit of "Astronomy" was particularly suited to presentation by the traditional method. Diagrams, facts, figures, mathematical relationships and formulae were utilized. The pupils were taught in a regular classroom where the seats were arranged facing the front in rows. Some demonstrations were given, in the form of shadow casting and measurement.

The unit presented to Division I was "Gases and Airs" designed and produced by the Elementary Science Study (E.S.S.). The materials were given to groups which were formed by the pupils themselves, and no group had more than five members. Cupboard space was allocated and each set of materials was labeled with the names of the group members. Each piece of equipment was checked against a master list to ensure completeness. The rest of the period was given to free investigation with the materials.

The second science period began with a demonstration and left the class with three questions. They were shown how to set up the apparatus for the "Burning-Candle" experiment, how it was to be carried out, and how to repeat it.

The burning-candle experiment is one in which a candle is fixed upright in a shallow tray of water. The candle is then lit and a jar or similar container is inverted over the candle so the open end is below the surface of the water. The flame on the candle is gradually extinguished and water rises in the container.

They were left with these questions: (a) "Why does the candle go out?" (b) "Why does the water rise in the tube?" (c) "Does the water rise the same amount each time?".

From this point each lesson was conducted in a similar manner.

During the science periods, individual attention was given to pupil questions and problems. In this way the group was more or less kept together with regard to techniques to be learned, and exposure to new experimental possibilities as motivations for more investigation. For some subjects, the suggestions were unnecessary because they had already done what was suggested, or they were beyond that point conceptually. For others the suggested routines provided more of a challenge than they could cope with, and they needed a disproportionate amount of the instructor's time for encouragement or more constant guidance.

After the discussions indicated that the class was aware of the fact that oxygen was involved in the reactions they were witnessing, they were taught how to calculate the percentage of air used up and to indicate reasons for a deviation between their individual results and the expected result based upon the percentage composition of air.

In total there were twenty official science periods devoted to the unit of study. In addition there was one period devoted to viewing films on another topic, one period devoted to a cleaning up of the equipment at the end of the unit, and one period lost as a result of the Thanksgiving holiday. Because of the flexibility in time tables in the school, the pupils were allowed to use the laboratory during language arts time if that area of their work was up to date and they wished to go on with their science studies. However, there was no coercion in this respect. This means, of course, that keener pupils utilized the laboratory facilities more than the allotted science periods but as records were not kept this factor can only be mentioned.

The unit presented to Division II was "Astronomy." The basis for this presentation was the unit designed by the Illinois Astronomy Project. There is a kit of materials provided but they are not of the same nature as those provided for "Gases and Airs." They consist of compasses, protractors, and metre sticks, plus various other items which were not used for this study. In addition to these tools, each pupil was given a sixteen page set of mimeographed notes and questions on the subject (see Appendix C). Although most of the questions could be answered directly from the booklet, some did require outside reading and research.

The initial lesson consisted of a demonstration of various optical phenomena and a history of astronomy, explored by way of discussion and lecture methods. The second lesson began the geometrical determination of distances and size. As the subjects had received no instruction in formal geometry, the basics had to be taught. Circles, triangles and angles were drawn and the relationships of their parts were shown. Notes were taken and various exercises were done by the class. These included naming the parts of diagrams, calculating the value of _pi_ and using protractors. The metric system was introduced and drilled with the aid of metre sticks. After several lessons they were assigned some reading in a text book and they were issued with the booklets mentioned. The answers to the questions were reviewed at intervals and private research was encouraged where interest was shown.

In total there were twenty official science periods devoted to this unit. In addition there was one period devoted to viewing films on another topic, and one period was lost as a result of the Thanksgiving holiday.

On December 9th, both classes were given Form B of the science test and the following day they were given the second battery of divergent thinking tests. On December 11th both classes began their new units. Division I began the unit on astronomy and the format already outlined pertained to that learning situation. Division II began an experimentally oriented unit regarding the various physical states of water because the "Gases and Airs" unit was unavailable. The amount of equipment was somewhat limited so there was some direction towards research in books, but the majority of time was spent doing experiments in the laboratory. Each pupil was given instructions in note form and all subsequent teacher-pupil contact was on an individual basis, with the exception of a review lesson and the summary lesson at the end of the unit.

The laboratory work included the determination of the boiling point of water alone, then with various amounts of salt added. The temperature of ice was determined without, then with salt added in various amounts. Observations were made both inside and outside the beakers and a relationship between what they saw and what occurs meteorologically, was established. Distillation apparatuses of the pupils' own designs were built in some cases, and commercial models were used in other cases, to obtain as accurate a boiling point as they could. Others devised their own experiments to discover what effect different materials had on the boiling point and freezing point of water, and to discover various methods of creating artificial precipitation in the laboratory.

The progress of these unit presentations was interrupted by the Christmas holidays, which lasted from December 23rd to January 4th. The first post-Christmas science period for both Division I and Division II began with a review of what had been in progress before the holiday, and the units proceeded to their conclusions on February 3rd. The next day, both classes completed science test A, and the day following that, the creativity tests were completed. In the case of both divisions, there were eighteen official science periods devoted to these units. Again, for the experimental approach, pupils who wished to, could go into the laboratory and continue their science experiments during language arts time, and no record was kept of this activity.

C. Conduct of the Experiment

The research was undertaken according to the following quadripartite design.

	Experimental	Traditional
Division I	Phase I	Phase II
Division II	Phase II	Phase I

During Phase I, Division I received the experimental approach and Division II received the traditional approach to science. During Phase II, the situation was reversed so Division I received the traditional and Division II received the experimental approach to science.

The testing was carried out accordingly. At the beginning of Phase I, both divisions were given the Educational Testing Service General Science Test, Form A, to establish a basis of general science knowledge. They were also given a battery of three tests in an attempt to establish a degree of divergent thinking. These divergent thinking tests were chosen from the work of Getzels and Jackson (1962) and Wallach and Kogan (1965). At the end of Phase I the tests were administered again, where the science test was Form B and the creativity tests were a different form than those given in the pre-test (see Appendix B). After Phase II, the original, pre-Phase I tests were given to establish final levels in both areas. Science test Form A was re-administered because of the lack of a third Form which could perform this function. The original creativity battery was re-administered to maintain a constant relativity with the Form A science test.

In all cases, the science tests were administered in the traditional classroom setting and were timed, forty minute tests. The battery of divergent thinking tests were given in toto to the classes, and according to the suggested times of the researchers mentioned above, one hour was given for their completion. On both subsequent testing dates, however, each item of the uses test was given three minutes, and each page of the Wallach and Kogan tests was given four minutes. In each case the Word Association test was given fifteen minutes. The reason for the change in the direction of the divergent thinking battery was the apparent lack of pupil response to some test areas as a result of their spending too much time on others. The revised presentation gained a better response and did not appear to hinder any pupils in any way, except that those who had few responses had to sit quietly and think of the immediate question while waiting for the instruction to go on to the next problem.

The pupils involved in this study were not apprised of the intent of the testing until after all the tests were given and the data collected. There were questions raised by them when they recognized the first battery upon its second presentation, but explanation was deferred until after it was written.

D. Testing Program

The tests were given in three series. The first was at the beginning of the research program, just prior to Phase I. The second series was given at the end of Phase I and prior to Phase II. The third series was given at the end of Phase II. Each series consisted of three divergent thinking tasks and an objective science knowledge test.

1. First Series

a) Divergent Thinking Tasks (see Appendix B)

The divergent thinking tasks chosen from the work of Getzels and Jackson (1962) were the "Uses Test" and "Word Association." The former is a list of five common articles, and the subject lists as many uses for each item as he can. The latter is a list of twenty-five words, each of which has multiple meanings, and the subject indicates as many of the meanings as he is able.

The third divergent thinking task was chosen from the work of Wallach and Kogan (1965) and was a combination of "Figural Meanings" and "Pattern Meanings." Wallach and Kogan used eight of each as separate tests. The experimenter chose to combine these and each submission to the subjects contained four of each task.* The four were arranged so

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*This decision was based upon the need for two different tests to accompany the two forms of the science knowledge tests.

they alternated between "Pattern" and "Figural Meanings," for a total of eight interpretations per session. The subjects wrote as many interpretations of each pattern or figure as they were able.

b) The Science Knowledge Test

The Educational Testing Service General Science Test, Form A was given to the subjects. It is of multiple choice design and tests areas of factual knowledge and deductive thinking. There are sixty questions to be done in a forty minute period.

2. Second Series

a) Divergent Thinking Tasks

The "Uses Test" was administered containing five items different from those in the first series of tests. In all other aspects the task was the same.

The "Word Association" task was the same as that in the first series.

The "Figural Meanings" and "Pattern Meanings" task involved the eight Wallach and Kogan designs not used in the first series.

b) The Science Knowledge Test

The Educational Testing Service General Science Test, Form B was administered. It contains sixty questions to be answered in a forty minute period.

3. Third Series

All tests given were identical to those given in the first series.

E. The Evaluation of the Tests

1. Uses

The scoring in this test was a total of plausible responses without regard to uniqueness. A total score consisted of the sum of responses for each of the five items. (See Appendix B, page 99, for test and instructions given.)

2. Word Association

Each subject's responses were given two scores. The first was the total number of replies which were correct and the second was the number of meaning categories given. For example, in response to "cap," the words "toothpaste, head, bootle," would score three for total number of responses, plus two for meanings, for a total of five. Credit was given for slang expressions, as in the word "cap" referring to a drug form or capsule, particularly L.S.D. Incorrect meanings or homonyms were not given any credit, for example "plane" got credit for "air" or "tool" but not for "land" or "not fancy." The two scores were summed for a total mark. (See Appendix B, page 98, for test and instructions given.)

3. Pattern Meanings

The subjects were requested to list as many different things as the pattern made them think it could be and the score for this test was based upon uniqueness of response. All responses of all subjects in each group were tabulated to determine uniqueness within each group, and those which were unique in ideational content were given one mark.

The total number of unique responses determined the score for each subject. (See Appendix B, page 97 for replications of the patterns.)

F. General Science Test

Tese tests were scored in accordance with the answer keys provided.

Timetable of the Experiment

Phase I

October 2	-	Divergent thinking tests, first series.
October 5	-	Began "Gases and Airs" unit, Division I.
	-	Began "Astronomy" unit.
October 6	-	Science Test, Form A.
October 23	-	Lorge Thorndike I.Q. Tests, both Divisions.
November 30	-	Ended "Gases and Airs."
December 2	-	Ended "Astronomy" unit.
December 9	-	Science Test, Form B.
December 10	-	Divergent thinking tests, second series.

Phase II

December 11	-	Began "Astronomy" unit, Division I.
	-	Began "Water" unit, Division II.

December 23-January 3 - Christmas Holidays.

January 4	-	Review of pre-Christmas activity and continuation.
February 3	-	Ended both units.
February 4	-	Science Test, Form A, both Divisions.
February 5	-	Divergent thinking tests, third series.

CHAPTER V

ANALYSES OF DATA

A. Pre-Test Scores

The data obtained from the testing program carried out prior to the application of the teaching treatments is given in Table V-1.

TABLE V-1

PRE-TEST DATA

Type of Test	Division I		Division II	
	Mean	St. Dev.	Mean	St. Dev.
Verbal Ability - Raw Scores	52.06	10.320	52.16	12.263
Non-Verbal Ability - Raw Scores	47.34	7.503	48.88	10.694
General Science Test, Form A	28.56	8.805	31.31	10.546
Uses Test	21.38	9.263	15.34	8.096
Word Association	72.91	20.375	75.69	23.449
Figure Meanings	9.97	9.201	9.50	6.600

Examination of these data shows that the two divisions are sufficiently similar to be considered as two samples from the same population. However the need for some specific comment is indicated.

a) The ability test means are so close that they can be considered identical but both the verbal and non-verbal standard deviations reveal greater variances for the Division II distribution. However, using the t-test ($P < .05$), the difference is not statistically significant and hence may be assumed to be due to chance.

b) The Division II mean and standard deviation for the General Science, Form A are greater than for Division I. The differences are not statistically significant.

c) The results of the initial Uses Test constitute a problem. The Division I mean (21.38) is significantly greater than the Division II mean (15.34) at the 0.01 level. As this is the only instance when the Division I mean is greater than the Division II mean and as the higher means remain in favour of Division I for the second and third testing one is inclined to accept that, on this test, Division I is superior. However the means for the subsequent administrations are less markedly different which tends to suggest that a testing anomaly may have caused the very low initial administration value. Also, note must be made that for this test the Division II standard deviation is also lower (this situation is maintained through the subsequent administrations) but the difference is not statistically significant.

d) From inspection of the results for the Word Association test the scores correlated positively with those obtained for the ability and achievement tests. This might be taken to indicate that this test measures convergent thinking whereas the more open Uses Test may measure a more divergent dimension.

e) Figure Meaning scores for the two divisions on the Pre-test are markedly similar and suggest a high degree of similarity to ability, achievement and Uses Test scores. However reference to the total data (see Appendix A) reveals a wide and apparently erratic range of scores. One is at a loss to know whether this test is markedly sensitive to divergent thinking or whether it is unreliable.

B. Phase I

During this phase Division I received the experimental or discovery method treatment whereas Division II was given the non-experimental or formal instruction treatment. Two hypotheses can be examined.

a) That the two treatments would result in different gains on the scores obtained from the Co-operative Science Test, General Science.

b) That different increments in the scores would be obtained from the divergent thinking tests.

A priori assumptions and reasoning suggest that more knowledge of science would be gained from use of the discovery approach than from use of the formal instruction method. Also the freer context of the discovery technique leads to the assumption that its use may result in significantly greater increase in scores on the divergent thinking tasks.

The following table summarizes the data obtained and enables comparisons to be made (Table V-2).

As noted in the discussion in the previous section the initial

TABLE V-2 – COMPARISON OF PHASE I TOTAL GROUP MEANS

	Division I			Division II		
	$\bar{X}$	s	P<.05	$\bar{X}$	s	P<.05
Co-operative Science Test						
Pre-test Form A	28.56	8.085		31.31	10.546	
Post-test Form B	29.78	9.987		35.88	10.005	
Diff.	+1.22	+1.902	.537 N.S.	+4.57	-.541	1.778 P<.05
Divergent Thinking Tasks Uses						
Pre-test	21.38	9.263		15.34	8.096	
Post-test	23.72	8.807		20.19	5.359	
Diff.	+2.34	-.456	1.084 N.S.	+4.85	-2.737	2.836 P<.05
Word Association						
Pre-test	72.91	20.375		75.69	23.449	
Post-test	77.72	18.401		74.91	18.398	
Diff.	+4.81	-1.974	.992 N.S.	-0.78	-5.051	.148 N.S.
Figure Meaning						
Pre-test	9.97	9.201		9.50	6.600	
Post-test	12.22	10.249		12.09	6.222	
Diff.	+2.25	+1.048	.925 N.S.	+2.59	-0.378	1.619 P<.05

differences between the means of the two divisions are not too great for them to be accepted as samples drawn from different populations but care must be taken in interpreting the data in the table above. The safest procedure seems to be to base comparison upon the significance (or non-significance) of the increments in the data from the divisions--i.e., between the means of the difference between pre-test and post-test scores for the two divisions.

In using these data some general aspects can be noted.

a) The increments derived from the Co-operative Science Test are 1.22 for Division I and 4.57 for Division II. From this it appears that the gain for the instructional treatment is superior to that for the discovery. This difference is statistically significant.*

b) The mean score for the instructional treatment group also increased significantly on the Uses Test but this assumes validity of the rather low pre-test mean for Division I. The investigator admits to feeling that this may not be a valid assumption.

c) The scores obtained on the Word Association Tests show that Division I (discovery) improved more than Division II (instruction) +4.81 and -0.78.

d) In the case of Figure Meaning the differences between pre-test and post-test scores for the two divisions are so close that they can be considered identical.

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*$p < .05$.

The hypotheses presented were supported in that different scores were obtained from the Co-operative Science Test, General Science and different increments were obtained from the divergent thinking tests. However, it would appear from these data that there is no basis for assuming that the two treatments lead to any consistent differences in performance. The instructional treatment seems to lead to greater improvement on the Co-operative Science Test and the Uses Test while the discovery treatment seems to favour improvement on the Word Association Tests.

C. Phase II

During this phase Division I received the non-experimental or formal instruction treatment and Division II received the experimental or discovery method treatment. The same two hypotheses are again examined.

a) That the two treatments would result in different gains on the scores obtained from the Co-operative Science Test, General Science.

b) That different increments in the scores would be obtained from the divergent thinking tests.

The following table summarizes the data obtained and enables comparisons to be made (Table V-3).

Using these data the following aspects can be noted:

a) The increments derived from the Co-operative Science Test are +2.26 for Division I and -2.97 for Division II. From this it

TABLE V-3 – COMPARISON OF PHASE II TOTAL GROUP MEANS

	Division I			Division II		
	$\overline{X}$	s	P < .05	$\overline{X}$	s	P < .05
Co-operative Science Test						
Pre-test Form B	30.08	9.86		35.88	10.99	
Post-test Form A	32.34	7.93		32.91	12.26	
Diff.	+2.26	- 1.93	1.009 N.S.	- 2.97	+1.27	1.129 N.S.
Divergent Thinking Tasks Uses						
Pre-test	23.72	8.09		20.19	5.36	
Post-test	26.47	10.79		24.59	9.72	
Diff.	+2.75	+2.70	1.155 N.S.	+4.40	+4.36	2.245 P<.05
Word Association						
Pre-test	77.72	18.40		74.91	18.40	
Post-test	80.13	19.78		78.28	16.38	
Diff.	+2.41	+1.38	.504 N.S.	+3.37	- 2.02	.773 N.S.
Figure Meaning						
Pre-test	12.22	10.25		12.09	6.22	
Post-test	13.34	14.32		11.41	5.97	
Diff.	+1.12	+4.07	.360 N.S.	- 0.68	- 0.25	.444 N.S.

appears that the gain for the instructional treatment is superior to that for the discovery. This difference, however, is not statistically significant.

b) The mean score for the discovery treatment increased more on the Uses Test, +4.40 for Division II and +2.75 for Division I but they are not statistically significant.

c) The scores obtained on the Word Association Test show that the discovery treatment of Division II achieved a greater increment (+3.37) than did instructional treatment of Division I (+2.41). These increments however, are not statistically significant.

d) The Figure Meaning test showed a greater increment for the instructional treatment of Division I (+1.12) than did the discovery treatment of Division II (-0.68), but they are not statistically significant.

Once again the hypotheses are supported but there is no consistent difference in performance. It may be noted that all increments for Division I are positive, and that the scores for Division II are negative for Co-operative Science Test (-2.97) and the Figure Meaning Test (-0.68). They proved not to be statistically significant.

D. Divergent Thinking Test Totals

The need to identify the High and Low scores on the three divergent thinking tasks led to the decision to add the scores for each of the three administrations for each of the Uses, Word Association and Figure Mean tasks for individual task totals. This summation was considered to be justifiable on the basis of additivity of like scores. The summation of the scores for the three different tasks was not done because the assumption of validity of addition could not be made. The data for the totals for each task is summarized below.

TABLE V-4

MEANS AND STANDARD DEVIATIONS FOR DIVERGENT THINKING TASK TOTALS

Test	Division I		Division II	
	$\bar{X}$	s	$\bar{X}$	s
Uses	71.56	22.106	60.13	17.444
Word Association	230.75	55.011	228.88	54.284
Figure Meaning	35.53	30.917	33.00	15.281

Unlike the data from the initial administrations of these tests these data reveal higher means and variances for Division I for all tasks. This is marked in the case of Uses. Consequently the close similarity shown by the Ability Tests and the initial administration of the General Science Test is not maintained for the Divergent Thinking tasks over the period of the experiment. This means that Division I and Division II cannot be deemed to be representative samples drawn from the same population with respect to this dimension or that the treatment applied to the two divisions has significantly affected this dimension. As both the "discovery" and the "instruction" treatment were given to both divisions (but in different order for each) it seems the former (i.e., samples from different populations) is the preferable hypothesis.

In view of this, prudence dictated that comparisons between the mean scores of the divisions at the conclusion of Phase I and Phase II of the investigation cannot be readily justified. Consequently comparisons have to be made in terms of the mean gain for each division.

E. High versus Low Divergents

It was hypothesised that although there might be no significant differences between the achievement of the two groups overall, there might be differences related to the thinking characteristics of subjects within each group. Using the data of the Uses, Word Association and Figure Meanings tasks the High and Low scores in each group were identified and their scores on the Co-operative Science Test compared. These data are set out in Table V-5a.

Note must be made that the High-Low division has been made separately for each of the three divergent thinking tasks. The argument for this and against combination of the scores of the three tasks to identify overall High-Low groups rests upon reservations of the experimenter regarding the assumption of additivity of the scores.

1. Comparison of High and Low Groups

The data is set out in Table V-5a and Table V-5b but it is the latter to which attention must be directed. The former is provided only for completeness of data disclosure.

The High and Low categories were determined by taking the highest eight scores and the lowest eight scores for each of the divergent

TABLE V:5a – COMPARISON OF HIGH-LOW GROUPS

	Division I						Division II					
	S_1		S_2		S_3		S_1		S_2		S_3	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Uses Task												
EX	258	185	279	195	282	232	262	228	305	272	276	239
EX^2	8914	4609	10481	5279	10608	7020	9320	7172	12133	10162	10598	7551
N	8	8	8	8	8	8	8	8	8	8	8	8
$\overline{X}$	32.25	23.13	34.88	24.38	35.25	29.00	32.75	28.50	38.13	34.00	34.50	29.88
S	8.61	6.43	9.69	8.11	9.13	6.04	9.61	9.18	7.94	10.69	11.60	7.17
Word Assoc. Task												
EX	282	222	257	227	299	236	307	166	324	226	337	180
EX^2	10296	6578	9765	6919	11965	7300	12227	39.16	13348	6976	14627	4344
N	8	8	8	8	8	8	8	8	8	8	8	8
$\overline{X}$	35.25	27.75	32.13	28.38	37.38	29.50	38.38	20.75	40.50	28.25	42.13	22.50
S	6.67	7.22	1373	7.73	9.94	6.50	7.47	7.68	6.28	8.60	7.34	6.06
Figure Mean. Task												
EX	270	241	263	259	302	270	270	241	297	304	290	278
EX^2	9530	7929	10157	8705	11992	9618	9636	8251	11329	12054	10810	10372
N	8	8	8	8	8	8	8	8	8	8	8	8
$\overline{X}$	33.75	30.13	32.88	32.38	37.75	33.75	33.75	30.13	37.13	38.00	36.25	34.75
S	7.22	9.14	13.74	6.32	8.60	7.95	8.09	11.13	6.15	7.92	6.10	9.43

Note: E has been used to indicate Σ.

TABLE V:5b – COMPARISON OF HIGH-LOW GROUP MEANS

	Means			Differences		
DIVISION I						
Uses	S_1	S_2	S_3	S_2-S_1	S_3-S_2	S_3-S_1
High	32.25	34.88	35.25	+2.63	+0.37	+3.00
Low	23.13	24.38	29.00	+1.25	+4.62	+5.87
Diff H–L	9.12	10.50	6.25	+1.38	-4.25	-2.87
Word Association						
High	35.25	32.13	37.38	-3.12	+5.25	+2.13
Low	27.75	28.38	29.50	+0.63	+1.12	+1.75
Diff H–L	7.50	3.75	7.88	-3.75	+4.13	+0.38
Figure Meaning						
High	33.75	32.88	37.75	-0.87	+4.87	+4.00
Low	30.13	32.38	33.75	+2.25	+1.37	+3.62
Diff H–L	3.62	0.50	4.00	-3.12	+3.50	+0.38
DIVISION II						
Uses						
High	32.75	38.13	34.50	+5.38	-3.63	+1.75
Low	28.50	34.00	29.88	+5.50	-4.12	+1.38
Diff H–L	4.25	4.13	4.62	-0.12	+0.49	+0.37
Word Association						
High	38.38	40.50	42.13	+2.12	+1.63	+3.75
Low	20.75	28.25	22.50	+7.50	-5.75	+1.75
Diff H–L	17.63	12.25	19.63	-5.38	+7.38	+2.00
Figure Meaning						
High	33.75	37.13	36.25	+3.38	-0.88	+2.50
Low	30.13	38.00	34.75	+7.87	-3.25	+4.62
Diff H–L	3.62	-0.87	1.50	-4.49	+2.37	-2.12

thinking tasks and using the three Science Test scores of those individuals for analysis. The S_1, S_2 and S_3 symbols refer to the three Science Test scores. The symbols H and L refer to the high and low groups in each case.

As the High-Low categories were determined separately for the Uses, Word Association and Figure Meaning tasks the analyses for each must be considered separately but before doing so some general remarks are appropriate.

a) Examination of the values given in the Diff. H-L rows in the S_1, S_2 and S_3 columns reveals that in all cases except Figure Meaning, column S_2, the mean score for the H category is greater than that of the L category. The difference in this one exceptional case is not statistically significant.

b) This data tends to establish and/or confirm that irrespective of the treatment and irrespective of the type of task used as the criterion measure to constitute the H and L classes, the H class scores higher on the General Science Test. This is to say that the tasks identify achievement factors.

c) Table V-5c further supports the statement that the H and L groups are separated according to task. That is, those who score high on the divergent thinking tasks also score higher on both the verbal and non-verbal ability tests.

TABLE V-5c

MEAN VERBAL AND NON-VERBAL ABILITY SCORES
OF THE HIGH-LOW GROUPS

	Verbal		Non-Verbal	
	High	Low	High	Low
Division I				
Uses	53.13	46.13	50.63	44.63
Wd. Assn.	63.13	41.75	47.38	47.13
Fig. Mean.	62.25	45.88	49.88	49.13
Division II				
Uses	55.63	45.88	64.25	56.00
Wd. Assn.	49.13	42.88	39.63	39.38
Fig. Mean.	55.38	50.38	54.38	45.50

2. H-L Categories (Uses Task)

Data in column S_2-S_1 for Division I and Division II High and Low on the Uses Task indicate that:

a) Division I (Discovery Treatment). H-group improved more than the L-group by +1.38. The difference, however, is not statistically significant.

b) In the case of Division II the S_2-S_1 figures for H and L groups are practically identical, 5.38 and 5.50.

From this it appears that the discovery approach is slightly more beneficial to the H-group than it is to the L-group.

Reference to column S_3-S_2 reinforces this view. During this stage Division I received the instructional treatment and the H-group scores show virtually no improvement (+0.37), whereas the L-group scores increased more (+4.62), but not enough to be statistically significant.

In Division II the Phase I increase which was nearly equal for both H and L, is almost completely offset and the mean scores revert very close to the initial level.

From this data it can be concluded that there are reasons for assuming that:

a) High scorers on the Uses task benefit more from the discovery treatment than do Low scorers.

b) If the two methods are used consecutively, the transition from the discovery treatment to the instructional treatment is more detrimental than is the transition from the instructional to discovery.

3. H-L Categories (Word Association Task)

Data in column S_2-S_1 for Division I indicates a decrement for the H-group (-3.12) and a very small increment (+0.63) for the L-group. Neither figure is statistically significant.

Phase II (S_3-S_2) for Division I shows a much larger increment for the H-group (+5.25) than the L-group (+1.12). Although this figure is not statistically significant, it indicates that the H-group performed better as a result of the experimental approach.

The results for Division II in the column S_2-S_1 show a larger increment for the L-group (+7.50) than the H-group (+2.12). This figure is statistically significant and indicates a better gain on the instructional program than on the experimental approach. This gain is almost totally negated during Phase II (S_3-S_2). This could be explained by assuming a frustration in the transition from the instructional to the experimental treatment on the part of the L-group.

From this data it can be concluded that there are reasons for assuming that:

a) Low scorers on the Word Association task benefit more from the instructional treatment than do the high scorers.

b) If the methods are used consecutively, the transition from the instructional to the discovery treatment is detrimental to the achievement of the low scoring group and beneficial to the high scoring group.

4. H-L Categories (Figure Meaning Task)

Reference to the column S_2-S_1 for Division I (experimental) for the H-group shows a low decrement (-0.87). This increases to a much larger increment (+4.87) upon completing Phase II (traditional).

In the same column for Division II the same effect is apparent. There is a high increment (+3.38) after Phase I (traditional) relative to the low decrement (-0.88) after Phase II (experimental).

The low scorers of Division I showed increments for both phases but the low group for Division II strongly reinforced the trend shown by the high scorers of both divisions.

From this data it can be concluded that there are reasons for assuming that:

a) The high scorers show better achievement after the instructional treatment than after the discovery treatment.

b) These findings tend to be supported by the low scorers.

5. Summary

In consideration of the H-L groups, the instructional treatment seems to lead to greater improvement on the Co-operative Science Test and the Uses task while the discovery treatment seems to favour improvement on the Word Association task. This statement is based upon the increments of total groups as indicators of a trend rather than the statistical significance of the figures.

Analysis of the means of the high and low scorers on the divergent thinking tasks indicates that irrespective of the treatment and irrespective of the type of task used as the criterion measure to constitute the high and low groups, the high group scores higher on the General Science Test. This is also true of the various tasks with relation to the scores obtained on both the verbal and non-verbal ability tests: the high groups score higher on the ability tests. These observations indicate that the divergent thinking tasks may have some predictive value for determining high science achievers.

There are indications from both the Uses task and the Figure Meaning task that there is a detrimental effect when the methods of the science learning situation are changed from experimental to instructional or *vice versa*.

There have been no statistically significant increments or decrements found which indicate a consistent bias in this study.

CHAPTER VI

CONCLUSIONS

A. On the Results of the Study

It may be seen from Phase I of the experiment (Table V-2) that the instructional method appears to be more effective in terms of the learning of science facts as based upon the test instrument. In Phase II there appeared to be no statistically significant difference between the methods of presentation in terms of the learning of science facts.

It was pointed out earlier that the subjects were acquainted with the discovery approach during their previous two years of schooling in science. It therefore would appear that the traditional or instructional approach would be a major change for them even though it was not entirely new. It may be that a change in method brings about an increased motivational factor (which was not measured) and would account for an increase in learning. It may be argued also that the instructional approach includes rote learning of facts which are more easily translated into objective answers such as those required in the multiple choice instrument used in this study.

The combined effects of the suggested influences on the subjects could account for the higher increment for the instructional treatment. However, the results were not consistent.

No method was used for evaluating either the conceptual or peripheral learnings of the discovery treatment because of the lack of a proper test instrument. These are important and often ignored areas of learning which deserve further research.

B. Biases

The sampling frame of this study included all the grade seven students in an elementary school during one academic year. It is therefore the total population of one attendance area in the school district, and cannot be construed to represent the whole school district. This is based upon the fact that the various attendance areas of school districts are not homogeneous with respect to cultural and socio-economic factors.

The school district in question is generally rated as a high socio-economic, professionally oriented area. The attendance area utilized is in the middle range of the total for the school district.

There was evidence of instrument decay inasmuch as some pupils appeared to get tired or bored during the testing programs. This applied mainly to the I.Q. tests and the divergent thinking tests.

Historical bias includes the changes of the test group with respect to experience both within and without the experimental framework. An important consideration regarding this age group is their maturation during the year. The mortality rate was zero as all subjects were constant throughout the period of research.

Instrument bias is evident in that all testing was verbally oriented. No scope was given for areas other than the written response. The science knowledge test required objective answers on a multiple choice form. This misconstrues the nature of science with the presupposition that there is only one correct answer to each question. Although some of the questions are designed to test "conceptual knowledge," a subjective approach would be a better method of evaluation. The solving of a problem in a laboratory situation suggests itself here.

The restrictions of time and finances precluded the development or procurement of the results in other forms for this study. The science tests were suggested as suitable and found to be available in the quantities required.

The temporal bias of Phase I versus Phase II of the study is in favour of the former and would further account for the significance of the results of the traditional method in that instance above. Phase II was interrupted by the Christmas holidays and the excitement and preparations for the festive season. This might account for a considerable motivational flux on the part of the participants.

C. Observations

A comparison of the two methods of science learning has produced no well-defined prejudice supporting either approach. There are, however, considerations to be made. The non-kit method with demonstrations is cheaper to administer, easier to handle in class, easier to evaluate in terms of testable results, and more efficient in that more "facts" can be covered in a given period of time. These observations sustain the assumption that the gaining of factual knowledge is a criterion for success in science.

The kit method promotes motivation and the spirit of inquiry and opposes the rigidity of facts to the versatility of concepts. The learning of scientific concepts is likely to have a more longitudinal effect than the learning of facts. The peripheral learning in a laboratory situation is very difficult to assess but there is definitely more than just science learned, especially on the social level.

The enjoyment of the experimentally oriented kits by the pupils is evident in their unsolicited responses in favour of them and in opposition to the "book learning" method. Regarding the creative-problem solving dimension of the kit approach, Cropley referred to an unpublished paper by J. R. Suchman, and stated:

> Another useful finding on this point was made by Suchman who taught two groups of science students in the fifth and sixth grades for a twenty-four week period. The first group (the experimental group) was taught by the method of 'inquiry training' which means that they were taught by being given problems (in physics) to solve for themselves. The role of the teacher was merely to answer 'yes' or 'no' to the students' queries and not to give them ready-made answers. The second group (the control group) was taught by conventional methods, which involved provision of facts by the teacher and learning of these by the students. At the end of twenty-four weeks there were no differences between groups in understanding of physics, but the experimental group was markedly more inclined to be curious and inquiring. In fact, Suchman concluded that the training had a strong effect on question-asking fluency of the experimental group. They were more highly motivated to learn than were the controls, and they seemed to enjoy the learning process, two highly desireable end results in the eyes of most teachers, which support the notion that creative learning is intrinsically motivated.[1]

With regard to further research, it has already been suggested that the peripheral learning of pupils is an area of tremendous importance

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[1]A. J. Cropley, Creativity (London, Eng.: Longmans, Green, and Co. Ltd., 1967), pp. 84-85.

and needs investigation. A second study which has been alluded to is the longitudinal effects of the divergent approach in learning science, and of course, the attendant inquiry training involved with it. With proper financing and time factors, this researcher's study should be replicated, using a larger battery of tests of different natures and greater sensitivity than those used to gain a better insight into the relationships involved.

APPENDICES

APPENDIX A

TOTAL DATA TABLES

TABLE A:1 TOTAL DATA : DIVISION I

S	Co-op Science Test					Uses Test				Word Assoc. Test				Figure Meaning			
	I	II	III	V	N-V	I	II	III	T	I	II	III	T	I	II	III	T
1	27	31	31	58	62	27	49	48	124	87	80	90	257	31	42	72	145
2	46	45	50	54	59	22	10	25	57	61	80	88	229	0	0	3	3
3	27	19	28	54	55	21	33	40	94	83	97	102	282	5	14	45	64
4	17	23	21	47	53	39	32	25	96	63	72	66	201	10	19	16	45
5	30	27	28	36	49	19	22	18	59	50	56	66	172	5	2	3	10
6	48	49	54	74	53	30	32	28	90	102	104	128	334	10	16	24	50
7	38	46	41	68	48	26	31	30	87	104	108	94	306	15	27	19	61
8	19	16	26	41	27	0	15	29	44	68	66	85	219	8	4	9	21
9	30	32	31	52	46	20	19	20	59	80	74	84	238	6	5	1	12
10	26	32	27	44	53	23	31	22	76	79	86	84	249	15	14	12	41
11	19	28	21	40	41	9	15	9	33	48	59	48	155	2	7	5	14
12	27	21	32	41	30	22	26	26	72	74	61	66	201	10	13	8	31
13	38	23	43	71	51	17	17	36	70	119	104	96	319	11	8	14	33
14	31	36	34	38	40	36	20	30	86	50	60	62	172	1	0	2	3
15	20	33	27	38	56	14	23	14	51	52	52	52	156	1	7	10	18
16	25	10	24	49	37	9	11	15	35	66	58	62	186	7	6	8	21
17	25	18	26	58	44	32	19	30	81	92	76	80	248	20	23	25	68
18	18	34	33	54	46	15	18	15	48	70	71	90	231	8	1	4	13
19	39	29	42	37	54	17	13	13	43	26	40	28	94	0	4	1	5
20	28	42	29	59	50	8	33	27	68	84	82	88	254	3	11	7	21
21	39	48	43	70	41	21	24	56	101	111	120	108	339	34	25	25	84
22	24	27	31	50	45	13	23	21	57	59	75	77	211	3	10	3	16
23	26	31	32	60	42	21	20	27	68	64	80	72	216	1	2	6	9
24	21	28	25	41	50	24	21	26	71	60	56	65	181	2	5	3	10
25	26	21	23	50	38	34	22	23	79	71	90	104	265	18	16	13	47
26	33	13	41	59	46	13	24	40	77	91	95	98	284	27	36	29	92
27	33	38	26	59	47	27	17	13	57	91	109	95	295	5	4	2	11
28	33	39	38	57	50	33	33	44	110	74	76	66	216	23	25	12	60
29	21	18	28	60	51	14	23	19	56	72	77	88	237	4	16	14	34
30	28	35	32	50	49	21	28	19	68	78	86	94	258	12	15	16	43
31	15	25	33	42	52	17	23	20	60	66	67	58	191	1	3	3	7
32	37	36	35	55	50	40	34	39	113	38	70	80	188	21	11	13	45
E	914	953	1035	1666	1515	684	759	847	2290	2333	2487	2564	7384	319	391	427	1137
E^2	28198	31573	35489	90144	73527	17366	20095	26143	179516	183375	204121	217960	1800696	5889	8139	12257	70987
$\overline{X}$	28.56	29.78	32.34	52.06	47.34	21.38	23.72	26.47	71.56	72.91	77.72	80.13	230.75	9.97	12.22	13.34	35.53
s^2	65.368	99.740	62.917	106.502	56.295	85.803	65.400	116.381	488.675	415.141	338.597	391.248	3026.210	84.658	105.042	204.976	955.861
s	8.085	9.987	7.932	10.320	7.503	9.263	8.087	10.788	22.106	20.375	18.401	19.780	55.011	9.201	10.249	14.317	30.917

Appendix A_2

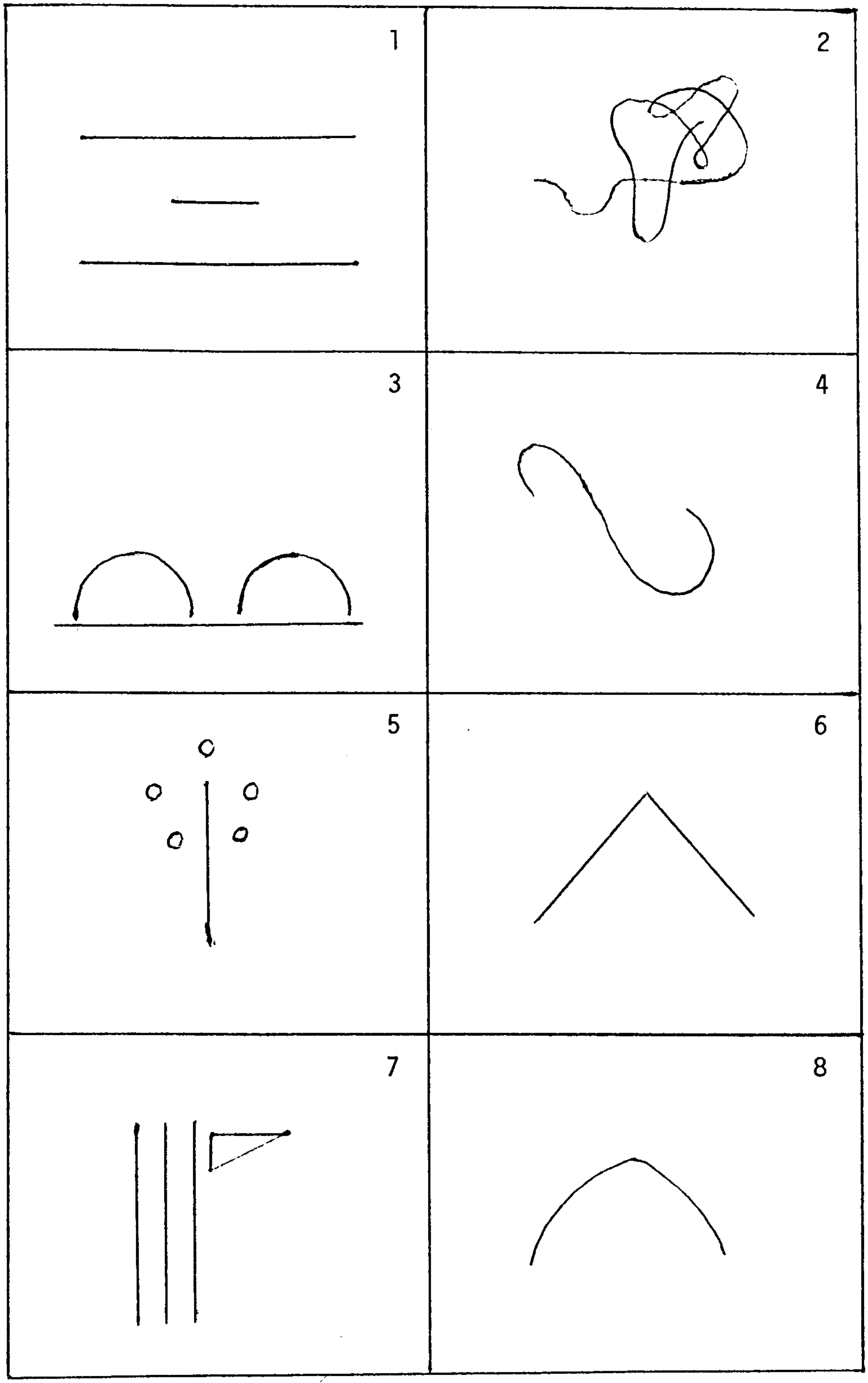
TABLE A:2 TOTAL DATA : DIVISION II

S	Co-op Science Test					Uses Test				Word Assoc. Test				Figure Meaning			
	I	II	III	V	N-V	I	II	III	T	I	II	III	T	I	II	III	T
1	27	31	27	45	52	23	22	39	84	60	69	86	215	2	5	11	18
2	20	27	22	45	53	10	22	24	56	46	75	64	185	11	7	8	26
3	42	45	50	62	58	13	26	26	65	93	111	99	303	10	17	6	33
4	11	32	25	32	39	14	21	19	54	48	54	44	146	4	5	5	14
5	34	43	34	62	46	14	13	12	39	78	78	74	230	12	14	13	39
6	32	39	34	59	54	11	17	18	46	97	89	92	278	14	8	11	33
7	33	39	31	48	46	18	18	19	55	78	78	68	224	7	16	12	35
8	35	12	29	57	56	14	17	25	56	64	80	82	226	8	10	7	25
9	50	53	51	55	45	24	17	31	72	86	80	95	261	11	3	8	22
10	18	29	36	49	58	26	24	32	82	85	74	93	252	10	14	16	40
11	34	38	33	56	52	0	17	13	30	90	86	78	254	21	16	8	45
12	41	47	48	69	60	33	22	27	82	84	79	72	235	0	7	6	13
13	43	34	43	67	60	24	18	33	75	101	76	98	275	10	25	16	51
14	29	29	12	39	47	20	22	30	72	98	77	72	247	8	11	13	32
15	21	23	17	31	23	12	18	17	47	51	68	52	171	11	7	6	24
16	28	32	25	44	41	0	19	31	50	45	35	56	136	14	9	8	31
17	17	30	15	28	19	20	20	17	57	51	58	66	175	4	13	9	26
18	47	50	46	68	60	25	14	27	66	82	68	82	232	4	19	13	36
19	39	42	43	47	56	16	15	34	65	70	64	70	204	16	16	11	43
20	22	40	26	54	54	17	24	33	74	90	79	92	261	0	22	15	37
21	36	45	36	50	49	13	26	52	91	57	55	60	172	7	7	13	27
22	25	29	23	43	47	17	17	20	54	60	62	65	187	15	17	17	49
23	31	40	34	53	46	7	19	20	46	83	75	82	240	1	6	11	18
24	21	29	24	42	23	0	13	15	28	68	66	81	215	8	7	3	18
25	33	33	34	44	57	6	29	33	68	99	81	92	272	5	12	6	23
26	43	47	39	51	53	0	19	19	38	74	87	87	248	35	21	28	84
27	21	24	20	48	45	20	23	11	54	29	26	58	113	10	7	11	28
28	27	39	35	63	42	14	23	16	53	114	104	104	322	6	8	7	21
29	34	35	39	68	63	18	24	26	68	82	99	97	278	14	29	32	75
30	12	13	20	39	46	21	10	10	41	31	66	50	147	10	8	12	30
31	46	50	48	72	59	24	39	43	106	135	117	104	356	6	13	15	34
32	50	49	54	79	55	17	18	15	50	93	81	90	264	10	8	8	26
E	1002	1148	1053	1669	1564	491	646	787	1924	2422	2397	2505	7324	304	387	365	1056
E^2	34934	44388	38515	91861	80100	9631	13960	22379	125418	200910	190383	204679	1770578	4282	5919	5305	42320
$\bar{X}$	31.31	35.88	32.91	52.16	48.88	15.34	20.19	24.59	60.13	75.69	74.91	78.28	228.88	9.50	12.09	11.41	33.00
s^2	111.218	100.100	120.780	150.381	114.362	65.545	28.719	94.498	304.293	549.856	338.523	268.272	2946.753	43.560	38.713	35.677	233.509
s	10.546	10.005	10.990	12.263	10.694	8.096	5.359	9.721	17.444	23.449	18.399	16.379	54.284	6.600	6.222	5.973	15.281

APPENDIX B

DIVERGENT THINKING TASKS

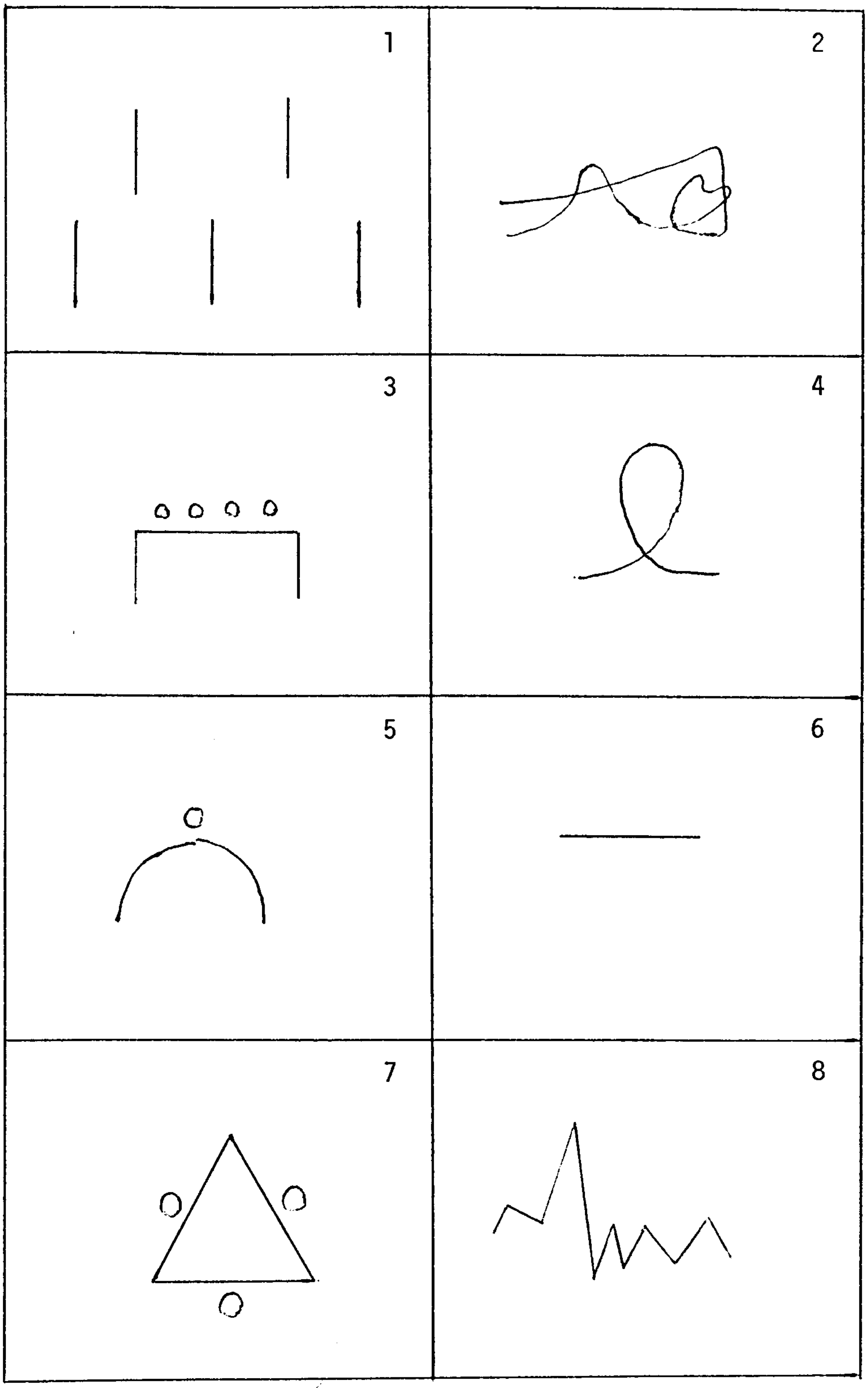
Appendix B1



Pattern Meaning Tasks Figural Meaning Tasks

(Refer to page 63 of text)

Appendix B2



Pattern Meaning Tasks Figural Meaning Tasks

(Refer to page 63 of text)

Appendix B3

WORD ASSOCIATION

Listed below are twenty-five words that have more than one meaning. In the space following each word, you should write down as many of the meanings as you can. The meanings need not be written out in full; writing down one word will usually do. For example:

BARK tree, dog, seal, boat

These four words bring to mind three different meanings for the word BARK: the outer covering of a tree; a certain noise made by some animals like dogs and seals; and a kind of boat. Notice that the meanings were not written out in full; only some words to remind us of these meanings were given. This is all you have to do.

Your score will depend both on the number of different words you write (in the example above this was four) and on the number of different meanings the words remind us of (in the example above this was three). So if you had time to write only two words for BARK, you would choose tree and dog, say, rather than dog and seal because the former words stand for two meanings but the latter words stand for one meaning.

When you are sure of what you are to do, you may begin.

1. ARM
2. BIT
3. BOLT
4. CAP
5. COIL
6. DUCK
7. FAIR
8. FAST
9. FILE
10. GRAVE
11. HOST
12. LEAF
13. MORTAR
14. PINK
15. PITCH
16. PLANE
17. POKE
18. POLICY
19. PORT
20. PUNCH
21. RAKE
22. SACK
23. STRAND
24. TACK
25. TENDER

Appendix B4

USES

Listed below are five objects. Your task is to write down as many different uses as you can for each object. Be sure to write down some uses for each object. Write down anything that comes to mind, no matter how strange it may seem.

Uses Test 1	Uses Test 2
1. BRICKS	1. ROCKS
2. PENCILS	2. TIN CANS
3. PAPER CLIPS	3. NEWSPAPER
4. TOOTHPICKS	4. CHOPSTICKS
5. SHEET OF PAPER	5. CRAYONS

APPENDIX C

ASTRONOMY NOTES

ASTRONOMY

Appendix C1

(Used by permission of E. Adams)

Part One

WHAT IS ASTRONOMY?

Astronomy is the scientific study of the heaven with its many constellations. It can also be considered to be the study of the universe.

THE UNIVERSE.

The universe, to the best of our present day knowledge consists of a vast space of unknown limits in which are contained untold numbers of Galaxies, billions of Stars, Planets, Asteroids, Meteors, and other heavenly bodies (objects) of different sizes, shapes, and characteristics.

No one knows exactly what shape or size the Universe has. It is said to be expanding constantly. Distances in space are too far to be measured in miles. They are measured in "Light Years". One light year is the distance travelled by light in 365 days.

N.B. Our Sun is smaller than the average star. It is completely gaseous (i.e. filled with gases) and rotates irregularly.

The two major portions of the Sun are

(a) its atmosphere, which is composed of 3 layers

(b) the nucleus, or Sun proper

The effective temperature of the Sun is approximately 10,000° F.

THE UNIVERSE.

Light travels through space at the rate of 186,000 miles per second. Therefore, one Light Year = 6 trillion miles, or 6 million million miles.

Among the celestial bodies of the Universe are, The Milky Way, and many Galaxies.

What is the Universe, and what does it contain?

The Earth, the Moon, the Sun, the rest of the Solar System, all the Stars, and other heavenly bodies make up what we call the Universe. In other words, the Universe includes everything that exists. Our Sun is the star nearest the Earth. All of the other stars, or suns, are so far away that they look like pin-points of light even through the most powerful telescopes. Perhaps some of these distant suns have their own solar systems. If so, there may be other planets in the Universe that have living things.

A Light Year is the distance that light travels in one year. It is not a length of time. Scientists have discovered that the speed of light is about 186,000 miles per second. To find out how many miles there are in a light year, you must first figure out how many seconds there are in a year. Then you multiply the number of seconds in a year by the speed of light. If you do this you will find that light travels nearly 6,000,000,000,000 miles a year. So a light year is about 6 trillion miles.

Except for the Sun, the nearest star is Proxima Centauri, which is about 4¼ light years away. A little over 8½ light years away is Sirius, the brightest star in the sky. See star charts.

When you look into the sky on a clear, dark night, perhaps you can see as many as 3,000 stars with your naked eyes. Though you see stars all over the sky, they do not seem to be evenly scattered. In some parts of the sky, there appear to be very few stars, but in another part they look so close together that they stretch across the sky in a wide band of light. We call this Band of Light the "Milky Way". Powerful telescopes show that the Milky Way contains millions of stars. These stars are not crowded close together as they seem to be. When a radio telescope is turned towards the centre of the Milky Way, it makes a loud hum, or hiss. The many stars each send back their own radio signals. Actually, they are very far apart. The Milky Way has a diameter of about 100,000 light years.

Astronomers believe that the Sun, the Solar System, and all of the Stars which we can see at night belong to a huge cluster of stars called a Galaxy. Our Galaxy is thought to contain about 100 billion stars. It is about 100,000 light years in diameter and from 5,000 to 10,000 light years thick.

Nebulae are glowing masses of clouds of gases and dust beyond our Galaxy in space. Astronomers estimate that these nebulae, or cloud-like formations of stars are about 2 million light years away.

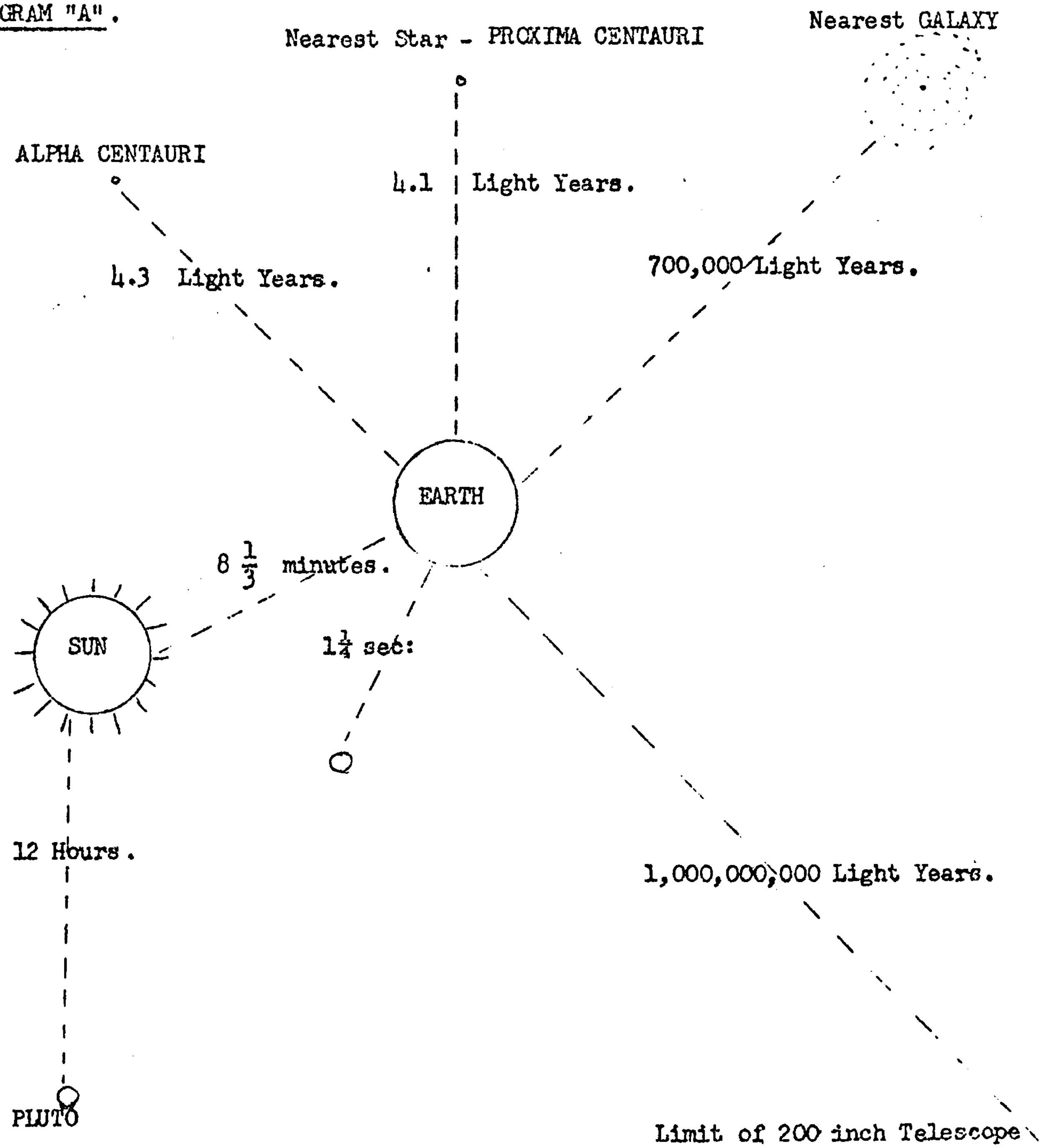
Light travels at the rate of 186,000 miles per second.

One light year = 186,000 miles x 60 sec. x 60 min. x 24 hr. x 365 days.

Light travels three-quarters of the way to the Moon in one second and from the Sun to the Earth in about eight minutes.

The distance from Earth to Proxima Centauri is about 4.1 light years. Some stars are millions of light years away. There are only 55 known stars within 16 light years of Earth. Giant telescopes can catch light that left stars more than 2 billion years ago.

DIAGRAM "A".



The approximate distances from the Earth in light years of some of the fixed stars.

The Sun	8 minutes
Proxima Centauri	4.27 light years
Sirius	8.7 " "
Vega	26 " "
Polaris (North Star)	40 " "
Ursa Major (Big Dipper Constellation)	70.8 " "
Betelgeuse	192 " "
Rigel	543 " "

The sizes of the Stars.

Our Sun is small compared with some of the largest stars. Arcturus has a diameter of 23 million miles. Its volume is 25,000 times as great as that of the Sun. Betelgeuse has a diameter of 240 million miles, and a volume of 27 million times greater than our Sun.

QUESTIONS: Self-testing exercise.

1. What do we mean by the Universe?
2. (a) What is a light year?
   (b) About how many miles is it?
   (c) Why do astronomers use light years?
3. About how many miles from the earth is the nearest star outside the solar system? About how many light years?
4. (a) What is the Milky Way?
   (b) Why does it look very bright?
5. (a) What is meant by a Galaxy?
   (b) What is the shape of our Galaxy?
6. (a) What do astronomers mean by Nebulae?
   (b) What are some nebulae believed to be?
7. (a) What are radio telescopes?
   (b) What use are they to the astronomer?
8. List four Big Ideas which you have got from studying diagram A.

Part Two

HOW CAN YOU LEARN TO KNOW THE STARS?

For hundreds of years people have enjoyed looking up into the sky on clear nights and finding the stars that they know. Many of the brighter stars have been well known since ancient times. Groups of stars which appear to form a kind of picture to the observer are called Constellations. The stars in a Constellation appear fairly close together, but they are many light years apart.

Because of the Earth's rotation on its axis, many stars appear to rise and set just as the Sun and Moon do. But if you look at the northern sky at night, you can find one Star that seems to stand still. This is the North Star, or Polaris. It appears to stand still because it is almost directly above the North Pole.

Other stars in the northern sky seem to move around the North Star in circles without ever setting.

Several well-known Constellations are among the stars that circle around the North Star.

You should become familiar with the

Big Dipper (Ursa Major) or the Big Bear.

Little Dipper (Ursa Minor) or the Little Bear.

The two front stars in the bowl of the Big Dipper are called the Pointers. They will help you find the North Star, the Little Dipper and other Constellations - Cassiopeia, Cephus, and Draco, the dragon, as well as other Constellations in the norther sky.

QUESTIONS: Self-testing exercise.

1. What is meant by a Constellation?

2. Why do many stars appear to rise and set?

3. Explain why the northern Constellations seem to circle the North Star.

4. Show that you understand what the following words mean.

Solar System,	Satellite,	Gravitation,
Universe,	Light Year,	Galaxy
	Nebulae,	Constellations

5. (a) What are meteors?
   (b) What are meteorites?

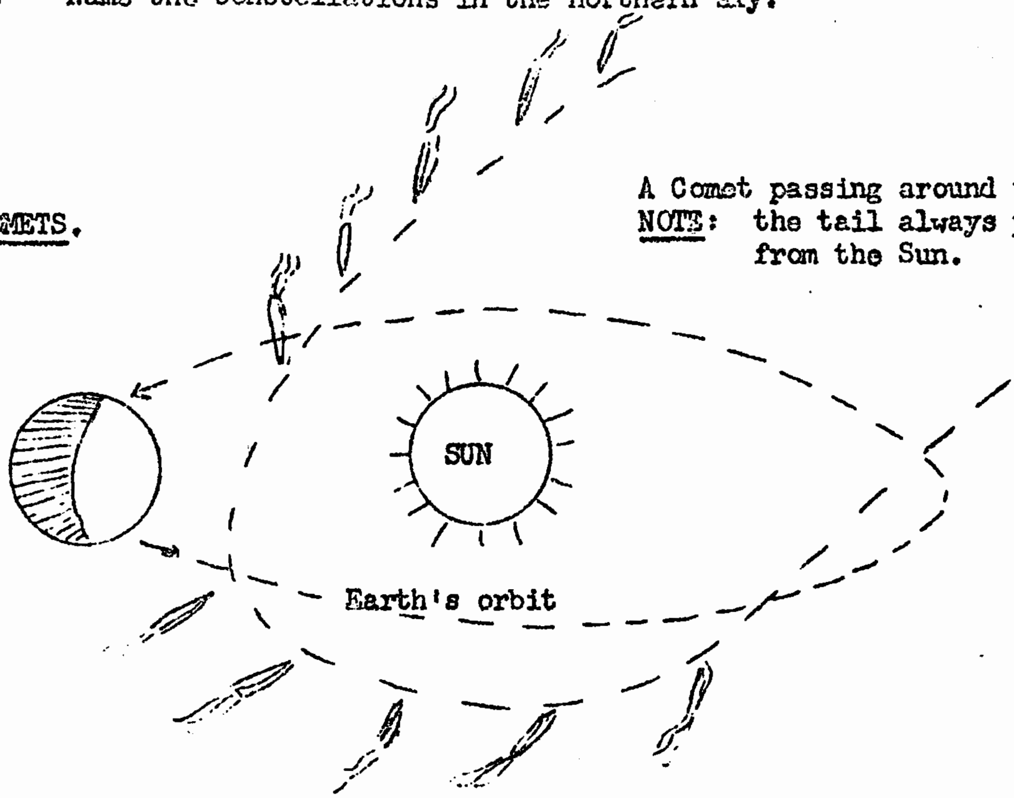
6. Of what is the Milky Way composed?

7. (a) How can you use the Big Dipper to find the North Star?
   (b) How can you find the Little Dipper after finding the North Star?

8. Name the constellations in the northern sky.

COMETS.

A Comet passing around the Sun.
NOTE: the tail always points away from the Sun.

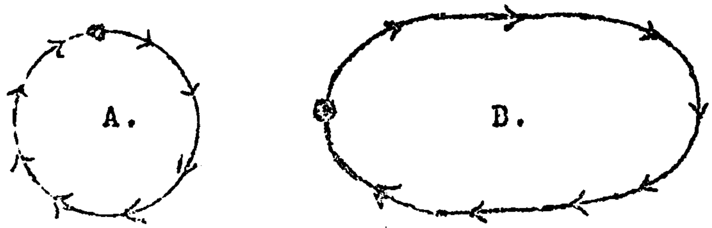


Comets create a great deal of interest whenever they appear. Many early superstitious people believed that the passing of a comet indicated (fore-told) the coming of evil times, and that they were put in the heavens to warn us.

The telescope, however, reveals that comets are bodies which shine by reflected sunlight. Most comets which we see belong to the Solar System and revolve around the Sun in orbits. Since comets are usually small, we can only see them with the unaided eye when their orbits come near to the Earth.

One of the largest and most peculiar of Comets is Halley's Comet. It has a very elliptical shaped orbit. It revolves around the Sun once in every 76 years. The last time it appeared was in 1910. You may see it for yourself when it returns in 1986. The streamer of light behind the Comet is called the tail of the Comet.

ORBITS:



A = Circular Orbit.

B = Eliptical Orbit.

FRAGMENTS FROM SPACE.

Comets are rarely seen, but on any clear night, you may see "shooting stars" or Meteors. Meteors are not stars. They are small pieces of rock which are travelling through space at a great speed. As they pass through the earth's atmosphere their speed and the friction of the Earth's atmosphere cause them to become very hot and incandescent (or glowing). This causes the streak of light which is commonly called a "shooting star".

When Meteors do not completely burn up in space from friction, and they drop to the Earth, such stones are called Meteorites. Many museums in Europe, Canada and the U.S. have Meteorites on exhibition.

QUESTIONS: Self-testing exercise.

1. What is meant when we say that a star is forty-one light-years distant?

2. At one time it was thought that disaster would follow if the Earth moved through a Comet's tail. How do you know that this is not true today?

3. (a) Do stars ever fall?

   (b) What causes "shooting stars"?

4. Light travels at the rate of 186,000 miles per second. How far will it travel in a year?

5. What do you know about Halley's Comet?

Appendix C8

Part Three

THE SOLAR SYSTEM.

One star, which is our Sun, nine planets and their thirty-one satellites, thousands of asteroids, billions of comets; these are the basic elements of the Solar System. The Sun controls the Solar System (see Solar System diagram), and the movements of the other planets and their bodies.

The nine planets can be divided into two groups according to size and density. First come the earthly, or innermost planets - four small solid ones - including the Earth.

Then come the four outer giants composed mainly of lighter elements.

The farther each planet is from the Sun the slower it travels, and the longer its year.

All of the planets travel in a counter clock-wise direction, and are kept in orbit by two opposing forces: Centrifugal Force which makes them want to fly off in a straight line, and the Sun's gravity which pulls them into a curved path. Besides the circular movement around the Sun, each planet also spins on its own orbit. Of the thirty-one satellites distributed in the Solar System, most circle their planets in the same direction as the planet spins.

Planetoids, or Asteroids are mostly located in the broad belt between Mars and Jupiter. They havetheir own orbits around the Sun. They are believed to be pieces of a big planet which once moved around the Sun.

QUESTIONS: Self-testing exercise.

1. In your science folders (note books) draw a neat, good diagram showing all of the planets in the Solar System.

2. Explain how the nine planets in the Solar System are kept in their correct orbits around the Sun.

3. What are asteroids? What is their origin, according to some astronomers?

Appendix C9

THE SOLAR SYSTEM.

What is the Solar System?

What is the Sun?

The Sun and all of the bodies which revolve around it is called the Solar System. The bodies which revolve around the sun are the planets together with their satellites, the moons, the planetoids and comets.

Though the Sun is 93 million miles from the Earth, it is our main source of heat, light and most other forms of energy. Without the sun, there would be no green plants. The Sun is a star around which the earth and other planets are constantly moving.

SUN.

Because the Sun is the nearest of all stars, it appears larger and brighter than others. Actually the Sun is only a medium sized star. Yet its diameteris 864,440 miles, and over 100 times greater than the diameter of the Earth. The sun's temperature is about 10,000°F. It is filled with hot gases, mainly hydrogen, helium. Iron, calcium and magnesium are metals found in liquid state. Most of the Sun's energy is produced when hydrogen changes into helium. This process of releasing atomic energy has been going on for over two billion years.

Astronomers have discovered streams of gases rising and spreading out from the Sun. These swirling masses are known as sun spots because through the telescope they appear as dark spots.

So far astronomers tell us that planets are all made of about the same materials as the Earth. Planets reflect light from the Sun. The Solar System consists of nine planets moving around the Sun in an orbit. Each planet is called a satellite of the Sun. (See diagram of Solar System). All except three of the known planets have one or more moons, or satellites. Each satellite revolves in an orbit about its planet much as the planets revolve in their orbits around the Sun.

Our Solar System is within the Milky Way.

Now let us take a closer look and then make a real study of each of the nine planets in the Solar System.

Mercury: The nearest planet to the Sun. Because of this it is very difficult to observe. It revolves around the Sun in a quarter of the time which the Earth takes. It completes one revolution of the Sun in about three months. Imagine a Mercury year only three months long!

Appendix C10

Because of its great speed, the planet was named Mercury after the swift wing-footed messenger of the gods. Its orbit is not quite circular, but elliptical.

Venus: The brightest of the planets was named after the Roman goddess of beauty. Venus, like our Earth, possesses an atmosphere which is very cloudy. Venus is sometimes called Earth's twin sister. Very hot temperatures are found on Venus.

Earth: The third planet in the Solar System rotates around the Sun once in 365 days.

Mars: An intriguing neighbour which may have life. It was named after the Roman God of War. It is reddish in colour, and is the only planet whose surface can be plainly seen from the Earth. Many of its features can clearly be identified. It has a diameter of 4,130 miles, half that of the Earth. Its gravity is two-fifths that of the Earth's. It contains an atmosphere only one-tenth as dense as ours. It contains at least twice as much CO_2 but no detectable O_2. Clouds sail across the surface, and winds sweep across the arid land. Temperature varies from 70° or 80° to as low as 150°F below zero. Some H_2O collects as frost at its poles. Experts believe that there may be traces of primitive life forms like lichens or mosses.

See chart on Solar System for information on the other planets.

N.B. The science of Astronomy has enlightened the world, and has reduced superstitions concerning the stars. Educated people no longer believe in "lucky" or "unlucky" stars. They now know that the positions of stars in the sky cannot affect their life for good or for bad. When comets appear in the sky they awaken our interest, and not our fears.

Appendix C11

IMPORTANT FACTS ABOUT THE SOLAR SYSTEM.

Bodies.	Average Distance from Sun in millions of miles.	Diameter in miles.	Speed in miles per second.	Revolution around Sun.	Satellites
Sun		864,400			
Mercury	36	3,100	29.7	88 days	-
Venus	67	7,700	21.7	225 days	-
Earth	93	8,000	18.5	365¼ days	1
Mars	142	4,200	15.0	687 days	2
Jupiter	484	86,700	8.1	11 $\frac{7}{8}$ years	12
Saturn	887	71,600	6.0	29½ years	9
Uranus	1,785	32,000	4.2	84 years	5
Neptune	2,797	31,000	3.4	165 years	2
Pluto	3,675	3,600	2.7	248 years	-

QUESTIONS - based on the above table.

1. Study the table on this page. State four ways in which planets are different from each other.

2. Scientists are fairly sure that no animal life exists on any other planet except the Earth. Why?

3. In about what year do you think H alley's Comet is expected to return. Give reasons for your answer.

4. If you see a bright flash in the night sky that quickly disappears; what have you probably seen? A comet, or a meteor? Explain.

5. What arguments are there for or against the theory that Mars is inhabited.

6. Project: Make a star chart of your own. Mark at least twenty of the largest and brightest stars. Try to name the stars you have indicated on your chart.

7. Look up and read the biographies, or life stories, of at least four of the following astronomers: Galileo, Copernicus, La Place, Sir William Herschell, John Kepler.
Give an account of these life stories to the class.

Appendix C12

SOME IMPORTANT FACTS ABOUT EARTH'S NEAREST NEIGHBOUR - THE MOON.

The Moon is not really a planet in the Solar System. In fact, it is a natural satellite of our Earth.

1. The moon is about a quarter the size of the Earth.

2. Its gravity is one-sixth that of the Earth.

3. It lacks any atmosphere.

4. No sounds can be heard on the Moon because of the lack of an atmosphere.

5. The surfaceof the Moon is extremely rugged with many pocked-marked craters probably caused by long constant volcanic action.

6. The range of temperature is very great; 215° F in the day, and 240° F below zero at night.

7. It completes one orbit around the Earth in approximately 27½ days.

8. It has a diameter of about 2,160 miles.

9. It is located about 239,000 miles away from the Earth.

10. The gravitational pull of the Moon on the Earth's oceans causes the changes in tides as we know them.

Tides and how they are caused.

If you visit the sea coast, you must be impressed by the rise and fall of the water on the shore. The rise of the tide is called the flow; the fall of the tide is called the ebb. This same rise and fall exists in the open ocean.

What are tides?

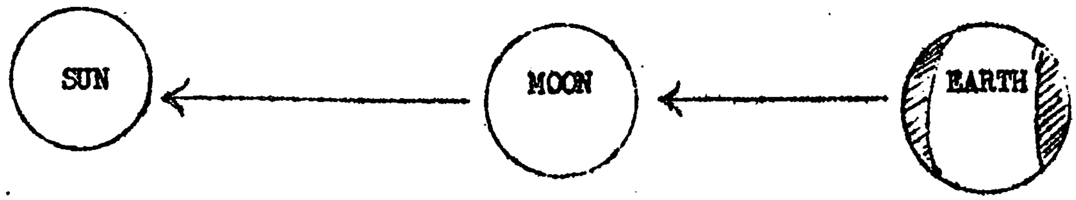
Tides are broad, gentle swells which pile up and become visible at the shore.

How are tides caused?

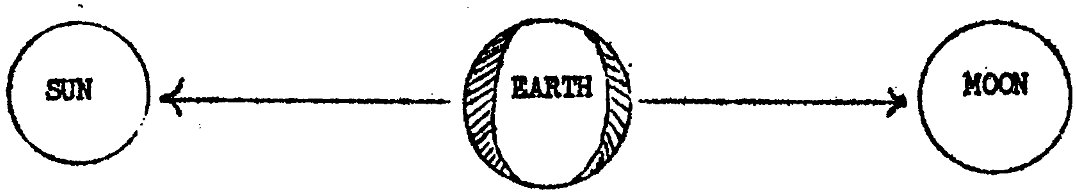
Tides are caused by the attraction of the Moon and the Sun on the Earth. The forceof gravity holds the Sun and the Moon together. The Earth attracts the Moon, and the Moon attracts the Earth. The pull of the Moon is sufficient to raise the waters of the oceans a slight amount on the part of the Earth's surface closest to the Moon, and to pile up waters on the opposite side. These two "bulges" are what we call tides. They move in the same direction as the Earth moves on its axis - west to east.

Appendix C13

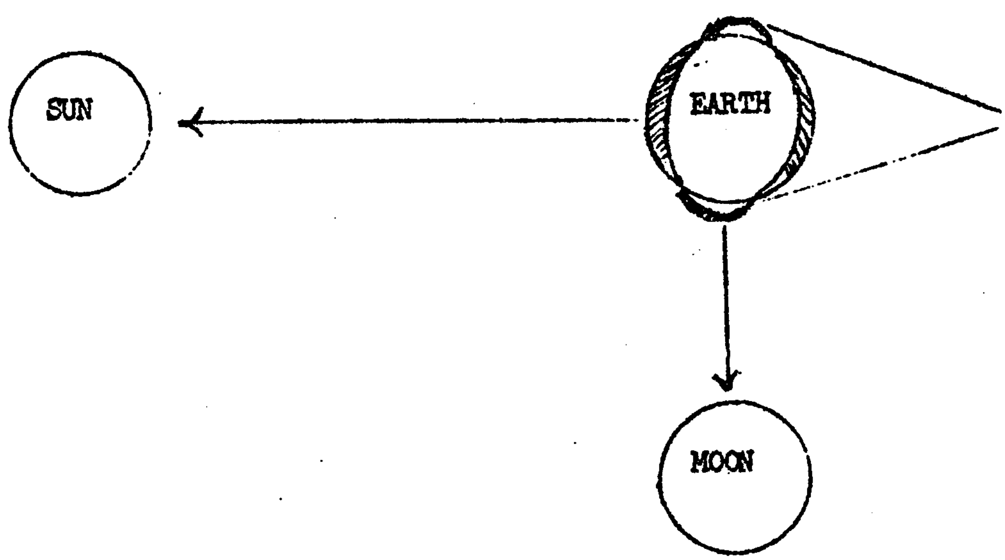
HOW THE SUN AND MOON AFFECT THE OCEAN WATERS.



FORMATION OF TIDES AT NEW MOON.



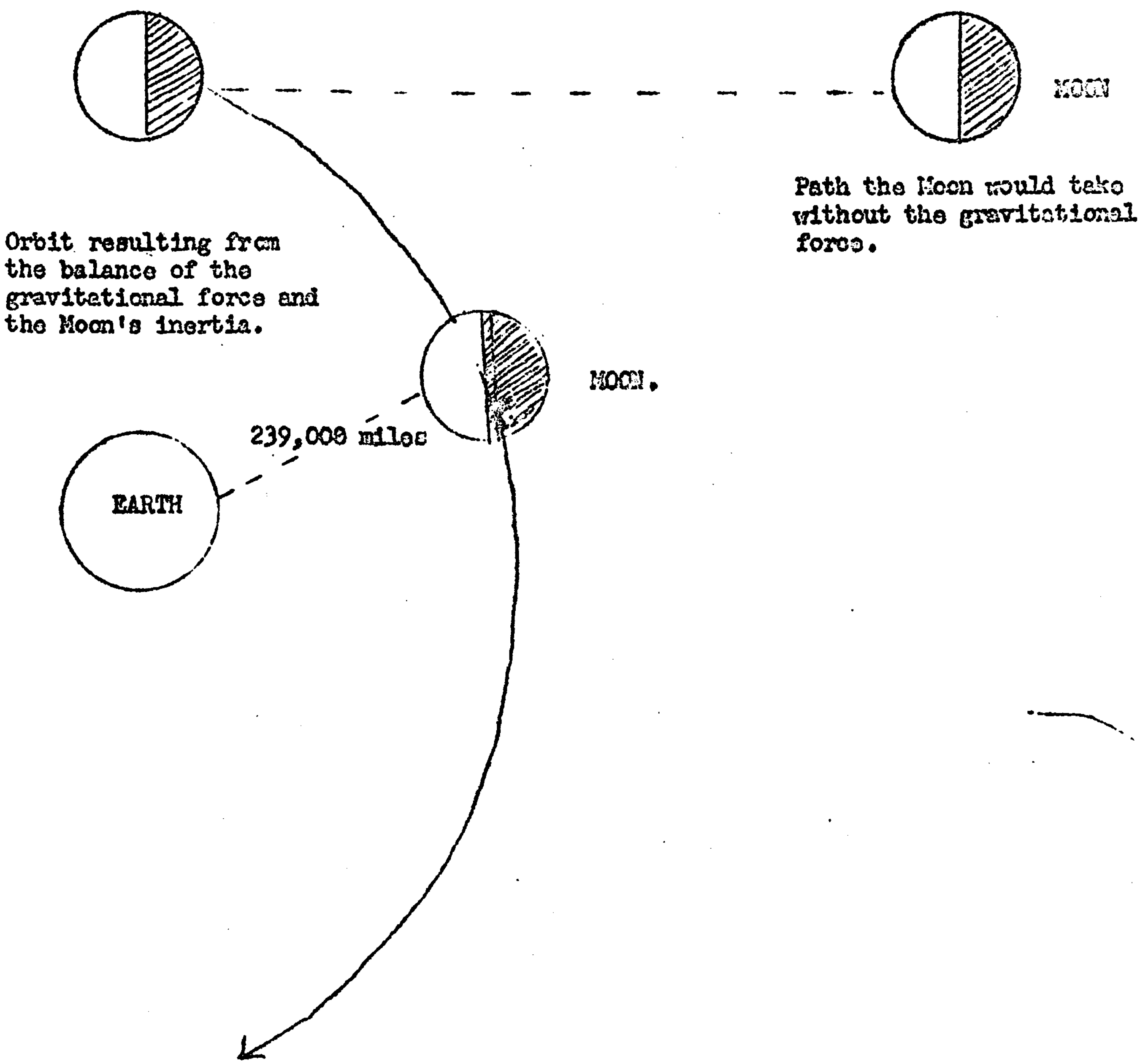
FORMATION OF TIDES AT FULL MOON.



FORMATION OF TIDES AT HALF WAY PERIOD BETWEEN FULL AND NEW MOON.

Appendix C14

DIAGRAM SHOWING EARTH'S ONLY SATELLITE AND HOW IT REMAINS WITHIN ITS OWN ORBIT AROUND THE EARTH.



N.B. We will be taking a look at man and his space programme after this unit of Astronomy.

PROJECT: You may use ideas from the chart in class in order to make a similar chart showing the Solar System and the many visible stars in the Universe. Include also in this chart the Milky Way, Planetoids and the Sun.

Appendix C15

ASTRONOMY.

Summary

Our sun is a star. Stars are suns. All stars except our sun are beyond the solar system. Some stars are hotter and some are cooler than our sun. Constellations are useful in helping us locate some of the brighter stars. We do not really see the stars, we see the starlight coming from them.

Distances to the stars are so great that astronomers measure star distances in light years. All the light which we see coming from the stars, except for that from our own sun star, has been travelling earthward (towards the earth) for four years or more. Atmosphere and distance cause the stars to twinkle and seem to have points.

Stars are all around the earth. The earth's rotation causes some of the stars to appear to rise in the east and set in the west. The stars above the pole of the earth do not rise and set, but can be seen all night long. Some stars can only be seen in one hemisphere. Stars shine all the time. Through the earth's atmosphere, stars cannot be seen in the daytime because their light cannot be seen through the very bright light of the sun.

The earth's revolution causes the changes we see in the constellations in the evening sky during the different seasons and months of the year.

The Milky Way.

The Milky Way, seen in the evening sky, is part of the Milky Way Galaxy. This galaxy is a vast system of more than 100 billion stars, of which our sun is one star. Our solar system is in the Milky Way Galaxy. There are billions of other galaxies in the universe. Not all galaxies have the same shape. Galaxies can be seen in space as far as the largest telescope can penetrate. Galaxies form groups.

SOME INSTRUMENTS ASTRONOMERS USE TO INCREASE THEIR "SEEING POWER" AND SOME OF THE THINGS THEY FIND OUT BY USING THEM.

Name of Instrument.	With what instrument used.	How it operates.	What it is used for.
Camera	Telescopes and Spectroscopes	Collects light on photographic film	To take pictures of planets, satellites, comets and the light from stars and galaxies.
Photoelectric cell	Telescopes and Spectroscopes	A light sensitive material in the cell (eye) releases electrons when light shines on it and converts the light energy into electricity	To investigate the brightness and temperature of the sun, moon, planets and stars. It measures differences in brightness more precisely than photographic film.
Radar (radio) telescope	Telescopes and Spectroscopes	Consists of concave shaped mirrors connected to short-wave receiving sets. It contains sensitive antennae which collect invisible light rays. One of the larger such instruments is located in Jodrell Banks, England.	
Reflecting telescope	Camera and Spectroscope	Light is collected on a large mirror. The Mt. Palomar 200" telescope in California gathers 360,000 times as much light as the human eye & can "see" two billion light years into space.	To photograph the members of our solar system, the light from distant stars, and the light from remote galaxies. It can penetrate into space farther than the largest refracting telescope.
Spectroscope	Telescope, Photoelectric cell and Camera	A prism which separates light passed through it into its spectral colours.	To investigate the composition of the atmosphere of the planets, size and weight of the stars, the speed of rotation and revolution of stars and galaxies and their distance from the earth. They also measure the speed with which they move away from or toward the earth

APPENDIX D

CONTRAST OF TEACHING METHODS

Appendix D

CONTRAST OF TEACHING METHODS

The differences in the physical setting and in the teacher's role in the classroom are the key points differentiating the discovery and instructional approaches to a learning situation. As a brief outline of these differences, the following table is presented exclusive of student's reactions; the effects of the two methods will be considered in the summary. The table is arranged in the order of chronological priorities in establishing a unit of study in the classroom situation. The summary will be of an observational nature as it is concerned with an explication of techniques rather than an evaluation of the distinctive approaches.

Discovery	Instructional
1. Physical organization of classroom.	
The furniture in the laboratory consisted of tables, chairs and flat topped desks which could be moved at the pupil's discretion.	The furniture consisted of one piece student desks with sloped tops and moulded seats. They were arranged in four rows of six desks plus two rows of five desks, parallel to the side walls and all facing the front of the room.
2. Seating arrangement.	
The pupils were told to organize themselves into groups, none having more than five or fewer than three members. Each group elected a monitor as directed by the teacher. Any changes in the groups or monitors took place only when a unit of study was concluded.	The pupils were allowed to choose their own seats initially but otherwise were not permitted to change seats except when told by the teacher. This occurred when there was too much talking or other distraction caused by an individual. The person at the first desk of each row was designated as the monitor for that row.
3. Materials used.	
The kit materials and equipment were issued to the groups in sufficient quantities for each group to perform experiments autonomously. Each lesson monitors spontaneously obtained their pre-packaged and labelled materials from the storage cupboard after having the routine explained to them once.	The row monitor issued to each child only that equipment required to duplicate the teacher's demonstration. Each pupil was also issued a copy of the notes on the unit (ref. Appendix C, page 100).

4. Inter-Pupil discussion.

A free exchange of ideas and observations was encouraged both within and between groups.	Discussion by pupils among their peers was discouraged.

5. Equipment manipulation.

Students were allowed to employ kit materials at the groups' discretion.	Students were allowed to use materials only as instructed by the teacher.

6. Questioning.

Questions were generally raised by the pupils.	Questions were generally asked by the teacher.

7. Responsibility.

Responsibility for the cleaning and storage of equipment rested with the monitors.	Collection and storage of materials was the responsibility of the teacher.

8. Motivation.

Presentation of incomplete experiments was given by the teacher demonstration as required by waning interest of pupils.	Questioning techniques and references to current events were used by the teacher.

Summary

The physical aspects of the two classroom situations under consideration provide a good focus for realizing the variation in the approaches. While the setting for the discovery technique was informal and changeable, the instructional situation was centered with a rigid, immovable backdrop. The discovery situation encouraged group interaction with a minimum of information being supplied by the teacher. The pupils spontaneously displayed a greater degree of intrinsic motivation than in the instructional instance; the latter case encouraged the use of the teacher as a resource through direct questioning. The technique of teacher response to student questioning varied considerably between the two methods and a demonstrative question and answer sequence is presented below:

Discovery

Pupil: What is a light year?
Teacher: Where is a good place to find out?

Pupil: The dictionary?
Teacher: Try it and find out.
Pupil: It says the distance light travels in a year.
Teacher: How can you figure that out?
Pupil: I don't know.
Teacher: How fast does light travel?
Pupil: (after reference to a book) 186,000 miles per second.
Teacher: How far is that in a minute?

The pupils would then be left to calculate the required product.

Instructional

If the same question is asked by a pupil, the answer would be, "six trillion miles" and the calculation would be shown by the teacher.

The questions most often raised by the students involved in the discovery approach were "how" questions. This infers that the pupils wanted to learn the technique of discovery. The instructional approach encouraged "why" questions involving theory rather than laboratory technique. This difference in student emphasis is a direct reflection upon the teacher's approach. The discovery method encourages the teacher to ask "why" of the students; the converse is the case of the instructional technique.

Some Detail of Lessons

The Second Lesson: "Gases and Airs" Unit

The class entered the science laboratory and representatives of each group obtained their materials from the cupboard assigned during the previous period. The material packages were opened with much anticipation and each pupil began to manipulate some piece of apparatus according to his own desire. Questions began coming from the pupils such as, "What is this thing used for?", and "Can I put water in this?" They were answered in such a way that no precise direction was given, except on those rare occasions when the safety of the children might be in question. In some cases a common answer given by the teacher was "Why don't you try it and find out for yourself?"

After about fifteen minutes the attention of the class was called and a demonstration of apparatus set-up was given by the teacher. The candle experiment referred to was the first shown. The apparatus was assembled but the demonstration did not include the actual lighting of the candle. The results therefore were not known prior to the time when the pupils did it themselves.

With this start the pupils in their groups went ahead and completed their experiment a number of times. Frequently the results varied. The pupils noted that in general the same kind of things happened but to a different degree with each trial. Questions were asked of the teacher about these differences. The teacher responded with such questions as:

- "How much of a difference was there?"
- "How can you determine how much of a difference there was?"
- "Did you do exactly the same each time?"
- "Did you notice any detail that was different in one trial from another?"
- "Why do you think there are differences?"

The students then began measuring with a ruler to find how high the water rose in the tube. They also recorded such differences in procedures as putting the tube over the candle more quickly or slowly than before and whether bubbles escaped or not. Because they were working in small groups, one pupil could concentrate on the mechanics of an experiment while the others acted as observers. They seemed to be very critical and voiced their criticisms loudly and often. Frequently there was an argument about just what had been observed. Each person had a turn doing the experiment several times.

At the end of the eighty minute period each group had to clean up, monitors replace their equipment in the cupboards, and each student recorded the last question for research before the next day. In the example cited the question was "Why did you have different results from each other and between your own trials?"

The Second Lesson: "Astronomy" Unit

When everyone was seated the first person in each row obtained a set of compasses, a protractor and a metre stick for everyone in the row. The pupils were then asked to observe the metre stick.

The teacher pointed out that one side of the stick was marked in inches and the other side was marked in millimetres and centimetres. He drew examples of rectangles on the board with measurements given and the pupils practiced the arithmetic use of decimals. They copied down the metric system of lineal measure and were shown the relationships between the various elements of it.

The pupils were next asked by the teacher to put pencils in their compasses and were shown how to do it properly. They drew a few circles for practice in using the instruments while pieces of cardboard and scissors were issued in the manner described above. They had to draw two circles of different sizes on the cardboard, to draw a line through the centre point of one circle to a point on either side of that circle, and to cut out both circles with the scissors.

Next the various parts of the circle were reviewed, i.e., the circumference, the radius and the diameter. The pupils were instructed to measure the diameter and the circumference to the nearest half millimetre. The latter was measured by placing an arrow at one of its points and rolling the circle along the metre stick.

This done with the measurement recorded on the cardboard circle, instructions were given to divide the length of the circumference by the diameter to two places of decimal.

After the majority of the class appeared to have completed the calculation, some of the results were listed on the board. No two were the same but all were fairly close to one another. The teacher explained that what they had calculated was a value of pi, and he gave the correct value of 3.141592. The pupils were asked why they thought their results differed from the value found in the dictionary. Some responses were:

- "Because the metre sticks are crummy."
- "My circle isn't cut out well."
- "I could only guess at the half a millimetre."

The students could see that their results were close to the correct answer and they indicated that they understood that there is a relationship between the diameter and the circumference because the circles used in the examples were not of the same size.

They were asked to do the same exercise for their second cardboard circle, to list the pertinent information on each circle, and to glue the cutouts in their exercise books.

Materials were collected at the end of the period and those who had not completed the tasks were told to do it for homework.

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