A study of some of the effects on children's creative thinking of the discovery approach to mathematics in the primary school

Richards, P. N.

A STUDY OF SOME OF THE EFFECTS ON CHILDREN'S CREATIVE THINKING OF THE DISCOVERY APPROACH TO MATHEMATICS IN THE PRIMARY SCHOOL

THESIS

submitted by P.N. RICHARDS B.Sc.,

as part requirement for the degree of

MASTER OF EDUCATION

in the

UNIVERSITY OF DURHAM

1970

A B S T R A C T

AIM

To consider the nature of creative thinking and its relation to mathematics teaching, and to provide some objective assessments of the effect of a discovery approach on children's creative thinking. Also to contribute some further evidence on the nature of creativity and its relation to other modes of thinking.

PROCEDURE

Tests of intelligence, creativity and mathematics were administered to 297 fourth year children from three carefully matched Junior Schools, in one of which the children had been taught for four years by a discovery approach to mathematics.

Means, standard deviations and intercorrelations were calculated for all 31 test scores within each school and for the complete sample of 265. In each case a factor analysis was carried out by both Principal Components and Varimax methods. A separate analysis was also carried out for the High I.Q. population.

RESULTS

1. Overall Analysis

Over the whole range of intelligence there was evidence of a dimension of creative thinking which, though not independent of intelligence, existed as a consistent complementary activity.

Furthermore, given a minimum I.Q. of 115 the creativity dimension and that located by the academic tests were relatively independent.

There was also evidence, however, that the ability to perform well

on creativity tests while consistently loading a 'creativity' factor is not entirely confined to that factor.

2. Discovery Approach Effects

Six hypotheses, covering attitudes, creative thinking, understanding of mathematics, concept formation, arithmetic, and flexible and logical thinking suggested results which have been thought likely to arise from following a discovery approach. Five were rejected, and the other was upheld by only one of five creative thinking tests. In many ways however the experimental school's successful performance on the one creative thinking test was of greater importance than its proportion of the hypotheses suggests. The very satisfactory results from one of the control schools gave weight to the headmaster's policy of 'keeping a balance'.

The study implies that teachers should be aware of the limitations of a discovery approach and should appraise the relative values of methods they adopt.

ACKNOWLEDGEMENTS

I gratefully acknowledge the help and advice given me by my supervisor, Dr. Bolton, of the Durham University Department of Psychology, the University Computer Unit, the Durham and Northumberland Education Authorities, and the headmasters and staffs of the schools concerned. I am also indebted to the Principal and Governors of Bede College, Durham, for granting me a term of study leave during which the experimental part of this study was carried out.

CONTENTS

PAGE

CHAPTER 1

INTRODUCTION

One of the most encouraging features in the field of education today is thought, by many, to be the way in which creativity and discovery have been adopted as ideals in the education of the child. The Plowden Report in particular is not only strong in its plea for a discovery based curriculum in the Primary School but also in its conviction that such methods would be beneficial if extended into the middle school years. The basis of such opinion is the belief that children involved in discovering relationships and active in exploring their environment are likely to derive not only more vivid and efficient a store of knowledge, but also a sense of personal involvement which is instrumental in developing a self-sufficient attitude towards learning, both critical and creative.

To what extent this teaching approach is well-founded will be discussed more fully later though in part it is an answer to the growing demands for creative personnel in science and technology and a belief in education as a means of developing an individual's capacity for creativity.

Much of the initiative for current innovation in education has arisen in America, where a great deal of finance has been provided both for curriculum development and educational research. In particular publications on creative thinking have grown exponentially since the time of Guilford's famous Presidential address on 'Creativity' to the American Psychological Association (1950). Unfortunately as Yamamoto (1965a) has pointed out in an analysis of the literature of creativity, there is at present a 'confused abundance' in publications on creative thinking, with diverse definitions, theories, and means of evaluation. After presenting an introductory view of the evolution of the present concept of creativity and its relevance for education, the present study will devote some attention to this question, especially as it relates to the interpretation of studies of creative, divergent and productive thinking and their relation to mathematics and problem-solving.

As a result of this analysis a number of creativity tests will be selected or adapted and others will be specially constructed for use in the experimental part of the study.

It is becoming increasingly recognised that the conventional intelligence test assesses only a very narrow range of easily examinable abilities, chiefly tied to the candidate's ability to converge in his thinking to the one correct answer. Abilities at the other end of the spectrum, indicative of a subject's power to think flexibly, to depart from well-trodden paths and rigid methods, and to contribute his own original ideas are less easily evaluated and have been omitted from standardised tests. Dissatisfaction with the traditional I.Q. tests has resulted in the use of 'divergent thinking' tests, and some experimenters claim that they reflect a dimension of creative ability distinct from that of intelligence. In general however most experimenters appear to believe that if 'intelligence' is conceived as broadly as it should be then it would include creative abilities. The relationship between creative thinking ability and intelligence is discussed in Chapter 4 of the present study and part of the experimental evidence should be very relevant.

Whatever the final outcome of the Creativity/Intelligence debate, it has certainly had the effect of bringing out into the open the fact that creative abilities are present to some extent in all children and that education can play a large part in either inhibiting or stimulating their development.

Novel ideas and individual patterns of behaviour are often thought to characterise the gifted, creative child who is not bound by convention but who seeks a more personal and unique means of communication. Unfortunately such behaviour tends to be neglected or even stifled in an atmosphere of strict formal teaching, in which the child is credited only with reproductive abilities or accurate application of a rule. As a reaction against this form of teaching the progressive elements in education have emphasised the importance of a fuller educational ideal more in tune with theories of child development and the belief that a child's intellect is best developed by active exploration in his environment.

In many cases the discovery approach has been thought to be the means best suited to this ideal, the child being encouraged to follow his initiative and actively explore situations under the guidance and encouragement of his far from authoritarian teacher. Seeing such methods in operation, especially as Plowden notes in the 'best' Junior Schools, one cannot but feel that a child's creative thinking abilities are more likely to develop in such an open-ended atmosphere than in that of a more formal approach. Children are certainly known to have enjoyed such an approach and to have reached high levels of attainment, understanding and personal creative work. The latter, however, are not corollaries of the discovery approach, and there are dangers that proper educational objectives might be lost sight of among subjective impressions, or that the approach might be too readily accepted as an end in itself.

It is unlikely that all the necessary educational objectives are best learned in a permissive atmosphere, that all children are capable of disciplining their own efforts, or can grasp theoretical concepts or formal academic structures by means of discovery. The most likely outcome will be that there are some areas most efficiently learned by formal means, and others by active exploration. Assertions that "sound and lasting learning can be achieved only through active participation (Schools Council 1965 Pg.XVI) are open to question, and it would be more honest, as well as beneficial to education, if projects were introduced not with millennial assertion but as an 'experiment', in order to find out, as Young (1965) suggests "whether the innovation is in practice as desirable as it may sound in theory".

Some of the theory and experimental evidence relating to the effects on children's abilities of various teaching approaches and conditions, particularly in mathematics, are discussed in Chapter 4, and the remainder of the study is devoted to the experimental investigation of some of these effects.

Numerous projects have been set up at various levels to develop pupils' abilities to think logically and creatively, and to understand mathematics. The present investigation focusses on a Junior School which has been committed for four years to such a project based on the discovery approach. The school is situated in a pilot area, affiliated to the national project by the County Authority, and is therefore not a special volunteer school. Testing was carried out in June 1969, and as the school was set up as a pilot area in 1965, the fourth year pupils were consequently among the first groups in the country to have experienced such an organised discovery approach for the whole of their time in the Junior School.

A great deal of preliminary investigation was carried out prior to the testing and two comparison schools were found, similar to the experimental school in as many ways as possible except that they put no special emphasis on mathematics. In particular they were chosen so that there was no significant difference in their mean levels of I.Q., nor in the social class of their pupils. Details of the schools were compiled over a number of visits and full descriptions are given in the text.

The County authority gave the writer a good deal of help in selecting the schools, and in allowing him access to their records which included the results of two I.Q. tests which had been administered to the pupils as part of the counties' 11+ selection procedure.

In addition to the results of the I.Q. tests a testing battery was designed to include measures of attitudes, creative thinking, problem solving, computation and understanding of mathematics. In particular the design of the tests had to keep in mind the need to do justice to both the traditionally taught children and those working by discovery methods, and to keep a balance between the tests in the interests of the subsequent factor analysis.

After a statistical analysis of the levels and pattern of performance in each school, the findings will be discussed in terms of the hypotheses concerning the effects of the discovery approach and the modes of thinking indicated by the testing battery.

Chapter 2

CREATIVE THINKING: AN OVERVIEW

Speculation regarding the nature and process of creative thinking is nothing new to psychology. Although traditionally man attributed the creation of works of Art or Scientific principles to a mental process which was beyond comprehension, many constructive attempts to understand 'creative power' have been conducted since the pioneer investigations of Francis Galton (1869) at the end of last century. The acceptance of creativity as some ultimate truth however was still in vogue at the beginning of the century; creative products were viewed with a sense of awe and it was common to regard the creators as possessing some innate power of genius which somehow enabled them to think in a way quite different from that of everyday thought. This view of 'genius' was approved by Ward (1918) who according to Spearman (1930) speaks of creativity as something 'that only transcendent genius displays'.

Spearman himself was not content to take 'creativity' as being itself the last word of explanation, and though he acknowledged that there is nothing necessarily wrong in so doing, he expressed the belief that it might be more profitable to investigate feasible alternatives in an effort to 'understand' the nature of 'creativity'. Theories to explain creative thinking have been suggested by several schools of thought; in terms of intellectual ability, the faculty of imagination, by a process of 'combination' of ideas and images, and by an appreciation of 'form' or 'gestalt'. More recent explanations often incorporate the better aspects of several of these earlier approaches.

Attempts at mental measurement early this century were of a far more comprehensive nature than the convenient, practical adoption of a single intelligence score might suggest. Binet in particular held a very comprehensive view of intelligence and his later acceptance of a single score as a means of convenient administrative selection was, both Spearman and Wynn Jones (1950) and Guilford (1967a) suggest, in obvious contradiction to his own convictions. Guilford (1965) sees creativity as an aspect of intelligence when the latter "is conceived as broadly as it should be" but suggests that research findings over the past 25 years indicate that the conventional conception of intelligence, with its single I.Q. score, is extremely narrow.

Although the latest findings of Terman's famous longitudinal study of a group of gifted children with I.Q.'s of 140+ shows that a high I.Q. is fairly adequate in predicting a successful career in later life, it fails to identify those who attain the highest levels of achievement. (Terman and Oden (1959)). As Goldberg (1965) points out, an analysis of the achievements of the superior adults in Terman's population, though including many people named in 'American Men of Science' and 'Who's Who in America' shows few people who are of the highest scientific standing or have made an outstanding contribution in any of the arts or letters. She suggests that this questions the adequacy of the I.Q. as a sole measure for determining potential giftedness and points to a new longitudinal study of the gifted which would include not only measures of intelligence, but also of creativity, curiosity, and achievement.

The studies of Mackinnon (1962) and Roe (1953a) raise the same doubts concerning the predictive value of I.Q. alone. Given a minimum level of I.Q. of about 120, Mackinnon reports that his studies of eminent men and women found no relation between I.Q. and outstandingly original work and concludes that "It just is not true that the more intelligent person is necessarily the more creative one." Similarly Roe in her three year study of 64 first class research scientists interprets the results of an I.Q. test as showing that "It is then, not essential to have this ability <u>at the highest level</u> in order to become an eminent scientist". The inference of these studies is opposed to an unitary concept of intelligence; Roe and Mackinnon suggest that the answer lies largely in the field of personality and motivation, while others, such as Guilford and his school, see the explanation in a broader conception of intellectual ability including factors of direct relevance to creative activity.

Guilford (1956) has constructed a Structure-of-Intellect model which postuates 120 potential intellectual abilities grouped in various ways.

Using his model to generate hypotheses regarding unique intellectual abilities and using appropriately designed tests and methods of factor analysis, he and his co-workers in the Aptitude Research Project at the University of Southern California have so far identified over 80 such abilities (Guilford 1967 a). His model effectively redefines intelligence so as to include factors of creative ability, the class of such creative-thinking abilities being labelled 'divergent-thinking', with a set of parallel abilities under the title of 'convergent-thinking'.

Divergent thinking moves away from sterotyped responses to generate diverse and original ideas and is measured by testing procedures which assess originality, fluency of ideas, flexibility, and the ability to elaborate on and redefine the given data.

Convergent thinking on the other hand moves towards responses that are known to fit the problem; it is the sort of thinking emphasized by conventional intelligence tests in which the subject proceeds to the one 'correct' answer which is fully determined by the information given.

Tests of divergent thinking are currently adopted by many as measures of creativity, and call for the production of new ideas, original and unconventional responses and departure from the one well beaten track. This is a definite departure from the role of the common type of intelligence tests which as Burt (1962) observes "tend to select children of an analytic or reproductive type rather than those of an intuitive or productive type". It is interesting to speculate on the extent to which Terman's (1906) study of seven bright and seven dull children might have influenced intelligence tests towards 'creative imagination' had he interpreted his results differently.

From a population of 500 school children Terman obtained two sets of 7 children, rated by their teachers as being the brightest and dullest respectively. He administered a large battery of tests, including one which he designed as a test of ingenuity in order to assess a measure of inventive and creative imagination. It was the only test of intellectual ability that did not clearly discriminate between the two groups. The other tests all correlated highly with the supposed 'intelligence' rating of the children and took their place in an intelligence test battery which excluded the measures of more creative qualities.

For some time after the establishment of tests of 'general intelligence' with their single score and implied monarchial view of intelligence, investigations of creative thinking continued in terms of an underlying group factor of 'imagination'. Hargreaves (1927) used a number of tests of imagination remarkably similar to contemporary tests of divergent thinking. Giving such tests as 'unfinished pictures', 'ink-blots', and 'story completion' to 151 children he found, marking the tests for 'fluency', that intercorrelations existed between all the tests and concluded that "imagination tests, marked for that aspect called 'fluency' had some group factors distinct from 'g'." A similar conclusion was reached by Spielman and Gaw (1926). Giving similar tests of 'creative imagination' they reported that although the tests correlate with general intelligence "Nevertheless there seems also to be a specific factor in imagination which is to some extent independent of intelligence". Karvè (1929) employed seven 'open-ended' tests in an investigation of a group factor of 'fluency' and concluded even more forcibly that "We have proved the existence of a 'fluency' factor, independent of intelligence, in tests of imagination and association." Karvè's testing battery would serve well as a modern test of divergent thinking: Nouns (as many as possible beginning with P, T, ... etc.), Unfinished Stories, Controlled Association (write down things made of leather), Picture Completion, Prediction (what might happen if it became unnecessary for people to eat and drink?), Ink-blots (what objects or pictures can you see in it?) and Free Association (write down as many different words as you can).

The concept of imagination was also used in attempts to explain the 'springs and mechanisms' of creativity. In particular the doctrine of 'combination' or 'association' of images or ideas is still present in many explanations of creative thinking, though usually with a greater emphasis on the part played by preparatory and evaluative abilities. Creative combinations of ideas have rarely been regarded as occurring purely by chance although the moment of 'illumination' is often related in terms of a sudden combination or recombination of ideas. Giselin (1962) provides ample illustrations and a classic example is that related by Poincaré (1968 (1906)) explaining his discovery of Fuchsian functions. After many unsuccessful attempts at proving their existence Poincaré retired to bed one night but could not sleep "ideas rose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. By the next morning I had established the existence of a class of Fuchsian functions." The essential question is beautifully expressed by Dryden who asks what is it moves "the sleeping images .... toward the light" (In Giselin (Ed) (1952)).

The relevance for creative thinking of the 'Gestaltists' approach lies in their conception of 'productive problem solving'as a process in which ideas are reorganised and one's perception of a problem restructured so that one is able to see into its structure in a new way, perceive its gaps and inadequacies and appreciate its nature as a whole. Recognising the whole 'form' of the problem in this way is to achieve an 'insight' which is the most important contribution to a 'creative' solution.

Wertheimer (1961 (1945)) relates the decisive steps in the development of Einstein's theory of relativity in terms of a search for a new 'gestalt' - a new way of reorganising the traditional structure of physics. Einstein was first troubled by a feeling that he "knew something was wrong", then after seven years of rethinking, of perceiving gaps in the whole structure of the problem, and in attempting solutions, he at last came to question the customary concept of time. From that moment it took him only five weeks to write his paper on relativity.

Experiments indicating a 'fluency' factor of imagination and explanations in terms of mental images and ideas were however not acceptable to the Behaviourists and as their theories became increasingly dominant the concept of any 'mental' capacity for creativity received little attention. As Burt (1962) observes "Concepts like 'imagination' or 'productive thinking' savoured too much of discredited introspectionist doctrines, and were deliberately excluded from behaviourist text-books".

Although some investigators cling to the product as the only valid criterion of creativity, investigations of the creative process are facilitated by considering the types of thinking which might lead to a worthwhile product. Once investigations are conceptualised in terms of the process of creative thinking and not the overwhelming excellence of a product, it becomes more natural to believe that the thinking process which leads to a commonplace result might not be too far removed in kind from that which produces a work of genius, and that creativity like most other human traits occurs in varying degrees in the whole population.

If a characteristic process of creative thinking does exist however, it is reasonable to suppose that it might be more readily investigated by studying those persons who have shown themselves to be highly creative. It is also likely that the achievement of greatness demands more than a mental ability for a high level of creative thinking, internal and external motivation and personality characteristics are no doubt just as essential. Although the latter are not the direct concern of the present study it is important to acknowledge how much they are likely to supplement the thinking abilities in achieving the creative activity which many see as being "more than a rational process" Gutman (1967).

Among their research at the Institute of Personality Assessment and Research of the University of California, Mackinnon and Barron have shown characteristic personality patterns in studies of highly creative writers, architects and mathematicians and indicated that non-cognitive factors are closely related to individual differences in creativity (Barron 1958, 1959). The personality research of Cattell (1959) is equally relevant. In a study of 144 leading research physicists, biologists and psychologists he found that the personality profiles of these research subjects differed significantly from that of an average group and from a group of equal intelligence who were outstanding in administration or teaching. In the latter case the researchers were more schizothyme, less emotionally stable, more radical, and uniformly lower on all primary personality factors measuring extroversion than the group of teachers and administrators.

Comparisons of the personality and behaviour of children when grouped according to their performance on I.Q. and 'Creativity' tests have also revealed patterns of functioning that are relevant to both the theoretical and practical study of creativity and carry a host of implications for education which will be discussed later (Getzels and Jackson 1962, Wallach and Kogan 1966, Hudson 1966, 1968).

The last twenty years has seen a revival of interest in creativity, Parnes and Brunelle (1967) reviewing the literature of creativity arrived at the startling statistic that in the eighteen months from January 1965 to June 1966 there were as many publications on creativity as in the previous five years, the ten years from 1950 to 1960, and in the hundred years prior to that. Guilford's presidential address to the American Psychological Association heralded the revival which has been fired by national concern for the development of creative talent and for a revision of educational objectives centred on the individual child. The time has been ripe too for a concept of ability which does not tie itself to the conventional intelligence test.

Reacting against the limitations of I.Q. tests in predicting the creative scientist or artist, and recognising the need to nurture scientific talent, some educational psychologists particularly in America have seized on the concept of creativity "as a distinguishing characteristic of the outstanding contributions in almost every field" (Torrance (1963). Education is seen as the means of developing this 'creative characteristic' both for the individual's personal fulfilment and to satisfy the growing needs of society for creative initiative. A formal, passive, authoritarian approach to learning is considered, however, to be antithetical to the approach needed to foster a child's ability to think creatively, for, as Torrance (ibid) maintains "A child learns creatively by questioning, inquiring, searching, manipulating, experimenting, even by aimless play; in short, by always trying to get at the truth."

The discovery method and the 'play-way' in education are not new ideas but they have never been so extensively adopted, not the least in Mathematics. The Schools Council, Curriculum Bulletin No.1 (1965) contains "a summary of intensive work in the learning of mathematics by discovery methods carried out with children and teachers during the past six years" and recommends in Whitehead's words that "every child should experience the joy of discovery". The Plowden Report on 'Children and their Primary Schools' (C.A.C.E. (1967)) endorses this view and notes that "The sense of personal discovery influences the intensity of a child's experience, the vividness of his memory and the probability of effective transfer of learning". The Nuffield Mathematics Project for the ages of 5 to 13 aims "to help the children develop gradually - and not overnight - from discovery with things to eventual abstraction with pencil and paper" Matthews (1969).

These policies in Education, in the Primary School in particular, are implicitly supported by Piaget's emphasis on the importance for intellectual growth of the child's active experience of his environment, by multi-dimensional views of the intellect such as Guilford's, and by the fashionable belief in education as a means of developing all the varied abilities of the individual. The Plowden Report makes it clear that "there are certainly areas of the child's thinking which remain unsampled" by I.Q. tests, and it recommends that "all good teachers must work intuitively and be sensitive to the emotive and imaginative needs of their children." There is a reminder in the Report that the new approach to mathematics has not removed the necessity for practice in computation and for accuracy, but it is significantly lower in the list of objectives than it would have been ten years ago.

Neither the concept of creativity nor the new approaches to learning are however without their critics. Burt (1962) for instance insists that in useful creative activities, general intelligence is still the most important constituent, and though he concedes that there is a distinct group factor of what he terms "productive imagination", he questions, with others, the criteria of "so vague a concept as 'creativity'".

Dearden (1968) in a timely work on the Philosophy of Primary Education sets out to bring to bear on Primary School problems some of the 'astringent intellectual scrutiny' recommended in the Plowden report. Although critical of the 'illiberal verbalism' of the traditional elementary school he also warns against the "reaction against the elementary school tradition which is altogether too undiscriminating". He points out the discontinuity which exists between theoretical and practical concepts, and stresses that the development of creative abilities in children will be a matter not just of unfolding in a permissive atmosphere, but will need constructive educating.

This view is also taken by White (1968); writing on Creativity and Education he attempts to show how the assumptions behind the various ideas that are currently propagated are radically confused. Both he and Dearden focus on the philosophy of creative activities and the learning experience but are less stringent in their analysis of any characteristic mode of thinking that might accompany discovery or invention by school children.

It is nevertheless true that there is a need for a great deal of clarification and appraisal of the claims made for a characteristic type of thinking which can be labelled creative, and of the implications for children's thinking, of the discovery approach in the Primary School. It is the intention of the next two chapters to consider more closely these two aspects.

Chapter 3

THE NATURE OF CREATIVE THINKING

The limitation of intelligence test results has led, particularly in America, to an attempt to broaden the dimensions within which youngsters can be identified as talented, and the conventional type of I.Q. test is giving way to additional criteria of assessment variously known as tests of divergent-thinking, open-ended tests or more collectively tests of creativity. The use of the word 'creativity' has evoked considerable emotion on both sides of the Atlantic, particularly when it is used to convey to governments and the public that children, perhaps with the makings of future scientists or men of Arts, are being unrecognised and unnurtured, even perhaps actively discouraged at school. 'Talented Youth Projects' and 'Societies for the Gifted' have been set up to identify and encourage creative talent and a great deal of research work carried out over the past twenty years.

The research results have covered a wide field, from claims that creative thinking is necessary for success even in relatively commonplace occupations such as sales clerk in a department store (Wallace (1961)) to Mackinnon's evidence (1962) that creative scientists, architects and novelists perform significantly better on certain creativity tests than their non-creative colleagues. There is much conflicting evidence, however, the results of studies by Roe (1953a) (1953b) for instance report eminent research workers in physical science as being predominantly convergent, while her results still recognise, as do Mackinnons, that there are abilities essential for high level scientific and creative work which are not measured by intelligence tests.

Despite the creativity boom that has become a bandwagon for the progressives there are a great many questions about the process and nature of creativity which remain unanswered. Reviewing the evidence Wallach and Kogan (1966) note that "the empirical warrant for distinguishing a new concept that would be appropriately labelled 'creativity' from the concept of general intelligence turns out to be far from clear". Going further Hudson (1966) sees creativity as a word covering everything from the answer to a particular kind of psychological test, to forming a "good relationship with one's wife." He rather cynically observes that it applies to all the qualities of which psychologists approve and like so many other virtues is as difficult to disapprove of as to say what it means. In a similar devaluation of the concept Dearden (1968) observes that it seems "One need only speak to be creative".

The elements of truth in their remarks should sound a warning to educationists who have seen 'creativity' in teaching as standing on the side of all that is 'good', active and enjoyable, and fitting in perfectly with the current fashion in education, the reaction against an authoritarian approach which, by implication, kills all the creative and original urges. There should be some doubts as to whether the use of a pleasingly emotive but dangerously undefined word is sufficent on which to base fundamental educational beliefs.

The difficulties of arriving at an integrated theory of creativity which will satisfy critics and devotees alike stem from what Yamamoto (1965a) has called the "confused abundance" of the literature in the study of creativity; the varying definitions, the differences in assumptions and presuppositions, and the differences in research strategies. To illustrate this confusion it is useful to consider some of the varying definitions.

DEFINING CREATIVITY

Guilford (1950) simply defined creativity as referring to those abilities that are most characteristic of creative people, but he hastens to add that the creative abilities only determine potential - the power of an individual to exhibit creative behaviour to a noteworthy degree - whether or not he does actually produce results of a creative nature will depend upon his motivation and temperamental traits. When Guilford's principle of continuity, "that all individuals possess to some degree all abilities, except for the occurence of pathologies" is added to his definition, the term 'creativity' becomes all embracing and provides a basis for investigating creative thinking in all individuals not only in those who have distinguished themselves.

Although supporting this belief in the 'universality of creative potential' Taylor (1964) stresses that to define creativity there must be a distinction between the creative product and the creative process, and, for the purpose of developing criteria for the evaluation of a degree of creativity he takes the point of view that assessment of the product is much more important and acceptable than assessment of the process. In particular, he reasons that the product is far more tangible and consequently more amenable to investigation. Wilson (1958) also argues that creativity as a process should be inferred from the product.

For the work at the Utah Research Conferences on the Identification of Creative Scientific Talent, Taylor (1964) and his associates therefore considered that the best definitions available to them were those of Ghiselin: "that the measure of a creative product be the extent to which it restructures our universe of understanding"; and Lacklen, who in scientific work at the Space Agency, defines creativity by "the extent of the area of science that the contribution underlies - the more creative the contribution the wider its effects". They acknowledge however that no single definition of creativity, or even a creative product, would suit all workers in the field.

In particular, definitions via the quality of a product involve value judgements and do not satisfy those who argue that we must consider not only 'social' but 'individual' creativity - the creativeness of the individual who makes, for himself, something that others unkown to him might have made before. This conception of 'everyday' creativity however is in danger of becoming commonplace and some, for example White (1968), would claim, confusing and meaningless.

Its justification lies in the study of the process of creativity - in considering the nature of creative thinking rather than emphasizing the product of any such thought. In contrast to Taylor; Gruber, Terrell and Wertheimer (1962), who also accept the universality of creative abilities, in the preface to their "Contemporary Approaches to Creative Thinking argue that there is an essential continuity from 'commonplace' creativity to that judged by the quality of a sublime product - to be found not in the product but in the creative process. It is the nature of the thought process that they consider the essential link between the creative activities of everyday life and those of the great scientist or artist. The process of creative thinking is seen as a variable which has greater intrinsic appeal when maximised in the eminent, but is also present in more modest beings.

It is, in fact, this psychological interest in the process of creative thinking that allows us to consider extensive studies of populations of school children, as valuable contributions to investigations of creativity. At the same time Gruber et al note the value of studying the variable at its maximum when "we are more likely to discover characteristics which are also present, though perhaps in a hidden form, in the usual range of the variable". (Ibid Page 22).

Torrance (1965) puts creativity firmly in the realm of daily living and defines creative thinking "as taking place in the process of sensing difficulties, problems, gaps in information, missing elements; making guesses or formulating hypotheses about these deficiencies; testing these guesses and possibly revising and retesting them; and finally in communicating the results". Working on the basis of this 'process' definition Torrance has investigated creativity in terms of the type of person who might be expected to engage most successfully in the process and the type of environment in which he might function most effectively. He sees the results of his investigations as being of particular relevance to the fashioning of a kind of education which will provide children with the most suitable opportunities to achieve their creative potential.

Bruner too is committed to the role of education in encouraging creative development amongst children. For him the hallmark of a creative enterprise is "an act that produces effective surprise" - the unexpected that strikes one with wonder and astonishment. Bruner (1962). Similarly Thurstone (1952) maintains that "an act is creative if the thinker reaches the solution in a sudden closure which necessarily implies some novelty for him".

It is interesting to note, as Bruner emphasised, that the 'effective surprises' need not be rare or infrequent, they are simply characterised as having a quality of 'obviousness' when they occur which produces a shock of recognition. This interpretation is evocative of the schoolboy's enthusiasm to communicate a result he has just 'seen'; the quality of sudden 'insight' explained by the 'Gestalt' School; and the 'Eureka Act' of sudden discovery described by Koestler (1964). We shall look more closely at these aspects later.

It has been suggested so far that considering creativity in terms of a thinking process, which to some extent is common to all, is likely to be more profitable in regard to psychological interest, teaching methods, and experimental investigations which can include wider samples of the population, than would be the case if creativity were confined to consideration of a product. However, even if we emphasise the definition of creativity involving the process of creative thinking, we have to adopt some criteria to assess the nature of the process or else be tempted to accept the valueless concept, already mentioned, of 'all thinking being creative'.

Cattell (1947) discussing creative thinking, in terms of the artist rather than the scientist, suggests that it "may aim to satisfy by what it is and by the emotion which it evokes rather than by where it gets the thinker in relation to the real world". Thurstone too as already noted (1952) sees creative thinking in terms of what is novel for an individual and argues that it does not make any difference how society regards the idea.

For others, however, thinking can only be called creative if it obeys certain external criteria which are relative to the society of which the individual is a part. Stein (1967), deriving his hypothesis from a study of the personalities of creative artists, observes the need to clarify between internal and external frames of reference for interpretation of the word 'novel' as it appears in definitions of creative thinking. He himself suggests that 'novel' should mean "that the creative product did not exist previously in precisely the same form". Though some might interpret 'the creative product' as a new thought pattern of the individual, or as the formation of a new, personal, mental schema, Stein considers that communication with self alone is insufficient and insists on the need for some external criteria. He accepts that creative thinking arises from a reintegration of already existing materials or knowledge, but when it is complete he maintains that it must contain elements that are new, and not only new to the individual. Though for

Stein, the child who fixes a bell to his tricycle for the first time may go through stages that are structurally similar to those which characterise the work of genius, the finished product is a return to a previously existing state of affairs - and is not creative in terms of any external frame of reference.

It is also possible to find definitions that have feet in both camps. Parnes and Brunelle (1967) define creative behaviour "as the production and use of ideas that are both new and valuable to the creator", and Mednick (1962) from consideration of anecdotal evidence of highly creative persons, defines creative thinking as "the forming of associative elements into new combinations which either meet specific requirements or are in some way useful". Wilson (1958) who, as we have already noted, favours the product criterion for assessing creativity, underlines the nature of the individual - social dilemma by noting that different criteria are often adopted for adults and children. He observes that with adults creativity is usually evaluated in terms of a social criterion bases on the 'newness' of a product to society or at least new to the group doing the evaluating, while with children it is more customary to adopt "a psychological criterion in which major emphasis is placed on the newness of an idea or object to the individual who produced it".

Wilson also emphasises the assumption that is made by those making an effort to develop creativity in children, and observes that "it is generally assumed that activities which promote self-expression or doing things which have not been done before are likely to produce adults who will be regarded as creative". Only in the long term will this assumption be readily validated but a belief that it is a sound hypothesis is the foundation of most of the educational developments in the field of creativity on both sides of the Atlantic. Even Burt (1962), critical of the concept of 'creativity' as a type of cognitive functioning distinct from that of intelligence accepts the above assumption in his assertion that "Education cannot create creativity; but it can do much to encourage and develop it".

At the same time it is essential to remind ourselves of the assumption and of the necessity to attempt to validate it in the future. White (1958) reminds us that "so widely has the cult of creativity been adopted ... that it is profitable to stop for a moment and look critically at some of the assumptions lying behind the various ideas which are being currently propagated". In particular he emphasises the need to prevent teachers, especially in Primary Schools, from changing their educational purposes to suit ideas of creativity that are often radically confused.

It would not be profitable to continue with a multitude of definitions of creativity but it is necessary at this stage to suggest the most appropriate working definition from the concensus of the views already discussed.

Bearing in mind the age of the subjects in the present study, putting an emphasis on the thinking process, and adopting the criterion of 'newness' or 'originality' which is an element common to most definitions, the following definition appears to be most suitable:

<u>Creative thinking is present when an individual reorganises his thinking so as to arrive at an idea or product which is new to him and produces 'effective surprise'</u>.

Adopting this definition as a basis it is now possible to continue a review of creative thinking within a framework which will be seen to include a number of theories of creative and productive thinking.

THEORIES OF CREATIVE THINKING

Our definition of creative thinking incorporates Bruner's belief that a creative act can be judged by its resulting in 'effective surprise'. Although this is only part of the definition which Stein (1967) considers necessary he puts it more explicitly, "it is suggested that when the final solution is attained, that is, when there is closure for the individual, he experiences a feeling of satisfaction with the final work, a feeling of exhilaration with the good gestalt". This is indeed the hallmark of making a new discovery even if only 'new' for the individual. To support this criterion, the example is often given of the child who makes a discovery which, unkown to him, has already been made by Pythagoras or Archimedes two thousand years earlier. He has certainly made a discovery 'new for him' but to what extent can it be ranked as a creative achievement comparable with the original discovery?

Kneller (1966) discusses this question with reference to a schoolboy who discovers the third dimension in painting - a discovery which when made by Giotto formed a turning point in Western painting. He does not see the schoolboy's discovery ceasing to be creative just because Giotto revealed it before him, but he judges the creativity to be "of an inferior order, for the schoolboy has the advantage, denied to Giotto, of growing up in a culture of which Giotto's creation is already a part".

The limitation of Kneller's example is that it involves the extent to which the child's experience has already shown him the 'discovery'. A better example is quoted by Kneller from Margaret Mead (1959):

> "to the extent that a person makes, invents, thinks of something that is new to him, he may be said to have performed a creative act. From this point of view the child who rediscovers in the twentieth century that the sum of the squares of the hypotenuse of a right angled triangle equals the sum of the squares of the other two sides, is performing as creative an act as did Pythagoras, although the implications of the discovery for cultural tradition is zero, since this proposition is already a part of geometry".

Even here however one cannot disassociate the child from a society which, as Kneller rightly points out, gives him the advantage of a cultural tradition incorporating this and other mathematical discoveries. Nevertheless, Kneller's discussion seems to be in agreement with the definition adopted above and he appears content to accept the criterion of creative thinking as being 'new to the individual', provided it can be limited to a certain 'level' by appropriate description. Even if this rider were adopted however, it is still unlikely that all would accept that learning, which involved some new insight on the part of the child, could be regarded as creative. Burton (1943) for example believes that though a child often discovers new knowledge he does not create it, and he would reserve the term creative for the production of something new, unique, and original.

In spite of this there are many psychologists, particularly of the Gestalt school who have made a sound case for recognising a new pattern of thinking as a creative act. The solution to a problem, for example, which necessitates, for the individual, a 'recentring' or reorganising of the elements of a situation so as to achieve an 'insight' or new understanding of the relations within the task. This theory fits in readily to the framework provided by the definition of creative thinking already adopted.

It is also possible to compare the idea of 'recentring' with one of the factors which Piaget (1950) emphasises as necessary for the development of adaptations in children's mental structures or schemata. For Piaget the term 'decentring' indicates the extent to which an organism can control shifts of orientation - as it 'sees' things in different ways so the child's schemata are modified, creating by accommodation the new 'organisations' of adult intelligence. In this sense "life is a continuous creation of increasingly complex forms and a progressive adaptation of these forms to the environment" (Piaget 1953).

It was perhaps this interpretation of creative which Dienes (1960) had in mind when he maintained that "when a child has effectively formed a concept from his own experiences he has really created something that was not there before". This contrasts with Burton's interpretation noted earlier; for Dienes, the child could shout 'Eureka' with justification but for Burton it would be at best an exaggeration of discovery. For a fuller account of some of the conditions and criteria necessary for an 'Eureka Act' as he terms it, we shall turn to Koestler's classic theory of the act of creation.

KOESTLER'S THEORY OF AN ACT OF CREATION

(1) The Eureka Act

Koestler (1964) explains the creative act in terms of what he calls a 'bisociation' of two hitherto separate and habitually incompatible frames of reference or codes of behaviour. The routine skills of thinking he sees as taking place on a single 'plane' and the creative act as operating in more than one frame of reference. The phrases 'planes of thought', 'frames of reference', 'universes of discourse', or 'associative contexts' are interchangeable throughout Koestler's theory, and he adopts the word 'matrix' to denote any ability, habit, skill or pattern of behaviour governed by a 'code' of fixed rules. The matrices will be conventionally represented as planes in the diagrams which will follow.

His theory is best illustrated with the aid of one of his examples - Archimedes' discovery of his famous 'Principle'.

Hieron, King of Syracuse suspecting that his crown, allegedly of pure gold, had been adulterated with silver by a dishonest goldsmith, asked Archimedes to turn his mind to investigating the problem. Archimedes knew the specific weight of gold but was faced with the problem of determining the volume. It would have been easy if he could have melted it down and measured the liquid gold by the pint, or if he could have hammered it into a rectangular sided brick, but these and any other such methods were impossible without ruining the crown.

Koestler pictures the 'blocked' ideas increasing stress and imagines Archimedes' thoughts "moving round in circles within the frame of his geometrical knowledge, finding all approaches to the target blocked, and returning again and again to the starting point". This is the familiar situation familiar to everyone who tries to solve a difficult problem and is schematized by Koestler in the following diagram:-

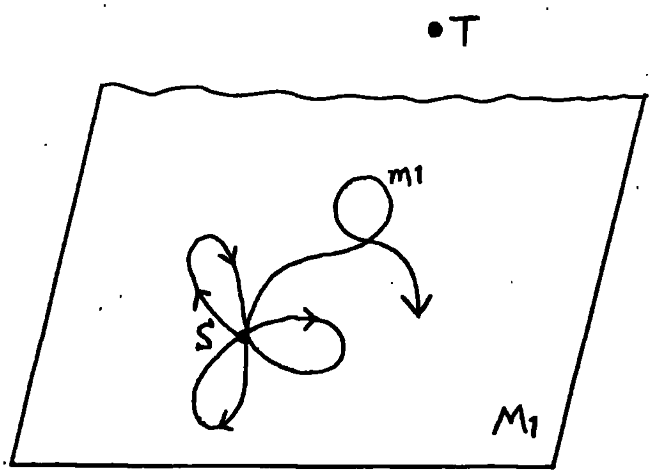


Figure 1.

'S' represents the starting point, and the loops m1 are the trains of thought within the blocked matrix M1. 'T' represents the target (i.e. a method of measuring the volume of the crown) which, unfortunately, is located outside the plane M1.

Then one day Archimedes, while in the bath, realised in a flash that the volume of water displaced when he entered the bath was equal to the volume of the immersed parts of his body - and that they could therefore be measured by the pint!

As is often the case after such 'insights' the discovery looks childishly simple - but before it came there had been no connection in Archimedes' mind, nor in anyone elses, between the commonplace associations of taking a bath and the scholarly pursuit of the measurement of solids. Suddenly for Archimedes the two "planes of thought" were bisociated, and at that instant he realised that the amount of rise of the water-level was a simple measure of the volume of his own complicated body. The act of discovery is schematized by Koestler as shown in Figure 2.

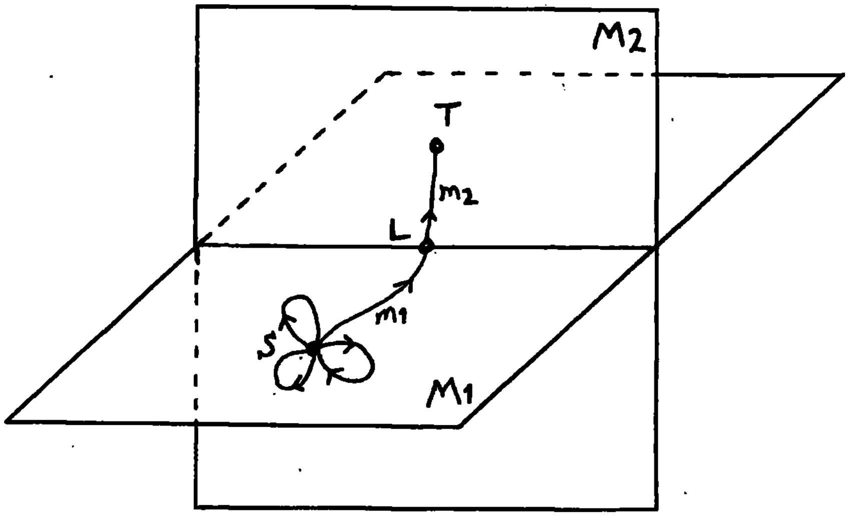


Figure 2

The matrix M1 is the same as in Figure 1, with the train of thought m1, governed by the habitual thought routines, "going round in circles". M2 is the matrix of associations related to taking a bath and m2 represents the new train of thought which effects the connection. The link L may have been a verbal concept or a visual one, the essential point being that at the critical moment both the matrices M1 and M2 were simultaneously active in Archimedes' mind. Koestler explains it in terms of the creative stress resulting from the blocked situation keeping the problem 'on the agenda' even while the beam of consciousness was drifting along quite another plane. I shall note later a similar sort of unconscious mental activity, described by Princaré as eventually leading to sudden illumination of a problem.

The sequel to Archimedes' discovery being so well known Koestler subsequently refers to this sort of discovery in its psychological aspect as the 'Eureka process' or 'Eureka Act'. Although the ingredients of such a discovery are often very well-known as separate parts, for instance the phenomenon of the rise in water level when one enters the bath, Koestler suggests that it was probably the verbalisation or conscious visualisation which made the implicit rule a consciously formulated piece of knowledge. As he notes "discovery often means simply the uncovering of something which has always been there but was hidden from the eye by the blinkers of habit".

(2) <u>Association, Bisociation and Creative Problem-Solving</u>

Koestler's interpretation of the creative act as one of 'bisociation' throws light on the interpretation of problem-solving as a process of creative thinking. Accepting that there is also a personality aspect to problem-solving - that some people sense a gap or refuse to tolerate an ambiguity when others are content with the status quo (cf. Guilford's 'Sensitivity to Problems') - the process of thinking involved in problem-solving is well explained in terms of Koestler's theory.

He notes that in studying the problem-solving situations of Dunker and Maier he found routine solutions combined with intimations of originality, the latter often in an embryonic shape but incorporating factors which he saw as part of the creative process. He is therefore committed to degrees of originality, reminiscent of Knellers 'levels', and contends that problems are usually solved somewhere between the two extremes of 'routine method' and 'flash of genius'. In doing so he is prepared to accept 'minor bisociative acts' or lesser acts of creativity than his unqualified term 'bisociation' implies.

In terms of Koestler's theory problems can be solved by means of associative thought where the thinking operates among the elments of a single matrix, or by means of bisociation in which hitherto autonomous matrices are brought together into a creative act. However there is a further criterion, for at times, even though all the information is "coded" in one plane the data may be presented in such a form that existing strategies in that plane are insufficient for the subject to arrive at the solution. In this case the matrix 'goes to pieces' and recombining them requires a certain originality. Koestler suggests that "We might even be generous and say that to combine them would be a minor bi-sociative act". In other words originality can be measured on a qualitative scale and any self-taught, novel solution to a problem is a minor-bisociative act.

This can be illustrated by one of Dunker's famous problems quoted by Koestler as an illustration of a minor-bisociative act.

Two trains a hundred miles apart start moving towards one another at 20 m.p.h. A bird sitting on the front of one of the trains is frightened when it starts and flies away at 30 m.p.h. in a straight line along the railway track until it meets the other train. It then reverses direction until it meets the first train, then turns again and so on. What distance will the bird cover to and fro in its flight until the two trains meet?

The problem is to compute the distance d, flown by the bird, and some subjects would attempt to compute the sum of the flight stretches. This however is a complicated task and there is a much easier way. The subject needs to think aside, forget the distances for a moment and compute the time until the two trains meet i.e. $2\frac{1}{2}$ hours. The bird has therefore also flown for $2\frac{1}{2}$ hours so it has flown 75 miles.

For the latter solution the subject needs to 'recentre' his thinking and switch his attention from the spatial to the temporal aspects of the process. All the ingredients for solving the problem would be readily available to most people - it is in reorganising the data to see the problem in a new light that the minor-bisociative act - or lesser act of creative thinking - takes place.

CREATIVE THINKING AS PROBLEM-SOLVING AND IMAGINATION

Koestler's description of a minor creative act taking place in problem-solving prepares the way for a closer look at the part which problem-solving plays in attempts to explain the nature of creative thinking. It is certain that a wide range of abilities dictate the quality of creative thinking; intelligence, skill, personality, imagination, and problem-solving ability will all play their part. Vinackre (1952) however sees the essence of creative thinking in the latter two abilities and he suggests that "Creative activity can best be understood if it is defined as a combination of problem solving and imagination." The importance of 'imagination' or some 'creative energy' is supported by most studies of creative abilities. Gutman (1967) sees "the ultimate source of creative activity" as "related to man's basic biological nature". This is the 'extra something' that allows the person to conceive of and solve new problems. "Creativity", he says "is more than problem-solving, although that is certainly part of it".

It is worth noting at this stage that 'problem-solving' does not necessarily imply 'mathematical' problems though this is the image that the word 'problem' evokes. Mathematical and logical problems are commonly used in investigations of thinking largely because they are experimentally convenient, the problem solving need not have an 'external' solution at all - the creative situation might arise, for example, from some personal problem and the 'correct' solution by one which in some measure satisfies the internal needs of the creator.

It is worthwhile to look more closely at these problem-solving and imaginative aspects of creative thinking and at the theories which support them.

1. Problem-Solving

In analysing behaviour in a problem-solving situation Vinackre (1952) distinguishes the following three stages:-

(i) Confrontation by a Problem

A situation is present involving a goal together with an obstacle between it and the individual. The individual must then come to some realisation that the situation exists. Motivation to overcome the difficulty ensues, accompanied by an effort to attain the goal.

(ii) Working towards a Solution

This is the essential intermediate period where the individual engages in activity to relieve the tension built up by the first stage. In attempting a solution the individual engages in activities that typically include three kinds of response, mental or symbolic processes, manipulation, and verbalisation; all three perhaps occurring simultaneously.

(iii) Final Stage

Ultimately the individual may reach the goal and achieve understanding and relief of tension, or he may fail to reach it and this recognition too may bring relief.

The exhilaration of completing Stage (iii) successfully is similar to the satisfaction noted by Koestler on achieving a creative 'Eureka Act', and the 'effective surprise' seen by Bruner as the result of a satisfactory creative conclusion. The intermediate stage of Vinackre's analysis is also reminiscent of the preliminary processes to Koestler's creative activity of bisociation.

Extensive investigations of the crucial 'intermediate' stage in problem-solving have been conducted with animals, in particular Thorndike with his cats, Skinner with rats and pigeons, and Köhler with his famous chimpanzees. While the former have experimented within a learning framework which usually points to a conditioning process of trial and error or instrumental learning, Köhler has interpreted some of his results in terms of real 'understanding'. The Gestalt school in general have developed a concept which they term 'insight' to describe a subject's sudden understanding of the relations within a task - as opposed to blind, fumbling trial and error.

Köhler's experiments with chimpanzees (1957 (1927)) are well known in this context, the following illustration being characteristic.

Nueva, a young female chimpanzee was tested soon after arriving in captivity. After being allowed to play for some time with a stick some bananas were placed outside the cage out of her reach. After several unsuccessful attempts at grasping the fruit the chimpanzee gives up and throws herself on her back moaning in despair. "Thus, between lamentations and entreaties, some time passes, until - about seven minutes after the fruit has been exhibited to her - she suddenly casts a look at the stick, ceases her moaning, seizes the stick, stretches it out of the cage, and succeeds, though somewhat clumsily, in drawing the bananas within arm's length. Moreover, Nueva at once puts the end of her stick behind and beyond her objective. The test is repeated after an hour's interval; on this second occasion, the animal has recourse to the stick much sooner, and uses it with more skill; and at a third repetition, the stick is used immediately as on all subsequent occasions" (Köhler (1957))

It appears that the animal achieved an original, independent solution to the problem, and it is certainly in a different category from a process of conditioning or trial and error. In Koestler's terms it is a good example of bisociation between two hiterto independent matrices; on one plane the chimpanzee knows that it can stretch out and reach for things with its arms or legs, and on the other plan it can think of the stick in terms of playing and scraping. When the two trains of thought are brought together to form the solution, real creative thinking, bisociation, has taken place.

Neither Koestler nor Vinackre, however, are entirely happy with the use of the word 'insight' to describe a form of thinking which implies an 'all-or-nothing' process. They see the final attainment as a more gradual process whose success is partly dependent on the raw materials available and is therefore a matter of degree. Nueva's problem for example would be far more difficult for a chimpanzee who had not had the chance to acquire previously the skills of using the stick and reaching for things. Hebb (1958) makes the explicit conclusion that "a new insight consists of a recombination of pre-existent mediating processes, not the sudden appearance of a wholly new process". He agrees though that such recombinations are a frequent occurrence and that "in a theoretical framework we must consider them to be original and creative".

It is not always clear what even the Gestalt psychologists themselves really mean by 'insight' but the foregoing suggests that Vinackre's definition of insight as a mode of attack to be contrasted with trial and error is generally acceptable. He reserves the term for "an approach where the inner relations, or basic principles are sought" (Vinackre 1952), and in this he includes both exploratory activity and a controlled approach where a definite inner relation is being sought.

In connection with problem-solving the works of Dunker (1945) and Wertheimer (1961 (1945)) are particularly designed to be illustrative of the concept of 'insight' and of the gestalt approach to problem solving. Both concern themselves not so much with the solution of a problem as with the thinking process that has led to it. A solution in itself may be arrived at by unimaginative routine methods - by what Dunker terms 'resonance' and Wertheimer 'B-processes'. These methods involve the application of already learned techniques and are obviously not creative, and 'productive' only in a very narrow sense. The real essence of 'productive thinking' for both writers lies in the reorganising of the elements of a siutation or in the utilization of objects in new ways so as to achieve what they describe as a 'good' gestalt. Productive thinking for Dunker and Wertheimer is therefore the creative solution which Koestler associates with bisociation and Vinackre with imaginative problem-solving.

Wertheimer's book 'Productive Thinking' is of particular relevance to a study of children's creative thinking as he focuses much of his attention on problems from the classroom and on the pedagogical implications of his theory. His message for teachers is clear in his insistence on <u>meaningful</u> learning, and he emphasises that productive thinking is a process involving structural insight and structural mastery and not blind trial and error or the application of routine drill. One of the tests to be used in the present study will be designed on the basis of his recommendations.

As a basis for his theory Wertheimer looks at an example in which a class of children are being taught that the area of a parallelogram is equal to the product of the base and the altitude. The proof given by the teacher is based on the familiar shaped parallelogram ABCD shown in Fig.3, in which the perpendiculars DX and CY form the rectangle DXYC and the congruent triangles AXD and BYC

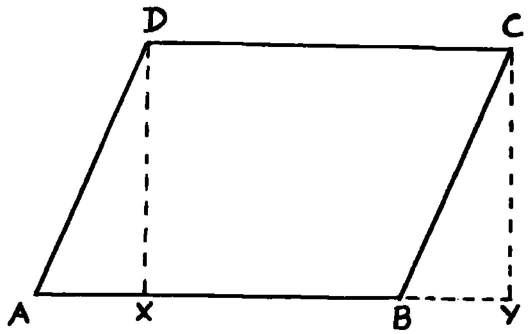


Figure 3

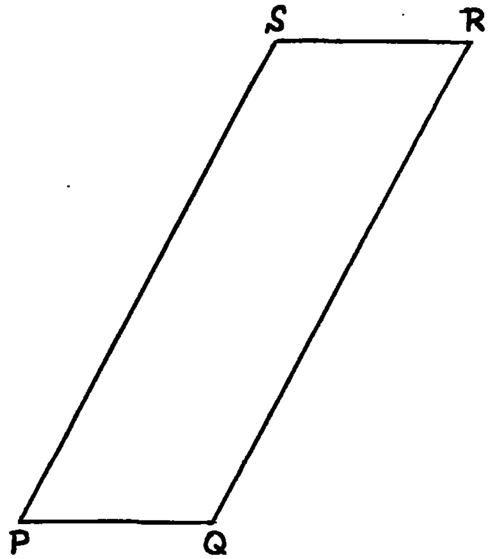


Figure 4

Wertheimer's question to the children entailed looking at the area of the parallelogram PQRS (Figure 4). The reactions of the children fell into two groups; the majority claimed that "We haven't had that yet" or made blind attempts copying the construction of the first case by dropping perpendiculars onto PQ as base, some others however changed the figure sensibly and dropped the perpendiculars onto QR. Wertheimer classes the responses in two ways; A-responses in which the figure is changed sensibly showing an understanding of its structure, and B-responses in which the learned responses are applied blindly and unsuccessfully.

The central processes mediating a successful result to a problem are seen by Wertheimer as centring, grouping and reorganising so that the structure of the problem becomes clear. Polya (1965) has the same thing in mind represented in the following diagram:

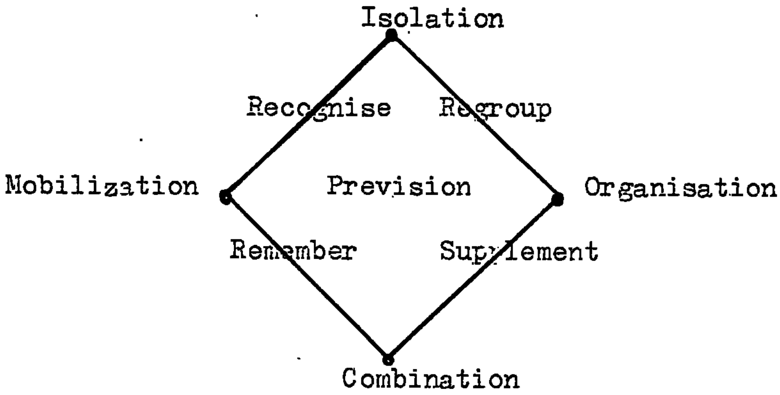


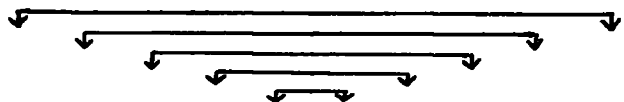
Figure 5

Pairs of opposite vertices and opposite sides represent complementary activities and 'Prevision' is the centre of problem solving activity aimed at the solution. The 'mode of conception of the problem' is continually changing as the problem-solver keeps on mobilizing and organising, isolating and recombining, reorganising and remembering all sorts of elements, regrouping and supplementing, in order to foresee the solution. If prevision comes abruptly, in a flash, we are said to have had an inspiration or illuminating idea and for Polya the central desire is to have such an idea.

Polya's attempt to distinguish between productive and creative thinking is not very illuminating, except that it makes the point that "the problem-solver may do creative work even if he does not succeed in solving his own problem" for "his efforts may lead him to means applicable to other problems". (Polya 1965) Thinking is productive, however, if it produces the solution to the problem in hand. By this criterion it is evident that, for Polya, creative thinking may not be productive and productive thinking need not be creative. As observed earlier, however, the Gestaltists normally understand productive thinking to involve the degree of insight and effective surprise that makes it creative. Wertheimer (1961), for example, in relating what he feels is characteristic for a child facing a new task and achieving a productive solution, observes that the child "ponders over it, then suddenly cries "I've got it'." and having understood the situation, the means and the goal structurally, he goes at this new task and solves it easily".

Both Wertheimer (1961) and Poly (1954) refer to the story of the young Gauss almost instantaneously solving a problem involving an Arithmetic Progression. The problem, simplified, involves the summation of a series for example: 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10.

If the terms are grouped as shown below the sum remains unchanged and is 'seen' to be five elevens



1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10

The essential feature of this solution to the problem is the reorganisation of the elements according to the structural inner-relatedness of the operations. It is this type of problem which will be used in the 'Wertheimer' test in the present study, and is looked at more closely when the tests are discussed later.

From another aspect Wertheimer sees productive thinking as involving processes of transformation which, by means of envisaging, recentring and regrouping, manage to close or reduce gaps or inconsistencies in a situation. A good solution is attained when "the gap is filled adequately, the structural trouble has disappeared," and "it is sensibly complete". Bartlett (1962) describes thinking in much the same way, seeing it as essentially a gap-filling process in which a gap is required to be filled in accordance with whatever evidence is available. The items of a situation have to be "brought into specific relation, ... in such a manner that they satisfy a requirement laid down".

There are three kinds of gap filling processes considered by Bartlett, and he maintains that all thinking appears to illustrate one of them. The first two involve 'interpolation' or 'extrapolation', which respectively fill a gap between information and then more information, or develop incomplete information. The third type more closely resembles the mode of thinking of the creative problem-solver: "It requires that the evidence given should be looked at from a special, and often unusual point of view, and that it should be recomposed and reinterpreted to achieve a desired issue". The three processes function within what Bartlett calls a 'closed system' containing a limited number of units with well defined properties, but which can be arranged in a variety of orders and relations. It is neither the commonest nor Bartlett observes "in any sense of the term, the 'simplest' form of thinking".

There is also an 'adventurous' type of thinking which takes place within a more open system in which the thinker is "less detail ridden" and "more schematic minded". Finally, there is a rapproachment between the freedom of the adventurous thinker and the need to obey the restrictions and principles of a closed system, in what Bartlett terms the 'effective thinking' of the original scientist.

In one of his experiments Bartlett asks subjects to work out a question of "simple arithmetic in disguise" in which they are asked to decipher the following addition sum:

```
   DONALD
+  GERALD
   ROBERT
```

The letters stand for distinct numbers from 0 to 9 and it is given that D = 5. The subjects are required to find the numbers corresponding to each letter. Only a very elementary mathematical knowledge is needed but the subject needs to penetrate the 'disguise' and use his knowledge in a different way. Some of the people attempting the problem were reported by Bartlett as being unable to give up trying to 'apply a method' even though they found it unrewarding.

The necessity for a subject to vary his approach and see the problem in different ways is a characteristic we have seen in other theories, and it is often the mark of great discoveries of the past that the experimenter was ready to reverse his beliefs and alter radically a method of approach which was the one commonly accepted. Whether the characteristics of 'risk-taking' and 'flexibility' possessed by some of Bartlett's most successful solvers in any way resembles the intellectual courage needed to challenge currently accepted theories is only a tenuous conjecture but it is interesting to note that Polya maintains that great discoveries in mathematics often occur "by observation and daring guess" Polya(1954).

Though he prefers not to use the phrase himself, Bartlett observes that in the above type of question "we get something that comes very near indeed to what has usually been called 'problem-solving'". His objection to the phrase, as Polya also observed earlier, is that it has the misleading inference that only a correct solution can involve the right sort of 'high-level' thinking, and he notes that very often "'efficient' thinking opens up more questions than it closes".

It was noted earlier that problem-solving is often seen as part of a creative thinking process but that many writers emphasise a further 'plus' element. Russell (1956) for example interprets the 'plus' as "putting isolated experiences into new combinations or patterns - by trial and error, insight or some other operation -". Although, as we have seen, this element is implicit in the theories of 'productive' problem solving already discussed, it is in fact the essence of the creative aspect of the problem-solving process. Guilford indicates its presence by observing that "all problem-solving that is 'genuinely' problem-solving is creative" (Guilford 1967b); and Mednick (1962) in his associative theory of creative thinking, mentioned earlier, sees creativity in terms of new combinations which, in meeting specified requirements or being useful in some way are solving certain 'problems'.

Most explanations of the process of creative problem-solving have at least implied the presence of this 'extra something', and many experimenters have chosen to approach it in terms of 'imagination'. The famous evidence of Poincaré (1968 (1906)) is very relevant. Describing the creative process from his own experience he tells of his efforts to solve a certain problem and of the "combinations which present themselves to the mind in a sort of sudden illumination".

It is the latter, seemingly irrational, part of the process of creative thinking, often arising from the anecdotal evidence of creative persons, that has received psychological attention in terms of 'imagination'.

2. Imagination

The role of imagination in creative thinking is currently regarded as part of the continuum of thought processes although traditionally it was seen in terms of 'images' distinct from the other mechanisms of thought or 'ideas'. The concept of mental 'structures' developed with the associationist school championed early in this century by E. B. Tichener who Vinackre (1952) quotes as saying that "thought is the verbal counterpart of active imagination. Active imagination is thinking in images". The images were claimed to be independent elements from which the ideas of thought were composed. The early work of Galton, Binet and Woodworth, however, cast doubt on the universality of imagery in mental processes and though images are often present in all forms of imaginative thinking, they are certainly not essential to it. Thouless (1960) for example points out an experiment which was carried out by Betts in 1909 which demonstrated the independence of a mental ability from its supposed dependence on the use of imagery.

Although the study of 'imagery' has lost its interest for psychologists (Guilford (1967a) observes that most of the attention to the subject went out of the window when behaviourism came in the door, and Burt (1962) notes that "Concepts like 'imagination' or 'productive thinking' savoured too much of discredited introspectionist doctrines and were deliberately excluded from behaviourist text books") it made clear the important conclusion that whatever the constituents of the mental process it is not completely understandable in terms of "conscious" element alone. The use of the word 'imagination' has consequently regained some credence as a description of those internal activities of thought which contrast with more realistic or externally directed thought.

Imagination, in this sense, is often included in 'Stage' theories of creative thinking, as a phase relatively free from external strictures prior to the incorporation of certain of its aspects in the final 'concrete' product.

STAGES IN CREATIVE THINKING

Although many highly creative persons show distinctly individual characteristics in their thinking, several general aspects have been widely identified. Wallas (1926) suggested that there were four familiar stages which he labelled 'preparation', 'incubation', 'illumination' and 'verification'. His categorising was intended for the purpose of more conveniently examining the creative process and has proved fruitful for many subsequent studies of creative individuals. Although he accepted that the pattern of creative thinking is seldom as clear-cut as his series of four steps, they have received a good deal of verification.

In particular a series of studies by Patrick (1935, 1937, 1938) found evidence for the four types of activity suggested by Wallas and in general she put them, with some exceptions, in a similar order. Patrick's experimental procedure, however, comes under fire from both Hadamard (1949) and Vinackre (1952) who, in particular, consider the time allocated to her subjects - hardly more than 20 minutes - insufficient for her to have identified a period of incubation anything similar to that intended by Wallas or recalled in auto-biographical accounts of creative experiences such as those of Helmholtz or Poincaré.

The experiences of 710 productive inventors were analysed by Rossman

(1931) in an investigation into the creative process and he formulated the following seven stages in creative production:-

1. Observation of a need or difficulty.
2. Analysis of the need.
3. Survey of all available information.
4. Formulation of objective solutions.
5. Critical analysis of the solutions.
6. The birth of the new invention - the idea proper.
7. Experimentation to test out the idea.

With the exception of the 'incubation' stage this list can be grouped in a very similar fashion to that of Wallas, and both lists correspond closely with an analysis of the essential stages of problem-solving described by Dewey (1933). Dewey's analysis consisted of five stages:-

1. Recognition of a problem:- Occurring in some disturbance of perpelxity, doubt, confusion or recognition of a need.
2. Analysis of the problem:- A period of searching, enquiring, and assembling of material bearing on the problem.
3. Suggestion of possible solutions:- As a result of Stage 2 the problem is seen more definitely and hypotheses for solution are made.
4. Testing of the consequences:- The possible solutions are elaborated and tested.
5. Judgement of the selected solution:- This final stage evaluates the solution resulting from Stage 4 by overt or imaginative action.

The Incubation Stage and the role of the Unconscious

Although the analyses of Rossman and Dewey lend support to the role of problem solving in creative thinking, discussed in the last section, they tend to neglect the period of 'incubation' reported by Wallas and put more emphasis on the structural thinking of the disciplined reasoner. In doing so they consequently neglect the role of 'imagination' and the unconscious in the creative process. Without extending the concept of creativity to an entirely psychoanalytic standpoint, Rugg (1963) has stressed a multi-disciplinary approach and the need to distinguish the creative acts of discovery from the concrete, reasoning acts of logical verification.

He stresses the importance of a theory which is concerned with the pre-logical and pre-conscious rather than the logical, analystical and the conscious. He believes that the first key to an explanation of creativity is the fact that "the creative flash of insight takes place in the trans-liminal, across-the-threshold border between the unconscious and the conscious states". Both he and McKellar (1957) approach the subject with the same belief in a continuum from conscious to unconscious and stress the importance of not only dealing with the "tiny, censorious conscious part" Rugg (1963). McKellar argues further "that it is fruitful to regard human thinking as ranging from logical reasoning and scientific theorizing, through creative imagination, dreams and related experiences, to the hallucinations of psychosis or 'insanity'".

This view is supported by Kneller (1966) who suggests that though especially strong in the 'preconscious', imagination and creativity are present in some degree at all levels of mental activity. This is a departure from the orthodox Freudian belief, that creativity originates in a conflict within the unconscious, as it emphasises the importance of a 'preconscious' origin for the creative process. The preconscious is a halfway stage between the unconscious influences, which are linked to repressed conflicts and impulses, and the conscious which is conventional and reality orientated. Its effectiveness for originating creative thought is seen in the degree to which a person can operate flexibly in the preconscious, assailed as it is by the opposing forces of reality and the unconscious.

In the Freudian view (1949) the tension in the 'id' is the driving force for creativity. It produces a possible solution to the conflict which is either repressed by the ego, or, if it is compatible with the reality orientated ego, will be expressed in creative behaviour. The energy generated by the unconscious is therefore the motivating force of both the creative person and the neurotic.

More modern developments of the classical Freudian theory, however, are less prone to couple creativity with the neurotic elements of the unconscious and some in fact emphasise that the ego of a creative person must be well-balanced, flexible and secure if he is to realise his full potential (Anderson, 1959).

There are obviously complex reasons why people with apparently similar intellectual abilities reach quite different levels of creation and there are widely differing theories. One point of departure of psychoanalysts' views is especially interesting, however, for whereas in the traditional Freudian view a person creates, just as he eats and sleeps, in order to allay certain drives and regain a state of equilibrium, there is a more positive view which sees motivation in terms of satisfactory interaction with the environment or "competence motivation" (White, 1961). There is, in White's view, a drive of an intellectual nature which stimulates creative exploration and experiment. This is similar to the theory of creativity put forward by Rogers (1962), in which motivation for creativity is seen as being stimulated by a drive for 'self-actualization' in one's environment and by an urge to fulful oneself in self-realisation.

The latter views are more in line with the more 'concrete' approaches to creative motivation such as that of Rossman (1931) who argues that "the assumption that the subconscious is responsible for the final condition is no answer to the problem". Rossman supports his conclusion from his study of inventors who were motivated by a dominant driving force which was the thrill of surmounting real difficulties or being involved in tough problem-solving. Nevertheless, although such theories see the incubation period as only "a charming but futile substitute for an explanation" (Guilford, 1967b), it is part of the answer given in their accounts of their discoveries by many men famous for their creative work.

Hadamard (1949), for example, quotes the classical cases of Helmholtz and Poincaré who stress their own experiences of the unconscious, and maintains that his experiences accord with those of Poincaré whom, he says, "attributes to the unconscious not only the complicated task of constructing the bulk of various combinations of ideas, but also the most delicate and essential one of selecting those which satisfy our sense of beauty and, consequently, are likely to be useful". Hadamard reaches the conclusion, again supporting Poincaré, that invention consists in the building up of numerous combinations, often he says in what Francis Galton terms the 'ante-chamber of consciousness', and choosing those which are useful. This conclusion is very much in line with Mednick's (1962) associative theory of creativity in which as we have already noted, creative thinking is seen as arising from the association of elements into new combinations.

McKellar (1957) quoting from the same autobiographical account of Poincaré which has already been noted (1968 (1906)) interprets the account in terms of creative stages and emphasises the role of the unconscious. He observes that Poincaré found "a period of preliminary conscious work ... always precedes all fruitful unconscious work" and regarded such thinking as a process of recombination of ideas which he likened to 'hooked atoms'. During the incubation period of unconscious work these 'atoms' collide to give new combinations. The process is not mere chance however for the ideas selected are those from which the desired solution could reasonably be expected. The preparation period is stressed for it is during the period of conscious work that the hooked atoms are liberated.

Stressing the importance of the incubation period McKellar emphasises that it no doubt plays a major part in the production of what he also calls the "Eureka experiences" or "sudden insights whose importance is often stressed by creative thinkers". Referring direct to Poincaré however it is worth noting that he does not give all the credit for his discoveries to the subconscious but notes that he "should hate to accept that ... the subliminal self is superior to the conscious self" Poincaré (1968 (1906))

The concept of stages in creativity is brought up to date by Guilford (1967b) who stresses its similarity to stages in problem solving and puts forward a general "transfer theory of productive thinking" to account for both. He formulates the theory within the framework of his 'structure of the intellect model' and though he indicates the special role of the divergent production abilities he emphasises that most of the abilities demonstrated in his intellect model have their parts to play.

He sees the generation of creative ideas being effected by a process of recall of information - but in connections other than those in which it had been originally learned. This infers a 'transfer of cues' and hence the title of the theory. There are four main stages:

1. An initial sensitivity to a problem situation.
2. An analysis of the problem.
3. A 'search' through stored information for relevant ideas.
4. Periods of evaluation (not necessarily confined to a final stage).

The divergent thinking abilities are seen as playing their fundamental part in the third stage where the effectiveness of retrieval depends on fluent production of information, flexibility to prevent the search from becoming too limited in scope, and transformation, redefinition and elaboration to achieve new insights and make new connections. We shall look more closely at these abilities, postulated by Guilford, later.

3. A BI-POLAR THEORY OF CREATIVITY

The respective roles in creative thinking of problem-solving and imagination are well summed up by Thompson (1959) who considers creativity as a bi-polar activity involving a 'switching of gears' between the 'Imaginative'pole and the 'Realistic' pole. He distinguishes the former as being the product of the unconscious part of the personality, determined by a motivational state and resulting in a free flow of ideas, while the latter is a region of deliberate organisation and control of data, application of skills and techniques, and the editing of one's own thought products. Problem-solving is seen as geared to the realistic pole with imagination playing just as important a part in truly creative thinking.

McKellar (1957) also distinguishes similar poles of thinking which he calls R-thinking (reality-adjusted thinking) and A-thinking (Autistic thinking), the latter being represented in 'imaginative experiences' such as dreams, nightmares, hallucinations, fantasy and reverie. It must be remembered, however, as McKellar himself points out, that thinking is more likely to range through a continuum of thought processes than be confined entirely to one or other pole. Part of the explanation of the nature of creative thinking no doubt lies in acknowledging that creative abilities are a matter of degree.

No great discoveries could emerge from entirely fanciful speculations, but a relaxed state of reverie has often been the source of key concepts which have later been orientated towards reality. Descartes is said to have seen in a dream the basic idea of his analytical geometry, Kekulé to have evolved the concept of the benzene ring from the pictorial content of a dream, and Poincaré to have discovered the existence of the Fuschian functions after a surfeit of black coffee and a sleepless night.

Perhaps it is still only a 'stop-gap' concept but for many 'imagination' clearly remains part of the psychological explanation of creative thinking. Taylor (1959) plainly maintains that "fantasy associations and relaxation for unconscious play are so essential for creative thought that creativity cannot be subjected to the same interpretations as logic, and scientific method".

There are obviously wide individual differences both in the pattern and degree of creative thinking, some creators being motivated by the need to serve extrinsic ends, others by internal needs, conflicts or desires. Typically, however, it is likely that the creative process runs an intermediate course, varying between and combining the realistic and the imaginative factors.

GUILFORD'S THEORY OF CREATIVITY AND HIS STRUCTURE-OF-INTELLECT MODEL

Guilford, as was noted earlier, is not content to describe creative thinking in terms of 'charming but futile' substitutes for an explanation, such as incubation, and makes an attempt to explain creativity in terms of a factorial conception of personality in which all individuals possess patterns of primary abilities which govern their capacity for creative thinking. The creative personality therefore is built up of a unique pattern of traits including the potential creative abilities and the other primary traits such as interests, attitudes and temperamental variables which affect creative production.

In his famous Presidential address to the American Psychological Association (1950) Guilford reawakened interest in creativity and suggested a number of tests and hypotheses of creative abilities which have had a profound effect on the subsequent developments. He expressed the belief that creativity and creative production extend well beyond the domain of intelligence and pointed out the inadequacies of the common, stereotyped intelligence test which has developed out of demands for objectivity and scoring convenience.

Fundamental to his theory of creativity is his belief that everyone possesses all abilities to some degree and that whatever the nature of creative talent, those persons who are recognised as creative merely have more of what we all have. He maintains that "Creative acts can therefore be expected, no matter how feeble or how infrequent, of almost all individuals." This belief, together with the definition of personality as a unique pattern of traits, and the techniques of factor analysis, are basic to Guilford's subsequent theory. Although there may be thousands of traits, many will be interrelated, and by incorrelation procedures Guilford suggests that it will be possible to determine the threads of consistency that run through the various categories and reduce the number of variables.

His conception of the intellect is therefore that of a multitude of primary abilities, different abilities being involved in answers to different tests. He therefore proposed that a fruitful exploration of the domain of creativity would be through a complete application of factor analysis, beginning with carefully constructed hypotheses and tests concerning the primary abilities and other properties.

The initial hypotheses made by Guilford on the nature of creative thinking were derived with certain types of creative people in mind, particularly the scientist, technologist and inventor. Although any factors isolated could also be relevant to the artist, writer and composer, Guilford observed that there might be further patterns of abilities more specific to this category. The factors that formed Guilford's initial hypothosis of creative thinking abilities (1950) are summarised as follows:-

(i) Sensitivity to problems

In postulating this ability Guilford illustrates it by considering two scientists, one of whom attributes a minor discrepancy in his results to experimental error while the other pursues the reason and finds important results. The question is what sort of ability challenged the latter and compelled him to pursue the results?

As possible tests of this ability Guilford suggests asking the subjects to compose as many questions as possible from a paragraph of expositary material, to suggest improvements to common household appliances, or to talk about a picture which has minor irregularities.

(ii) Ideational fluency

This factor is the ability of an individual to produce a large number of responses relevant to some stimulus, verbal or figural. As a test a subject might be asked to name as many objects having a certain property as possible in a given time, or to give appropriate titles to a picture or story.

Fluency of Inferences may be tested by asking for consequences to a hypothetical occurrence, such as a new invention making it unnecessary to eat.

(iii) Ideational Novelty

The creative person has novel ideas. This might be tested in terms of the frequency of uncommon, yet acceptable, responses to items such as verbal associations in a word-association test, or similarities in a similes test.

(iv) Flexibility

An individual's flexibility of mind, the ease with which he changes 'set', can possibly be indicated in several ways by means of tests - with its probable opposite rigidity. For example, does the examinee tend to stay in a rut or does he branch out readily into new channels of thought? Tests whose items cannot be correctly answered by adherence to old methods but require new approaches, would be appropriate here.

(v) Synthesising ability

Much creative thinking requires the organising of ideas into larger, more inclusive patterns. For this reason Guilford hypothesized a synthesising ability.

(vi) Analysing Ability

As a counterpart to the above, this ability is needed whenever symbolic structures are broken down to allow new ones to be built.

(vii) Reorganising or Redefining ability

This ability, from Gestalt Psychology, suggests that there may be a factor involving reorganisation or redefinition of organised wholes, and Guilford observes that many inventions have been in the nature of a transformation of an existing object into one of different design, function or use.

(viii) Span of Ideation Structure

This ability has to do with the degree of complexity or of intricacy of conceptual structure of which an individual is capable. For example, how many interrelated ideas can the person manipulate at the same time?

(ix) Evaluating ability

Creative work that is to be realistic or accepted must be done under some degree of evaluative restraint, and this factor is needed in the selection and evaluating ideas or responses.

Guilford anticipates the question of the validity of his proposed tests and has two answers: firstly there is the factorial validity which will measure each factor and its extent in the tests used, and secondly there will be the practical relation of the factors to creative productivity in everyday life. The latter relation is more long term and will need to be established but Guilford emphasised his conviction that the hypotheses were in the right direction and that "only after we have determined the promising factors and how to measure them are we justified in taking up the time of creative people with tests". He also noted the experimental time which would be wasted if one had to study the practical validity of every test before it is analysed.

This confidence has not been entirely misplaced for although there is still no concensus on what Guilford's tests really measure, they have the practical validity of being able to distinguish between two types of thinker, the 'converger' and the 'diverger'. As Hudson (1968) emphasises "We justify the use of open-ended tests not in terms of their test-retest reliability, but of their external validity - their power to differentiate among variables other than themselves". This being established Hudson continues to observe that "I cannot for the life of me see why research in the field has placed so little confidence in demonstrable differences between convergers and divergers".

Guilford hoped that once factors could be established as describing the 'domain of creativity' we would have a basis for selecting individuals with creative potentials and for providing an education to suit and develop their potentialities. However, although the open-ended or divergent thinking tests used by most investigators owe their origin in considerable part to Guilford's early hypotheses, his hopes of establishing a 'domain of creativity' have not been fully realised.

Writing six years after his original address, Guilford (1956) reported a developing picture of the structure of human intellect as seen in terms of factors, the structure then containing about forty different factors "many only recently demonstrated". Enough were known however to suggest the outlines of a system in which the factors fell into two main groups, thinking and memory; the thinking group containing the majority of items, sub-divided into three groups of factors, cognition, production and evaluation. In each of these sub groups in turn the content of the thinking is arranged as figural, structural and conceptual. A further principle of classification divided both the thinking and memory divisions into the kinds of things produced or remembered.

A multidimensional view of the intellect continued to develop from these beginnings and by 1959 Guilford (1959(b)) had demonstrated about 50 intellectual factors and arrived at the structure of intellect model in its now well-established form containing 120 cells. However, he had already found that two cells contained two or more factors each and the prognosis was of even more than 120 abilities. It is rather alarming to consider how far one might take Guilford's conclusion (1959(b)) that "The major implication for the assessment of intelligence is that to know an individual's intellectual resources thoroughly we shall need a surprisingly large number of scores."

Although he claims that each factor is sufficiently distinct to be detected by factor analysis, Guilford's work revealed that he could group the factors together according to certain ways in which they resemble one another. The grouping of factors, into which Guilford considers one can fit "all kinds of information psychologically" gave him the following classification:

(a) Five groups of Intellectual OPERATION:

Cognition, memory, divergent thinking, convergent thinking and evaluation.

(b) Four kinds of CONTENT:

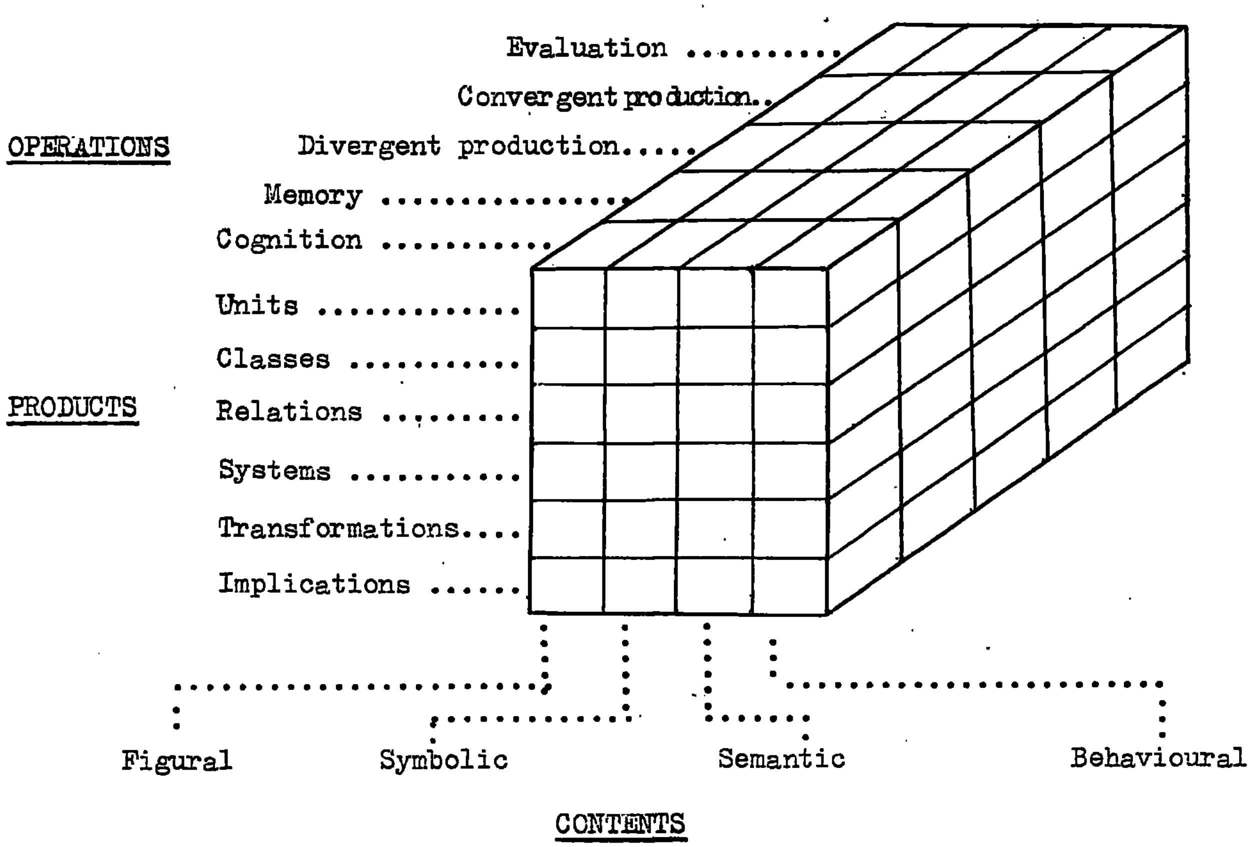
Figural, symbolic, semantic, and behavioural.

(c) Six kinds of PRODUCT:

Units, classes, relations, systems, transformations, and implications

When a certain OPERATION (a) is applied to a certain kind of CONTENT (b) the PRODUCTS (c) can be themselves classified in six different ways. The complete classification consequently has three dimensions which can be represented in a three-dimensional model (which Guilford wrongly labels a 'cubical' model) as shown in Figure 6.

Figure 6 **GUILFORD'S STRUCTURE-OF-INTELLECT MODEL**



In this model of 'The Structural-of-Intellect' each dimension represents one of the modes of variation of the factors in (a), (b) and (c) above, and each cell, one of the 120 hypothetical factors, 82 of which Guilford (1967a) has identified by means of appropriate tests. Of the 24 cells in the divergent-production (DP) category, as envisaged by the Structure of Intellect (SI) theory, 16 had then been investigated and all 16 demonstrated.

Although the nomenclature has changed a good deal the following examples should make the categories more recognisable in terms of some of the creative abilities hypothesised in Guilford's earlier work.

The well-known ability of word fluency, tested by asking the subject, for example, to give as many words as possible beginning with 's' or ending in 'tion' is now regarded by Guilford (1959(b)) as a "facility in divergent production of symbolic units". That is it fits into the 'cell' designated by the operation of divergent-production, the content being symbolic, and the product one of units.

The parallel semantic ability, in which the responses involve verbal meanings or ideas, is known as ideation fluency and is tested, for example, by calling for as many objects as possible which are round and edible.

To illustrate the divergent production of classes one applies a test such as the well-known 'Uses for a Brick' test. If, for example, the subject responds by giving: build a house, build a barn, build a garage, build a school, build a chimney, he would have a score of five for the number of ideas but a very low score for production of classes. To receive a high score the responses need to be flexible and belong to different classes. For example if another subject gave: make a door stop, make a paper weight, throw at a dog, use as a hammer, make a red powder, he would also have five marks for ideation fluency but a much higher score for flexibility of classes of response. The latter ability is therefore described by Guilford as the factor of 'spontaneous flexibility'.

The cell for divergent production of semantic transformations has been shown to be the factor more frequently labelled 'originality', and defined by Guilford as involving shifts, transformations, or changes in the meaning of semantic material resulting in novel, unusual, clever, or farfetched ideas. The 'Plot Titles' test, when marked for clever or unusual responses to its request for appropriate titles to a short story, is a good measure of this factor.

Although the most obvious aspects of creative thinking are related to problem sensitivity combined with the divergent thinking abilities including fluency, flexibility, and the ability to effect transformations, Guilford considers that his model is such that any or all kinds of abilities represented can play their useful roles directly or indirectly.

Some Limitations of Guilford's Theory

Guilford's efforts to extend the concept of intelligence so as to include his categories of convergent and divergent abilities, his interest in Education, and his refined methods of psychological measurement, have all contributed a great deal to the resurgence of interest in creativity. Unfortunately, however, his Structure-of-Intellect model seems to have become largely academic, and the increasing fragmentation of abilities does not seem to enhance the theory of creative thinking or that of intelligence. A multiple-score approach to measurement of abilities may be useful if some particular qualities are sought after for some specific vocation, but there is only limited use for a theory incorporating 120 factors in which, as Guilford himself observes, "Each intellectual component or factor is a unique ability that is needed to do well in a certain class of tasks or tests" (1959b)

Many experimenters such as Burt (1962), Vernon (1964) and Eysenck (1967), have serious objections to Guilford's theory of intellect well beyond its implications for work on creativity, and although it is the productive thinking aspects that are the chief concern of the present study it must be noted that there is general unease at the wider implications of his theory.

Eysenck(1967) makes it clear that many psychologists see a psychometric approach to intelligence as being too far removed from psychological theory, and as relying too much on pure test 'scores' which do not adequately reflect individual differences on test items. Criticising Guilford's theory in particular he suggests that the possibility of infinite sub-divisions in such a statistical approach is almost a 'reductio ad absurdam' of factorial studies of the intellect.

The traditionally British approach to intelligence has followed Spearman in supporting the concept of a general 'g' factor, and is exemplified in the hierarchical models of Burt (1949) and Vernon (1961). Both the latter writers have criticised Guilford's extensions of the factorial approach which is the typical American view of intelligence. In particular, whilst Guilford has stressed the distinct differences between the factors which his tests measure, Burt (1962) notes that the positive correlations between such tests and their positive correlations with more conventional intelligence tests indicate that "a single general factor would fully account for the correlations observed".

In spite of the differences in their conceptions of intelligence, however, Wiseman (1967) suggests that the end products of the American and British views bear strong resemblances and that "No doubt before long further research will bring the emergence of a rapprochement".

Whatever the final verdict, it has been necessary to note some of the limitations of Guilford's theory whilst at the same time recognising its influence on studies of creativity. In the present study, discussion of abilities in the classroom will inevitably return to numerous studies which have been either stimulated by Guilford's work or which have used tests based on his open-ended tests of divergent thinking. A discussion of the effects of the Creativity/Intelligence distinction on Education and particularly on Junior School mathematics is the subject of the next chapter.

CHAPTER 4

CREATIVE THINKING, INTELLIGENCE AND THE DISCOVERY APPROACH

Underlying much of the current educational interest in creativity is the growing dissatisfaction with the conventional intelligence test as a means of assessing the whole of a child's capabilities. Although the development of Guilford's early work has become too purely a psychometric exercise for many psychologists, his early contention (1950), that the correlations between creativity and intelligence tests would be small thereby indicating that many abilities important for creative behaviour are not included in the conventional I.Q. test, is basic to much of the current thinking. Even Burt (1962), critical of much of Guilford's theory of the intellect, agrees that "there can be no doubt whatever that these new tests have succeeded in eliciting supplementary activities that are rarely tapped by the usual brands of intelligence test." The relationship between intelligence and these 'creative' activities is the subject of the first part of this chapter.

(i) Creativity and Intelligence

Much of the discussion of creativity versus intelligence has revolved around what Hudson (1966) terms a question begging approach to labels too arbitrarily applied to the tests. There is no reason, other than for ease and objectivity in marking, why 'intelligence' tests should include items only of the convergent type. Hudson sees the error that was originally made by applying to such tests, the word 'intelligence' being repeated by calling divergent tests ones of 'creativity'. At the same time he values the use of such tests for their demonstratable power in distinguishing between two types of thinker, the converger and the diverger. (Hudson (1968).

Other doubts of the appropriateness of the label 'creativity' as applied to divergent and open-ended tests such as those devised by Guilford, Torrance and others, have already been discussed and will remain until long term validity studies have been carried out. Nevertheless, however valid they are as a means of predicting future creative achievement, it is necessary to consider what such tests are measuring and whether evidence has shown them capable of verifying the existence of a separate domain of cognitive abilities distinct from that of intelligence. Burt (ibid) considers that the evidence hardly suffices to prove that there is no such thing as a general factor underlying all known cognitive processes, though this has been the claim of several major studies and a great number of smaller ones. In particular those of Getzels and Jackson (1962) and Wallach and Kogan (1966) have had the greatest publicity and provoked the most vigorous reactions.

The study of 'Creativity and Intelligence' by Getzels and Jackson (1962) has been criticised as being based on an over-simplified view of the creativity/intelligence distinction and on statistically inadequate data. As Freeman, Butcher and Christie (1968) note however, it has served "to illuminate, in a way which is impossible to ignore, a general dissatisfaction with the tests of intelligence and attainment in current use, and has stimulated a great deal of the re-thinking about their limitations."

The study was carried out with gifted adolescents in a private school in the Chicago area, the greatest proportion of students coming from middle and upper class families and having I.Q.'s well above the average. The mean I.Q. for the sample was 132, with a standard deviation of 15. For the purpose of assessing creativity the authors administered a battery of tests of Guilford/Torrance origin; Uses for Things, Word-Association, Hidden Shapes, Fables, and Make-Up Problems. Intelligence measures were obtained from the school records, and from the results of these and the creativity tests Getzels and Jackson selected two groups, one of adolescents in the top 20% on I.Q., but not in the top 20% on 'creativity', and vice versa.

They then compared these groups on school achievement, aspects of behaviour and attitudes, and how they were regarded by teachers and parents. To put the results in perspective however, it is essential to consider the exact constitution of the two groups resulting from the selection procedure, for the labels applied to them could be misleading. The investigators labelled their groups as 'High Intelligence' and 'High Creative' respectively though in a small footnote on Page 21 they do remind a reader that "Students who were high in <u>both</u> intelligence and creativity were of course also excluded". The reader must nevertheless keep reminding himself that not only is the whole experiment conducted with gifted children but that the 'High Creativity' group, implying low I.Q., will include a substantial proportion of individuals with I.Q.'s above the mean of 132; and that pupils in the top 20% on both intelligence and creativity are excluded. Each of the two groups in fact contains only about 5% of the total sample.

One reviewer writing in the 6th Mental Measurements Year Book (Buros 1965) emphasises the statistical inadequacies of the study and observes that by confining their attention to the 'high' groups and by further excluding the 'high-high' group, Getzels and Jackson used only a very small proportion of the subjects, and that although their stated purpose was to isolate two types of cognitive excellence, the effect of their drastic reduction in the size of the sample was to manufacture two fictitious types of people.

Allowing for the limitations in the statistical design and in the numerical evidence presented in their study (the authors sound a cautionary note themselves on page 62), it is still full of sound educational implications and their anecdotal evidence indicated two very different modes of thinking in the experimental groups. Hudson (1966) suggests that criticisms focussing on the statistics and the implications of the results for the general factor theory of intelligence, are preoccupations with technical red herrings, and he points to the valuable features of the study, the crucial one being its demonstration that "a knowledge of a boy's I.Q. is of little help if you are faced with a formful of clever boys".

Both of Getzels and Jackson's groups turned out to be equally good at school achievement and this, they suggested, showed creativity to be as important a factor in academic success as 'intelligence', and that the divergent thinking abilities should deserve as much attention as is traditionally given to intelligence. Their study was seen in the light of the increasing evolution of a society based on an examination-passing meritocracy judged by conventional I.Q. measures, and in this context their plea for the proper recognition of creative youngsters, too often given the perjurative title of 'overachieves', has considerable educational importance.

Torrance, (1962, 1965) who has been especially concerned with the educational implications and development of creative potential, also sees a serious defect in the use of I.Q. as the sole criterion of giftedness, and he has supported most of the findings of Getzels and Jackson. He maintains that on the basis of I.Q. alone, selection of the top 20% of a school population would include only about 30% of those children in the top 20% on measures of creative thinking, and the group traditionally regarded as containing the gifted therefore overlooks about 70% of the highly creative.

Reporting an investigation of 320 Canadian schoolchildren Cropley (1967) also provides some support for the academic importance of creativity by noting that, among a group selected as above average in intelligence, those who were highly creative were superior on tests of school achievement than those who were low in creativity test scores. A similar result emerged from studying the performances of children in the low I.Q. group. Cropley's population, however, was above average in I.Q., having a mean of 114.3, and less confirmation of Getzels and Jackson's results have been found with more representative samples. Edwards and Tyler (1965) studying children in a non-selective American Junior High School found almost entirely negative results, and they concluded that Getzels and Jackson's findings about the relation of creativity, intelligence and school achievement were not widely generalisable.

In a Scottish research project Hasan and Butcher (1966) also produced results which found little confirmation of the findings of Getzels and Jackson. They found that their creativity measures, including four tests which had been used in the American study, overlapped with 'intelligence' to such an extent as to be hardly distinguishable. They even found it difficult to form groupings such as those used in the American study, but, as far as their groups were valid, they found little indication that the more creative children were scholastic 'over-achievers' or that their abilities were unappreciated by their teachers.

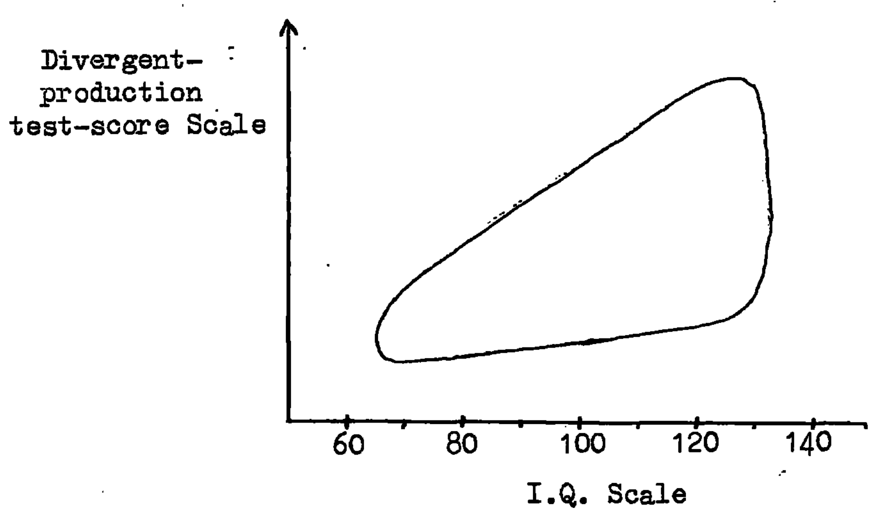
Yamamoto (1964) provided some support for Getzels and Jackson in a study which found a positive relationship between performance on creativity tests and success in school learning not due to differences in I.Q. In a further study (1965b)however, Yamamoto concluded that creativity and intelligence measures are not wholly independent and that "we should regard creativity tests as complementary components in new and more inclusive measures of human intellectual behaviour and not as a measure wholly independent and exclusive of the general factor of intelligence". Lovell and Shields (1968) in a study of gifted children arrived at a similar conclusion after factor analysis of measures of creativity, I.Q., and logical thinking. They concluded that although their analysis indicated factors distinguishing components of creativity, I.Q. and logical thinking, the tests also loaded a single factor indicating a central intellective component common to all the tests.

These conclusions are in accord with the convictions of Burt (1962) and Vernon (1964) who have criticised the concept of creativity as a distinct intellectual ability different from that of intelligence; and also with Marsh's (1964) reanalysis of the Getzels and Jackson data.

It is worth noting, however, that there appears to be a much more tenuous relationship between creativity and intelligence as the I.Q. level is raised. Mackinnon (1962) has found evidence for this in his studies of creative individuals and Yamamoto (1965b)showed a consistent decrease in the size of the correlation between creativity test scores and intelligence as the I.Q. level of his various groups became higher. He concluded that his results seemed to support the concept of a 'threshold of intelligence', that beyond a certain minimum level of intelligence, being more intelligent does not guarantee a corresponding increase in creativity. The results did not suggest however that creativity is an entity independent of other facets of human intellect.

The question of distribution of creative abilities is discussed by Guilford (1967a) and he illustrates, Figure 7, what he calls a typical shape for the scatter of individuals when scores for divergent-production tests are plotted against corresponding I.Q. scores. This pattern, which he calls a triangular scatter diagram, is also suggested by McNemar (1964). Guilford points out two striking features, the scarcity of cases combining low I.Q. with high status on divergent production; and the incidence of conjunction of low divergent-production ability and high I.Q.

Figure 7
Typical scatter: Divergent-production ability and I.Q.



Nunally (1964) points to the same features as Guilford by asking the crucial question of why only some of the children with high I.Q.'s are creative, and by noting that rarely does one find a highly creative individual who is not also above average in intelligence. This recognition of two gifted groups of children, those intelligent but not creative, and those intelligent and creative is of growing educational concern.

While such distributions of creativity and I.Q. scores support the concept of a threshold of intelligence beyond which the relationship between creativity and I.Q. is thought to break down, not all experimenters support this pattern. Ginsburg and Whittemore (1968) attempted a direct examination of the relationship between creativity and I.Q. assessed by a verbal test, and suggested that the relationship does not break down in the upper segments of the I.Q. range. Rather, they claim, a relationship between the measures is preserved throughout the I.Q. range, though the relationship is curvilinear and the gradient of the curve decreases above a certain level of I.Q.

The persistence of much contradictory experimental evidence regarding the relationship between creativity, intelligence and other measures is due in large part to the wide variety of tests of creativity and to the varied methods of administering and scoring the tests. Wallach and Kogan's study (1966) is an important attempt to establish a conceptual framework for the concept of creativity together with appropriately detailed measurement tasks and procedures.

Having reviewed some of the previous studies Wallach and Kogan expressed the view that there was little evidence for acknowledging a creative dimension of individual differences which was either cohesive and unitary or relatively distinct from general intelligence. In particular their examination of the study by Getzels and Jackson (ibid) led them to conclude that the different types of test used were unlikely to provide indices of a common psychological concept, creativity, and that in that experiment the conceptual framework for a possible creativity domain was inadequate. In spite of the lack of success of previous experiments to establish a cohesive domain of creativity, however, Wallach and Kogan undertook to set up their experiment on a new conceptual analysis based on an "associative conception of creativity".

Appealing to the anecdotal experience of a number of highly eminent creative individuals, most of them reported by Giselin (1952), Wallach and Kogan accepted Mednick's (1962) definition of creative thinking as "the forming of associative elements into new combinations which either meet specified requirements or are in some way useful". They consequently set up a hypothesis that creativity most appropriately refers to "the ability to generate or produce within some criterion of reference, many cognitive associates and many that are unique".

This conception of creativity suggested the experimental procedure of considering the pattern of responses of subjects to some stimulus word or object. Two types of response patterns were suggested. Considering the hierarchy of possible responses to a stimulus word, the experimenters suggested that the more conventional, stereotyped answers would be readily available and the more unique ones less readily available. Two types of people were then hypothetically suggested, one who is low in creativity but quick to produce stereotyped responses and another, high in creativity who, though likely to offer stereotypes to start with will go on longer with increasingly unique associates.

In contrast to previous testing procedures, this consideration, together with a conviction that a relaxed and permissive atmosphere is necessary for creativity, led Wallach and Kogan to set up an experimental situation in which the subjects would be free from constraints of time and an atmosphere of evaluation.

The experiment was carried out with 151 children comprising the whole of the 5th grade in a suburban state school. The mean age of the children was 10 years 7.6 months, and their background was predominantly middle-class. Five creativity tests were administered individually in a 'playing games' context by two young women experimenters who had spent some time getting to know the children. The general intelligence measures were obtained from both individual and group tests, some of them already having been administered by the school in its normal routine.

The five creativity tests incorporated many of the suggestions of Guilford and other experimenters, but the emphasis on a relaxed atmosphere free from implications of examination was a significant departure from common practice. The following are examples of the tests used:

Instances: "Name as many round things as you can think of"

Alternate Uses: "Tell me all the different ways you could use a newspaper"

Similarities: "Tell me all the ways in which a potato and a carrot are alike"

Pattern Meanings: "Tell me all the things you think each drawing could be"

Line Meanings: "Tell me all the things the drawing makes you think of".

The creativity results were analysed for both number and uniqueness of responses and an impressive series of intercorrelations with the I.Q. tests led the experimenters to conclude that their measure of creativity was "strikingly independent of the conventional realm of general intelligence, while at the same time being a unitary and pervasive dimension of individual differences in its own right".

Having established two modes of cognitive activity, Wallach and Kogan continued by investigating possible correlates of individual psychological differences between types of children classified according to their I.Q. and Creativity. Differences in level of creativity did not appear to contribute to behavioural differences between boys, but girls showed a number of significant correlations between their behaviour and modes of thinking. In particular, the group high in creativity but low in I.Q. presented a very disturbing picture, much more so than those children low in both I.Q. and creativity. They were the least communicative, most subdued, were upset by rebuff and criticism, and were neither sought by nor sought the company of their peers. They were the most deprecating of self and work and the least motivated towards academic tasks.

Wallach and Kogan concluded their study with a valuable summary of the implications of their findings for education, though it is now habitual to regard studies of creativity with some caution and it is likely that their study will be no exception. A number of re-analyses of their data have already been carried out.

In an oblique factor analysis of the Wallach and Kogan correlations between creativity and intelligence, Ward (1967) obtained four significant factors. The first two had 28.7 and 23.8 per cent of the total variance respectively and showed "the presence of two apparently near orthogonal and easily identifiable sets of measures", and Ward concludes that though the experiment was not intended to prove or disprove the inferences drawn by Wallach and Kogan "the results tend to support their choice of procedure". At the same time he also noted that the study indicated the multifactorial nature of creativity in spite of the two nearly orthogonal factors.

Fee (1968) performed a Multiple Group factor analysis as an alternative to Ward's procedure in analysing Wallach and Kogan's data and concluded that his analysis "supported Wallach and Kogan's view that they have established a 'creativity' dimension relatively independent of general ability as measured by the usual tests of attainment and intelligence". Fee also noted however that this independence may not be as complete as Wallach and Kogan maintain and that 'creativity' is clearly not unidimensional.

Cronbach (1968) in a stringent statistical reanalysis and reinterpretation of the Wallach and Kogan data supports some aspects of their study but is in disagreement with several others, particularly with what he terms Wallach and Kogan's 'injudicious' within-sex analysis, and their acceptance of a level of significance up to, and even beyond, the 10% level.

Although he notes some reassuring similarities, Cronbach stresses the differences which, derived from his more powerful statistical analysis, negate a number of the Wallach and Kogan hypotheses regarding the psychological characteristics of the subjects. He found, for example, that 13 of their relations disappeared in his reanalysis and that seven other relations emerged that were not found in the original experiment. His final impression was that the 'creativity' measure "has disappointingly limited psychological significance".

Regarding the Creativity-Intelligence distinction Cronbach expressed his discontent with the 'suggestive' labels which he felt too many people would be likely to accept at face value, and recommended the adoption of neutral names which would not invite the reader to make interpretations that have not been validated.. At the same time, in neutral terms, he accepted that Wallach and Kogan study" succeeded in developing a battery of measures that cohere and yet are uncorrelated with a conventional ability measure", though he concludes with the opinion that an attempt to draw out implications and applications would be premature.

An experiment partly replicating that of Wallach and Kogan was carried out by Cropley (1968). Five intelligence tests and the Wallach and Kogan tests of creativity were administered to 124 first-year university men. The resulting correlations indicated that the battery of creativity tests possessed a high degree of internal consistency, and were relatively independent of the five intelligence tests. A principal components factor analysis, however, revealed a large general factor accounting for 28.8% of the total variance with high loadings from both creativity and intelligence tests. The second factor with 20.87% of the variance was clearly a bipolar factor of creativity versus intelligence. Cropley concluded that keeping the general factor in mind, his results, showing internal consistency in the creativity battery and usefully low cross-correlations with the intelligence tests, lent modified support to the conclusions of Wallach and Kogan, especially as in his experiment the tests were administered in a group form contrary to the Wallach and Kogan procedure.

(ii) Creativity and Teaching Methods

Notwithstanding the diverse theories and varying results of experiments to assess creativity, the large volume of recent research has at least compelled educationists to consider creative potential not as a mysterious ability confined to the peculiar few but as a valuable talent which all children possess to some degree. More people are recognising that the large differences in creative ability that can be observed in real life are more due to a person's failure to realise his inherent potential than to any original limitations, and it is becoming generally recognised that though education cannot create creativity, it can do much to encourage and develop it (Burt 1962).

Once this fact is accepted the implications for education and teaching method are enormous, particularly when it is recognised, as Vernon (1964) points out, that "some schools do much more to stimulate and foster, or else inhibit creative talent than others".

A large number of problems, however, still face the teacher wishing to cater for creative talent. How does one recognise and assess creative potential? What new approaches should be adopted in order to foster its development? How is one to judge whether existing practices are hindering or promoting the emergence of creative thinking? There is, as yet, no definitive theory for a new 'creative' education and there are, no doubt, many features of existing practice that are not only essential for a general education but also valuable in developing creativity. Even Torrance (1964), who has promoted a number of experiments in teaching for creativity, is quick to point out that it would be wrong to assume that there is need for a complete reorganisation of teaching method so as to suit creative thinking, and he suggests that "we need to determine which kinds of information can be learned more economically by authority and which by creative means".

One of the conditions thought most likely to foster creative thinking however is that of a stress-free atmosphere in which, Wallach and Kogan claim, the highly creative child "can blossom forth cognitively". Such a situation implies a considerable change in educational values but ideally it would reinforce a child's ability to make his own individual contributions. Often, as Torrance (1959) points out, creative children will contribute ideas which do not conform to the standardised dimensions, the behavioural norms on which conventional responses are judged, and in order not to stifle such responses the teacher must be willing to accept and discuss them in an atmosphere of mutual respect. This is quite a departure from the traditional teaching method in which the teacher's role was an authoritarian one and the child's answer right or wrong in conformity with the teacher's judgment.

Discussing the dangers which arise from pressure to conform, Crutchfield (1964) suggests that such pressure serves to inhibit creativity and quell motivation, and often results in an individual "assailed by doubts concerning himself and his personal adequacy." Faced with a choice between his own thoughts and those of others he tends to defer to the 'superior' judgment of his teacher and becomes a conformist member of a group. For those who rebel against such a pressure to conform the result can be just as damaging to their creative development, for in a reaction into 'counterformity' they tend to seek difference for difference's sake and once again transgress their personal standards of self-reliance. In both cases Crutchfield suggests that a person's creative powers are undermined "by weakening his trust in the essential validity of his own processes of thought and imagination".

The recognition that formal teaching is to some extent guilty of putting too great a curb on children's powers of self-expression and self-discovery, has resulted in a greater emphasis being put on motivation which is intrinsic to the child.

The result both in this country and in America has been a growth in the 'discovery method' of learning in which the pupil is encouraged to think for himself and apply his creative energy by actively following his own ideas under the guidance of his teacher.

Even following such a method however, a degree of guidance must be given to the child and it will always be necessary to feed children with a certain amount of information. The danger is that in a reaction against formality these considerations might be overlooked, and in over-enthusiasm it is easy to read too much into statements made with the best intentions. Guilford (1965) for example claims that "We remember best and with the greatest potential usefulness those things that we discover for ourselves and that have greatest meaning and significance. The active child is thrilled by his discoveries. We should encourage the learner to seek information actively, not to be a passive receiver of information that is fed to him. Information passively obtained is not likely to be functional". The possible disadvantage of this sort of appeal for active learning is that it might wrongly be taken to imply that verbal learning has to be passive, and that any sort of 'formal' teaching is consequently to be avoided.

The effects of a movement towards a teaching method emphasising the freedom of a child to work actively and make his own discoveries, is becoming increasingly evident, and nowhere more so than in the teaching of mathematics where, in many respects, the changes are long overdue. In Junior Schools in particular much of the work has traditionally focussed on formal arithmetic, with a method of getting the correct answer to complicated calculations all important in view of the 11+ examination. With the disappearance of this examination and the advent of new approaches, children are no longer so tied to the demonstrated method - failure to grasp which could spell disaster for their subsequent work and a loss of confidence in their mathematical ability. As Land (1965), commenting on the process of change in the teaching of mathematics observes, the new approaches are more thought provoking and have an emphasis on understanding which means that there is "less chance that children's confidence in themselves will be destroyed by their superficial vulnerability".

The discovery method is particularly suitable at Primary School level and projects have sprung up on both sides of the Atlantic. In America the Madison Project: "Discovery in Mathematics"(Davis 1964), has an emphasis on creative informal exploration by the children, and in this country the Nuffield Foundation has sponsored an extensive Primary School Mathematics project with an emphasis on learning by discovery. As Ross (1969) pointed out recently "Mathematics, quite clearly, is now one of the creative studies and long may it remain so". On the same occasion the Organiser of the Nuffield Primary Mathematics Project, Matthews (1969), explained that the purpose of the project is to aid teachers in helping the children develop gradually from discovery with things to eventual abstractions with pencil and paper. The central message, he emphasised was to "Let the children think" a motto which reiterates the aims expressed in the Project's first Bulletin - that the new course aimed to foster in children "a critical, logical, but also creative, turn of mind" (Nuffield Foundation 1964). The belief that discovery methods are those best suited to promote this sort of thinking is also present in the 'American School Mathematics Study Group', and Wooton (1965), describing their work, notes that in the writing of the text books "Many of the exercises had to be of a 'discovery' type that would extend the treatment in the text, and promote original thinking and creativity on the part of the student"

Technological and industrial considerations have led to a growing recognition of the need for creative thinking and have promoted a good deal of the present change in teaching methods and syllabus content. Such considerations however have been supported, if not led, by current theories of child development, and, in this country, the work of Piaget has had a profound influence on Primary School work.

Piaget's work centres on his belief that thinking ability in children develops in stages from pre-operational thought in infancy, through a concrete operational stage to the formal thought of the maturing adolescent. While this sequence is now generally recognised, the corresponding ages at which different children reach the stages has been found to vary widely and the same individual has even been found to reason at different stages in different fields (Peel 1960). Many of the early criticisms of Piaget's work focussed on the age ranges given by Piaget as a guide to the stage at which a child's thinking might be operating, and these were often taken too literally by some experimenters.

Too great an emphasis on Piaget's position as a developmentalist, however, neglects his view that the development proceeds via interaction with the environment and is essentially a learning process effected in stages by experience. Piaget has been described as "a learning theorist without a learning theory" (Borger and Seaborne 1966) and as this interpretation of his work has come to the fore his interactionist view of intellectual development has had its influence on education, particularly in mathematics. Churchill (1958, 1960) has reported that by providing the child with appropriate materials for manipulating, ordering, combining, dividing up and matching, the onset of the concrete stage of thinking can be accelerated and she suggests that children also do much of their learning from everyday situations which evoke curiosity and call for some sort of solution to a problem. As a result children are involved in a good deal of active learning sometimes on their own initiative and sometimes through an experience shared with the teacher. It is this sort of experience which has shown the relevance of Piaget's theories for a classroom situation, and which has also provided some of the evidence in favour of a discovery method of learning, particularly for young children.

The essence of the discovery method lies in its contrast with passive or rote learning and it can be regarded in many circumstances as a problem-solving activity. The position of the problem in the development of mathematical activity in children has been the subject of a report prepared by the Association of Teachers of Mathematics (1966). It points out the hard fact that our civilisation needs mathematical creators and underlines the importance of helping children to develop their mathematical abilities and of giving them the freedom to use their creative energies in both solving problems and creating new ones. At one point the exploration of significant problems is seen as being the only possible procedure for the modern infant's teacher; though elsewhere there is a note of caution lest "in our enthusiasm for providing active experience for young children ... we run the danger of abdicating from mathematics altogether".

As usual, the dangers lie in the extremes and at times the aims of the discovery method are lost sight of in attempts to provide only stimulating experiences. The Schools Council (1966) in its Curriculum Bulletin No.1 on "Mathematics in Primary Schools" notes that the aim of the discovery method is to achieve understanding before practice, though the latter is sometimes lost sight of in spite of the fact that, as Bruner (1960) reports, "computational practice may be a necessary step towards understanding conceptual uses".

Many teachers wishing to encourage experimentation in mathematics whilst keeping in mind the mathematical concepts they wish the children to learn have adopted a 'guided discovery' approach to mathematics learning such as that advocated by Dienes in his numerous publications.

To each of Piaget's three main stages in the formation of a concept, Dienes (1960), has formulated three corresponding types of learning. In the first, a preliminary or 'play stage', a seemingly purposeless, undirected activity is performed and enjoyed for its own sake. Though as free as possible however, Dienes introduces, as play material, ingredients of a concept which the teacher believes is appropriate to the level of the child's thinking. The second stage is more directed and purposeful but again a number of experiences are provided, of varying structure, but all leading to the same concept. The third stage provides practice in fixing and applying the concept that has been formed.

Dienes sees this kind of learning taking place in small groups, with a system of assignment cards from which the children can work. The teacher is responsible for keeping up the 'dynamic equilibrium' of the activity, seeing that the lines of communication from the sources of information to the child are kept open and introducing the child to further appropriate experiences. As he observes, "It goes without saying that an authoritarian attitude would not be helpful in a learning situation of this kind. The essence of a creative learning situation is keeness to inquire, and authoritarianism does not foster a spirit of inquiry."

Communication is essential to Dienes' ideal of creative mathematics learning and he is echoed by Mooney (1967) in his essay on 'Creation in the Classroom setting'. Mooney too sees as elemental the system of communication between teacher and pupil and suggests that unless they can communicate education fails, for communication is at the centre of the educative system.

As an aid to this sort of mutual enquiry in learning, many educators emphasise the importance of devising appropriate learning experiences for the child, not only from the real world but with the aid of various types of material. For mathematical experiences many different types of structural apparatus are available to help the child discover mathematical relationships and develop concepts; Cuisenaire Rods, the Stern apparatus based on gestalt principles, Montessari beads, and Dienes' Multibase Arithmetic Blocks and Algebraic Experience Material, are just a few of those available.

With the aid of such material, and with an emphasis on the individual, Dienes (ibid) suggests that "it is possible to establish fully creative mathematical learning situations at all stages of mathematics learning". He also emphasises that mathematics is not a set of mechanical processes to be learned but an interlocking set of complex structures. By putting children into physical situations which embody certain of these structures, they are consequently led to discover what the structures are, and how they relate to each other and to the real world. (Dienes 1964).

This belief is in many ways an echo of Wertheimer's concern with mathematics learning and his emphasis, more than others of the gestalt school, on the role of experience. He too emphasises the need for children to grasp the structure of a situation and "not to be bound, blinded by habits; not merely to repeat slavishly what one has been taught, ... but to look at the situation freely, open mindedly, viewing the whole, trying to discover, to realise how the problem and the situation are related". (Wertheimer, 1961).

In much the same way Bruner (1957) sees discovery as going beyond the information given, and he maintains that discovery, whether by a schoolboy going it on his own or by a scientist cultivating the growing edge of his field, is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insights.

It is almost certainly true that profound involvement in any area of knowledge, insight and discovery do not come about by being given explanations or handed information by the teacher. Nor on the other hand is it sufficient to just leave children to find out for themselves. As Moustakas (1967) suggests, it is far more likely that genuine learning requires a sense of mutuality and a feeling of encounter in learning. It is essential for the success of a discovery approach that the teacher plans appropriate experiences from which the children are likely to develop useful concepts, and that he partakes in discussion with the child.

The claims for the effectiveness of the discovery approach in mathematics learning are wide and varied. Skemp (1965) considers that by leaving children free, within the guidance of the teacher, to make discoveries for themselves and in their own way, we shall be giving them the kinds of activity and enjoyment which are most likely to lead to true originality in the future. Dienes (1960) considers that by forming his own concepts from mathematical experiences the child is building up something important into his personality, as important as from more aesthetic processes such as painting, writing or acting. The Mathematical Association's (1956) report on the Teaching of Mathematics in Primary Schools bases many of its ideas on the basic belief that the processes of mathematical thinking are the same as for all thinking, and that children learn through their active response to experiences that come to them. Matthews (1969) suggests as an aim of the Nuffield Primary Mathematics Project, the policy of letting the children think, and as a result he is hopeful that the Project's discovery approach will help produce "happy, thoughtful and numerate children". The motto of the Schools' Council's bulletin on 'Mathematics in Primary Schools' (1965) could well be its quotation of Whitehead that 'every child should experience the joy of discovery', and it goes on to make the rather exaggerated claim that "the psychology of learning provides unchallengeable evidence that sound and lasting learning can be achieved only through active participation". Bruner (1961) makes the same point but in a more qualified fashion when he observes that in general "material that is organised in terms of a person's own interests and cognitive structures is material that has the best chance of being accessible in memory".

To what extent the discovery approach is effective in realising the claims made for it by its supporters is, as yet, largely debatable, though there are some relevant experiments which will be reviewed later. Even Dienes (1966), while generally in support of guided discovery, clearly points out that they have by no means resulted in unqualified success, and he notes that the experimental evidence is by no means unanimous in its support of learning by discovery methods. The evidence from a variety of sources, such as it is, leads him to suggest that it is very difficult to engineer successful conditions for this kind of learning, and that there may well be kinds of materials that are better taught by more direct methods.

Motivational benefits of the discovery approach have received a good deal of subjective validation and the opinions of many teachers actively participating in the method testify to the fact that children are indeed 'enjoying their new experiences' and are 'no longer frightened of sums'. Miss E.E. Biggs, H.M.I. who has been responsible by means of her in-service teachers courses for a great deal of the interest and enthusiasm for discovery methods, writes that "Many teachers in this country have established, beyond doubt, that the pupils can discover mathematical relationships naturally by using the simple materials of their environment"(Schools' Council 1965). Viewing children working in such a way, it certainly appears that their attitude to mathematics is one of pleasure and enjoyment. Children work together investigating shapes, sizes, and densities, conduct surveys, make models, and, it appears, are able to explain coherently their procedures and ask perceptive and vital questions. One cannot but feel that they are gaining social, verbal and mathematical value out of their activity.

The conviction that because the children look happy and are obviously enjoying themselves, they are learning in the most efficient and beneficial manner is unfortunately not necessarily valid. Under the old rote learning system 'ends' were the chief, if not the sole criterion of success; under the new system of working by discovery one has to beware lest the means become everything. Keeping the children happily occupied is a very valuable achievement but it must be remembered that the discovery methods also aim to produce balanced, happy, skilful and productive adults.

A major study into the learning of mathematics in the Primary School was conducted for the N.F.E.R. by J.B. Biggs (1962, 1967) involving over 5,000 pupils of average age 10 years 3.55 months. The subjects selected were divided into three groups according to the types of teaching predominating in their schools; a 'traditional' category (T) aimed at mastery of techniques, using formal methods emphasising reproduction of standard procedures and extrinsic incentives; a 'structural' group (S) aimed at an understanding of basic concepts by using structural apparatus such as that by Stern, Cuisenaire or Dienes; and a 'motivational' group (M) placed an emphasis on learning from real-life environmental activites and stressed understanding with a 'social' bias. The latter category however did not exclude the use of practical 'everyday' aids which might include such things as counters, cubes, squared paper etc., and in these circumstances the motivational category could almost use 'home-made' structural apparatus not unlike the commercial material of the Structural group. Biggs admits that in such categorisation "the dividing line between structural and motivational methods becomes very thin indeed" (Biggs 1967). The traditional group in fact needed a subdivision into a category (TT), traditional throughout the age group, and a traditional mixed (TM) group where traditional and non-traditional methods were mixed in one year group.

A further limitation of the group classification throws more doubts on the reliability of the basic data of the experiment. Biggs himself raises the question of the adequacy of the structural category and notes that the types of structural apparatus being assessed had been available on the British market for a few years only and that many teachers were still 'feeling their way' with the apparatus. Some schools had in fact been using the method for only a year, and the children tested had used the apparatus only as illustrative or practice material and not at the crucial stage when the concepts were introduced.

In some ways the experiment might also have been premature in its formation of a 'motivational' group for although defined as incorporating real-life, environmental activity methods emphasising interest but discouraging premature formal reasoning; the absence of any organised project to foster such an approach, and the presence of the 11+ examination, would suggest that headmasters would be reluctant to put too great an emphasis on this aspect of mathematics teaching.

In assessing the degree of formailty in a school, Biggs used headmasters' own ratings together with an index of formality derived from a questionnaire which gave the headmasters' opinions on the use of such things as text books, ink, and individual assignments. This index correlated well with the views of local inspectors of schools who knew the schools concerned and also the headmasters' own self-rating.

Accepting the limitations of the categories, Biggs' study compared the various groups on a number of criteria including calculating efficiency, the ability to perform standard types of arithmetic problems, understanding of the structure of arithmetic, and attitudes to the subject. Some of Biggs' tests will be discussed later but it is worth noting his observation that some of his tests were "at best ambiguous and ought to be interpreted with caution". This caution was not always noted in some of the publicity given to the publication of his findings. It is also worth noting that the formation of Biggs' 'motivational' group, with its emphasis on activity, methods, is in many ways similar to that of the 'discovery' group in the present study.

Among the findings of Biggs most relevant to this study was his conclusion that the structurally and motivationally taught children were not superior to traditionally taught children on tests involving understanding, nor did they have more favourable emotional reactions to arithmetic as measured by Biggs' anxiety scale. The inclusion of the 'TM' sub group, a mixture of traditional and motivation, contributed significantly to the negation of many of the hypotheses of the experiment for it appeared superior to all the other groups in both mechanical arithmetic and understanding, though surprisingly it was the most number anxious of all.

If, in place of Biggs' anxiety scale, teacher's ratings of the pupils were taken into account there was some indirect evidence that motivational methods did create positive motivation but attainment results for the motivational group were still compartively poor.

Although his study investigated aspects of mechanical problem and concept attainment and children's attitudes, Biggs acknowledged that there were no doubt other implications of the different teaching methods which remained uncovered. In particular he noted that his study had not considered the results of the different methods on the children's enthusiasm, nor the effects of the various approaches on the original and creative manifestations in the children's thinking. The present study is designed to look particularly at these latter items.

Although direct investiations of the effects of the discovery method on children's creative thinking have not yet been widely undertaken, a number of studies have considered the effects of various teaching approaches on the related aspect of rigidity in problem-solving.

The concept of rigidity has received a good deal of attention from the gestalt school in terms of 'functional fixedness' Maier (1930), and in studies of creative thinking, in terms of its positive counterpart of 'flexibility'. Guilford (1950). The relevance of such concepts as flexibility, redefinition or restructuring for creative thinking has been discussed earlier and it was observed then that Wertheimer's work on productive thinking also contains a direct appeal for more enlightened teaching methods, and a warning of the dangers of rigid method work. Having received from some pupils a number of foolish and unsuccessful attempts at solving one of his problems, Wertheimer emphasises that "the habit of thoughtless repetition, as developed in certain schools by emphasising blind drill, does seem favourable to responses of this kind" (Wertheimer (1961)). His observations are borne out by a number of studies.

The results of researches which had investigated the effects of traditional and activity methods were summarised by Wallen and Travers (1963) into 'authoritarian' and 'non-authoritarian' categories. They report a striking unanimity of results and report that although in the early grades results in arithmetic and reading were below expectation for the activity groups, the inferiority was overcome by the age of 12 (6th grade). Moreover the children from the progressive classes tended to be average or somewhat superior throughout their school years in achievement areas involving language usage, and tended to be rated higher on such dimensions as initiative, work spirit, and critical thinking.

Studies more closely directed at the effects of teaching method on problem-solving have also shown that a higher degree of flexibility in thinking has often characterised the progressive, non authoritarian approaches as opposed to formal learning methods. Luchins (1942) investigating mechanisation in problem solving put forward a concept of 'Einstellung' as a type of 'set' or 'rigidity' in regarding problem situations. He found that children who had successfully applied a problem solving strategy would refuse to discard it in repetitive situations even if it were no longer appropriate. This tendency was particularly marked in children coming from authoritarian and highly formal schools. They tended to approach problems 'according to the rules' and not from the individual demands of the problem. Even when hints were dropped or failure had shown the inadequacy of the methods subjects were still prone to keep to a 'rule'. This tendency was much less marked in children coming from an informal, activity based progressive school.

Luchin's findings were confirmed by Miller (1957) who in a further study of Einstellung investigated the effects on problem-solving of an emphasis on rote learning and method drill. The same teachers took two different groups of pupils one of which was taught with an emphasis on repetitive rule following. This group was found to be significantly more rigid in problem-solving than the less rule-bound group.

Kellmer Pringle and McKenzie (1965) clearly defining rigidity in problem-solving as "the inability to restructure a field, in which there are alternative solutions to a problem, in order to solve that problem more efficiently" were unable however to find a consistent overall difference between the effects of a 'progressive' and a 'traditional' school. The two primary schools which were contrasted in terms of progressive and traditional teaching methods however differed somewhat in the abilities of the pupils concerned, attainment measures in the traditional school being higher than in the other. Even so the study did indicate that among the children of low intelligence, there was some evidence that progressive methods did reduce rigidity. In a recent attempt to evaluate the effects of differing teaching approaches on divergent thinking abilities, Haddon and Lytton (1968) suggested the hypothesis that informal, progressive teaching would promote these abilities more than formal, subject-centred teaching. 211 children, between eleven and twelve years old, and covering the whole ability range were tested, half coming from 'formal' schools and half from 'informal' schools. The formal traditional schools placed an emphasis on convergent thinking and authoritative learning, while the informal, progressive schools emphasised self-initiated learning and creative activities.

I.Q. scores were available in the schools and seven divergent thinking tests were given, five of them adapted from Torrance's Minnesota Tests of Creative Thinking. The results showed that pupils from the informal schools were significantly superior in divergent thinking abilities on five out of the six tests completed and particularly so on the figural tests. It was concluded that the informal schools provide an environment which develops qualities of personality that result in a high level of divergent thinking ability; and speculating on the qualities of the informal approach which were beneficial, the experimenters suggested that they were based on the teacher's confidence and expressed pleasure in the child's ability to think adventurously and in new directions.

Sears and Hilgard (1964) arrived at a similar conclusion in their review of the teacher's role in the motivation of the learner. They endorsed the value for a child's creative thinking of a climate of mutual participation with the teacher, and suggested that creative thinking and adventurousness in problem solving were more common when the teacher placed an emphasis on encouragement and personal interest rather than on threats, punishment and external incentives. One is tempted to equate these modes of teaching with activity and formal methods respectively though, as Sears and Hilgard also point out, motivation also revolves around the personality and interests of the individual teacher. It is true nevertheless that mutuality in learning is, or should be, a corollary of the discovery approach, whereas it is less likely to occur in formal teaching where the teacher presents the child with material in a more authoritarian manner.

For some years the prevailing fashion in education has been to look favourably on the progressive and to condemn the traditional methods as passive rote learning and parrot-like repetition. More recently, however, as has been noted, some warnings have been given of the dangers of such a position. The cautions have not sought to devalue the worth of discovery learning but have asked that it be looked at in perspective, lest, in accepting it as a panacea one might lose sight of its valuable objectives and its position alongside many other approaches to learning.

Putting forward a case in defence of verbal learning, Ausubel (1966) claims that it can be a valuable and meaningful approach distinct both from 'discovery'and 'rote' learning. In particular he questions the belief that verbal learning is invariably rote unless preceded by recent non-verbal problem-solving experience, and he criticises the opinion of Brownell and Hendrickson (1950) that all attempts to master verbal concepts and propositions are forms of empty verbalism unless the learner has recent prior experience with the realities to which these verbal constructs refer.

Ausubel admits however that verbal learning can be unsatisfactory if applied prematurely with cognitively immature pupils, though even with those of Junior School age he maintains that 'actual discovery' is not necessary if direct, non-verbal contact with the data is an integral part of the learning situation. It is convenient at this point to remember that a'discovery approach' need not be confined to practical activity, for often 'ideas' stimulated verbally can only be fully apprehended or 'discovered' after a mental process of assimilation or accommodation whereby the learner can reconcile the ideas with his existing concepts, or translate them into a new frame of reference thereby recognising or 'discovering' a 'new' relationship. In common with other mathematics projects Wooton (1965) notes that some of the expository material written into the text books of the School Mathematics Study Group was characterised by a sense of sharing, by the writer and the reader, of the discovery of various mathematical properties. The books in particular made use of sections entitled 'explorations' from which the children were stimulated to ask significant questions and to work at discovering the answers to their questions.

The values of a discovery method in learning have been stressed both in principle and by practical teaching projects, and it appears that the discovery approach can have an essential role in developing favourable attitudes to learning and enquiry and towards the possibility of solving problems on one's own. The discovery approach, however, does not have a monopoly of such benefits, but it is likely that many advantages will arise both from an approach which encourages regard between teacher and pupil, and an atmosphere in which children are able to develop their own ideas and feel free from the stress of constant evaluation. These conditions are very similar to those advocated by Wallach and Kogan (1966) for the development of children's creative potential and it is appropriate to end this chapter with their belief that "it should be evident that the 'discovery method' ..... is therefore of relevance for creativity". To what extent this belief can be demonstrated from the effects of a Primary School's commitment for four years to a discovery approach in their teaching of mathematics, is to be investigated in the present study.

Chapter 5

DESIGN OF THE EXPERIMENT

The background to the present enquiry has now been presented in both theoretical and practical terms. Creative thinking has been discussed in terms of imagination, problem solving, divergent thinking and productive thinking; and the present educational emphasis on innovation in the curriculum has been observed to have led to practical attempts to foster 'creativity', and to projects designed to develop a child's ability to think mathematically. In particular it has been noted that the Nuffield Foundation Primary School Mathematics Project, in its extensive use of discovery methods and expressed aim of "letting the children think" (Matthews 1969), provides a practical opportunity to consider some of the effects on children's creative thinking of one of the most extensive projects at present being sponsored in the Primary School.

The purpose of this experiment is therefore to add some objective data to the mainly subjective assessments of new innovations in the curriculum, and to contribute some further evidence in the continuing debate on the nature of creativity and its relation to other modes of thinking.

Although the latter question is one that has been investigated at length in other researches, and the particular results of the present study lie in the result of the inter-school analysis, it is essential to consider it in relation to the present study before the patterns of thinking within the schools can be fully discussed. The aims of the experiment can therefore be expressed, in general terms, as attempts to answer two questions. Firstly, what modes of thinking will be indicated by a battery of tests designed to test intelligence, creative thinking and mathematical ability; and secondly, how do the patterns of creative thinking and attitudes to Mathematics compare between the 'experimental' school and its more traditional counterparts?

The first question is of an exploratory nature and would be valid if conducted in any school provided the school variables were adequately defined so as to permit comparison with other samples. The second question, however, demands a strict experimental design, and even then it is acknowledged that no experiment comparing teaching methods or evaluating syllabuses can be 100 per cent valid when different groups of children and different teachers are involved. Nevertheless, it is believed that if the main variables are controlled and the results interpreted with some caution, the second question can be validly investigated. Hypotheses regarding the outcome of this question will be made later in this chapter after the initial design has been discussed.

The design of the experiment falls into three main categories:

1. The selection of the schools; to be as alike as possible in all respects except that one of them will have followed a new Mathematics syllabus based on the discovery approach whilst the others will have followed a traditional approach. Rather than rely on a large number of schools to lend validity to the results, it was decided that it would be better to rely on a small number of very well matched schools. The selection procedure therefore focussed on one 'experimental' and two 'control' schools.

In addition to investigating the methods of mathematics teaching and the school environment, the selection necessitated analysing samples of possible schools so as to control for other variables such as I.Q. and social class.

2. The selection and administration of a battery of tests which will be likely to cover a number of different dimensions of the children's ability including divergent thinking, mathematical thinking and intelligence; and the children's attitudes to school subjects particularly Mathematics.

3. An analysis of the data collected, using a computer assisted factor analysis of the testing battery to discover categories for classifying the children's performances, and the appropriate test of significance to determine differences between the mean scores of the experimental school and its control schools.

The results will then be in a form which can be interpreted in terms of the questions and hypotheses posed by the experiment. Categories 1 and 2 are discussed in the present chapter and Chapter 6 will be devoted to an analysis of the results.

1. Selection of the Schools

(a) Preliminary Investigations

The writer was fortunate in having within easy reach two counties which had been carrying out innovations in Mathematics teaching for some years, and in having personal acquaintance with some of the developments in the area.

Schools in both counties were involved with the Nuffield Foundation Primary School Mathematics Project. One county, being one of the fourteen pilot areas chosen to launch the project, had schools which were just completing four years of the new approach, and the other, having joined the scheme in its first 'proper' phase had schools which were completing three years.

In spite of their associations with the project, however, many of the schools involved were unable to say that they had fully committed themselves to the approach and the materials which had been gradually circulated. Several stressed the experimental nature of the project and the fact that they were not changing their whole approach to that of an alternative scheme which had not yet been proved. Although innovation is most likely to succeed when carried along by enthusiasm and total conviction it is necessary for someone to appraise its value. The uncommitted attitude of some of the teachers would console those educationists who fear that a project launched under the national sponsorship of the Nuffield Foundation and the Schools Council might become firmly established before one remembers its experimental nature. It seems that the voice of the Schools Council is not as widely heard in schools as one might tend to think.

The attitudes of headteachers were therefore of major significance, for the result of the writer's preliminary investigations made it clear that there is less difference between the school nominally committed to a project, and a school without official commitment which is nevertheless attempting, in its own way, to keep abreast of current developments. In particular, this emphasised that there are few schools today that have not been affected by the less authoritarian and more active approaches to mathematics, and the search for schools suitable for the present study narrowed to County 'A', several areas of which had made definite committments to act as pilot schools and keep as well as they were able to the ideals and approaches of the Nuffield Project.

In the pilot area the fourth year pupils had therefore received all their Junior School Mathematics along the lines suggested by the project, and this gave the best opportunity to assess the effects of the approach, after a period of four years and before the children left for their secondary education. The schools involved were supported by special financial allowances for mathematics materials, and by two full time mathematics advisers working from two permanent and well equipped Centres.

The schools themselves, however, were not special in any other respect, they were not even volunteer schools, for all the schools in a particular area had been affiliated to the mathematics scheme by the County. This aspect increases the viability of finding comparison schools which are similar in most respects other than the approach to Mathematics.

(b) Final Selection

Two towns, both in the pilot area of County 'A', were next chosen as being likely to provide a suitable 'experimental' school, and after a number of observation visits and discussions with headmasters, L.E.A. officials, the County Inspector responsible for Mathematics and the permanent staff of the Mathematics Centres, a short list of possible schools was compiled.

Throughout the selection it was borne in mind that it was necessary to choose a school with a large number of pupils, which was in a non-exclusive area that could be readily matched elsewhere, and with an academic level that could also be duplicated. The latter criterion was available from the L.E.A. records which already contained the results of two Moray House Verbal Reasoning Tests used in connection with 11+ assessment. This availability of a measure of the children's I.Q. was a further advantage of using a fourth year sample.

Scrutiny of the assessments and I.Q. scores showed very different standards of attainment amongst schools in the county. Entry to Grammar Schools is uniformly graded throughout the County on the basis of the I.Q. tests, with headmasters assessments resolving any difficult cases. The diversity of I.Q. distribution between schools can therefore by seen by considering the proportion of grammar school places allocated. In a high class residential area, a school, with its lowest I.Q. in the region of 90, will send 56% of its pupils to a grammar school, while in a very large school in a deprived area, a very long tail of I.Q.'s in the low 70's might result in a pass rate as low as 10%. It was therefore attempted to select schools for the present study from the 'middle range' of schools in the county.

From the schools short listed, the experimental school, which we shall now call School C, was finally chosen with an "average" I.Q. and Social Class background, both of which could be matched elsewhere in the county. The school had just over 100 pupils in the fourth year group.

The selection procedure had therefore isolated a school which was extremely well catered for with regard to mathematics teaching but which in size, rate of success at 11+, and type of catchment area, was fairly typical of a number of other schools in the county. The overriding difference was the emphasis on mathematics, exemplified by teachers well versed in the new aims and approaches (who have had to attend regularly at mathematics courses), in an abundance of project material and equipment, and above all, in the encouragement and freedom for the teachers and children to play their complementary roles in the discovery approach.

The question posed earlier now has a definite basis. Will the children from School 'C' show any significant differences in their performances on a variety of thinking tasks when compared with similar children who have lacked the special emphasis on a discovery approach to their mathematics?

The next task was to obtain the 'control' schools, 'A' and 'B', that is, to find two schools as alike the 'experimental' school in as many ways as possible whilst keeping a dichotomy in their approaches to mathematics teaching.

The discussions which had taken place in choosing School 'C' had kept in mind the need to find such control schools, and a number of possible schools were matched in their 11+ attainment levels and visited in an attempt to ensure similar neighbourhoods and social class background. In order to obtain school information which could be directly compared for facilities, organisation, staff, attitude to the new innovations in

Mathematics, equipment and methods, a questionnaire was compiled and used by the writer in personal interviews with headteachers. The information given in reply to the questionnaire, and other information and impressions gained by the writer in his visits to the schools are incorporated in the following descriptions of the three schools finally selected. Details of the questions, and areas dealt with by the questionnaire are given in the Appendix.

School A

School A is situated on the western boundary of a city in the North East of England. It serves primarily a post-war council estate, though some private houses are included in its catchment area. Its present attendance totals 390 of whom about 95% are from council houses.

The council estate is a pleasant, mature, post-war development of semi-detached houses with moderately sized gardens, and is in demand by families from other council estates. It is immediately adjacent to a private housing estate which, though once in the catchment area of School 'A', is now served by another school built at the other end of the estate. The area borders open farmland on the side away from the city.

Built in 1954, School 'A' is a bright, open building with a large window area. It has accommodated as many as 440 pupils and at 390 is functioning with plenty of classroom space and a good overall pupil/teacher ratio of 32.5:1. The fourth year however has nearly 120 pupils and as many as forty children in a class.

The school is unstreamed in the first year and is then organised into two unstreamed 'B' forms and one 'A' form. Only five of the staff have less then ten years teaching experience, though two of these are in their first year. The headmaster took over the school two years ago.

The ethos of School 'A' is by no means formal, it holds open evenings for parents twice a year and a visitor to the school sees plenty of the children's work on display. There is however no special emphasis on Mathematics although about half a dozen of the staff had attended a Nuffield Mathematics Course and the headmaster is happy that they try allocating perhaps one lesson in five to 'new approaches'. The teacher chiefly 'responsible' for mathematics in the school takes the top 4th year class. There is no special mathematics centre available as there is for teachers in the 'Nuffield' areas.

The headmaster sums up his attitude to Mathematics as 'keeping a balance' and in general he aims to help the teachers encourage the children to find interest in their work and discipline their own efforts. The amount of formal work varies between teachers but generally there is little 'formal' teaching. In the Mathematics, however, there is still a good deal of computation and work on the four rules, though the headmaster encourages practical applications to measuring and the like.

Although, generally, the work in the school is not formal, assignment cards for individual or group work are not very much used at present. Some ssts of cards are being gradually built up, but the work is usually initiated by directing the child to refer to a book or the blackboard. One hour per day is given to Mathematics.

The school has bought quite a lot of mathematics equipment over the last year or two but is also trying to build up a stock of science equipment. Shapes, construction kits, number lines and balances are the main types of apparatus. Structural apparatus is not much used. There is no class 'text book' for use in Mathematics but there are some smaller sets of books for reference. There is also a set of Nuffield Guides in the school which can be referred to.

Each child has a rough book and a neat book and also uses large sheets of drawing or graph paper. Neat work is done in ink, most of the children having their own fountain pens. The teachers keep a record book with marks of the mental and written tests which they set, and, from the schemes of work that the teachers submit to him each week, the headmaster sets the English and Mathematics papers for the school's bi-annual exams. He sets three papers in Mathematics, mental, mechanical and problem, and these demand a good knowledge of basic computation techniques and their applications.

All the pupils enter the school from the same Infants department which has a special interest in i.t.a., but no special emphasis on Mathematics. Their aim in preparing the children for the Junior School is to give them a degree of computational ability, some tables and the elements of measurement and money.

School 'B'

School 'B' is less than a mile from School 'A', situated on the same western boundary of the city. It has an intake of about 80 pupils a year giving at present a total attendance of nearly 330. The headmaster estimates that about half of the children live on a nearby council estate and the other half in private houses mainly of an older terraced type. The council houses are once again of good quality, post-war, and with a population which is "nothing like slum clearance".

The school itself is mainly an old stone building built just after the turn of the century, but has some newly built classrooms nearby, and a large playing field. It can theoretically accommodate 350 children but at 330 some of the lower classes have over forty children. At present there is a spare classroom used as a Mathematics room but the headmaster would divide up the large classes and absorb this room if he had his full allocation of staff; it is not greatly used at present.

The pupil/teacher ratio is 36.5:1 but the fourth year is slightly worse off with 77 pupils in the two streamed classes. Of the nine teachers, only three have had less than ten years experience and none are in their first year; two are near retirement. Several have only recently joined the staff however and the headmaster took over only a year ago. He is reappraising much of the organisation and is beginning to implement some of his ideas. The present description of much of the school's activity pre-dates the present head.

The school is most likely the most 'traditional' of the three taking part in this investigation as regards mathematics but there have been other attempts at innovation in the school including a team teaching project. The headmaster considers the Mathematics to be "mainly traditional" and though he is encouraging those teachers who are trying out new methods, the approach is still chiefly 'whole class' orientated.

As was the case for School 'A', there is no special mathematics centre for the teachers but once again, several teachers have attended a Nuffield Mathematics Course. The County organises a number of Mathematics courses each year when representatives are required from most schools.

It would therefore be surprising to find any school which did not have several teachers who had attended such a course.

Unlike both Schools 'A' and 'C', in which the Mathematics 'specialist' takes a fourth year class, the specialist teacher in School 'B' takes the top third year class. As the 11+ selection takes place early in the 4th year there is less scope for experiment with the third year than might take place with fourth year children after the 11+ assessments have taken place.

Quite a lot of "basic work" is done in Mathematics, including methods of computation and work on the four rules. Assignment cards are not generally used, nor are the Nuffield Guides, though they are available in the school and referred to by one or two of the teachers. The children usually work neatly in their books, writing in ink, but some teachers encourage the use of different methods of presentation using large card and graph paper.

A good deal of apparatus has been obtained for Mathematics during the last couple of years although the school is also trying to build up science equipment and the school library. Structural apparatus, Dienes Multibase Arithmetic Blocks and Cuisinaire rods are not used very much but more general apparatus, balances, number lines and shapes are beginning to be more widely used. One hour per day is timetabled for Mathematics. The children are assessed by the class teacher's own tests, general impressions, and the work they produce.

There is once again only one Infant School providing the Junior intake and it has no special emphasis on Mathematics though a good reading record.

School 'C'

Although in a large coastal town some ten miles from the city in which the previous schools are found, School 'C' is situated in a very similar environment. It is on the boundary of the town and once again takes a large proportion of its intake, about 60%, from council houses. The standard of the council houses is also of a similar high standard to those in the catchment area of the previous schools. A post-war development, it is described by the headmaster as being "not easily distinguishable" from some of the private development.

The school is a pleasant brick building, built in 1949 with a school yard and playing field. With 420 pupils, however, it is at a maximum with no scope for spare rooms. The pupil:teacher ratio is 35:1 but the three classes in a year group are divided into two 'A' classes and one 'B' class, the 'B' class having slightly fewer children than the others.

All but two of the staff have had between ten and twenty years teaching experience, the two least experienced being in their second year. Four teachers retired about two years ago but all the teachers in the school attend the permanent Nuffield Mathematics Centre once a fortnight. Three of the teachers have attended regularly for the whole of the last four years, all the teachers have had at least one years attendance at the Centre, and most of them much more.

The commitment of the schools in this area as pilot schools of the Nuffield Foundation Primary School Mathematics Project has completely changed their approach to Mathematics teaching and it is this factor that distinguishes this school from Schools 'A' and 'B'.

The whole basis of this school's approach to Mathematics is consequently an activity one, and the headmaster estimates that discovery methods and assignment card work accounts for at least 90% of the one hour per day allocated to Mathematics. The time allocated is exactly the same as in both School 'A' and School 'B'. The aim of the school in following the new approach is to encourage the child to acquire a grasp of the breadth of Mathematics rather than just Arithmetic, and the time given to techniques of computation is very little. For example, there has been no teaching of multiplication of tons, cwts. qtrs. stones, lbs., or working of 'money' sums for the past few years.

The assignment cards are mainly produced by the teachers, the old class 'text-book' used before joining the project is no longer used, and some modern books are available for reference. Every teacher has a set of Nuffield Guides.

On beginning the scheme, the school was allocated a special allowance for mathematics equipment by the County authority, spread over four years. It has more than doubled what might otherwise have been available and has enabled the school to build up a large storeroom stocked with mathematics equipment; four calculating machines, balances, shapes, equation balances, weights, pin boards, trundle wheels, tapes, number lines, Unifix, Cuisenaire rods, Dienes M.A.B. and Algebraic Experience Material are some of the stock available and all the apparatus, including the sets of structural material are used very extensively.

Each child has a rough jotter, assignment book, graph book and book for computation. They are also encouraged to use large sheets of plain paper and graph paper in order to present their results. Considerable emphasis is placed on the children writing clear accounts of their discoveries, in ink, in their assignment books.

Initiative from the children is encouraged a great deal and they are given every opportunity to work out their own ideas and discuss them with the teacher. The teachers make their own assessments, record the child's progress on an assignment card grid and set questions for an annual school test.

As in the case of Schools 'A' and 'B', School 'C' is served by one Infants School and in this case the Infants School too has placed a good deal of emphasis on mathematics by activity - even before the formation of the Nuffield Project. It also makes extensive use of Cuisinaire rods.

Further Details

(i) Social Class of the Catchment Areas

From the descriptions of the schools, it is evident that they are situated in similar areas and are likely to have an intake with the same social background. This was confirmed by a classification of the father's occupation according to the Registrar General's Classification of Occupations (1960).

Each child was asked to fill in, on a slip of paper, his father's occupation, and also whether his mother worked full-time or part-time.

The father's occupation was allocated to one of the following five social classes as designated by the Registrar General's Classification:-

I Professional, etc. occupations

II Intermediate occupations

III Skilled occupations

IV Partly skilled occupations

V Unskilled occupations

The frequency distribution of these classes within each of the three schools is shown in Table 1 and figures (i) (ii) and (iii),(8).An analysis of the results showed no difference between the mean social class of the parents in the three schools. In no case did the differences reach even a 15% level of significance (see Tables 2 and 3).

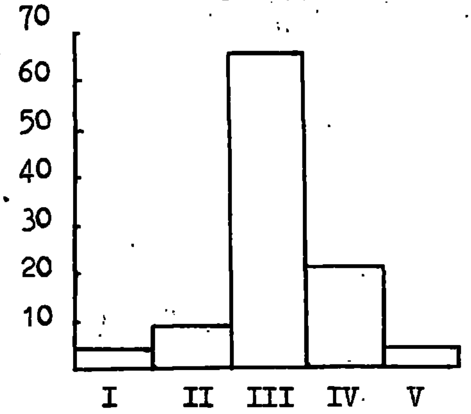
TABLE 1 Social Class of parents Schools'A' 'B'and'C'

Social Class

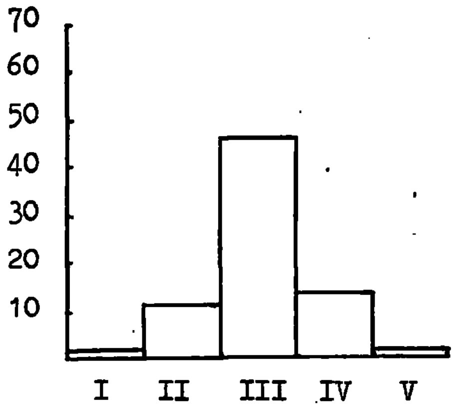
	I	II	III	IV	V
School 'A'	3	8	64	19	3
School 'B'	1	11	46	13	1
School 'C'	6	9	50	17	12

Figure 8 Distribution of Social Class

(i) School 'A' n = 97



(ii) School 'B' n = 72



(iii) School 'C'   n = 94

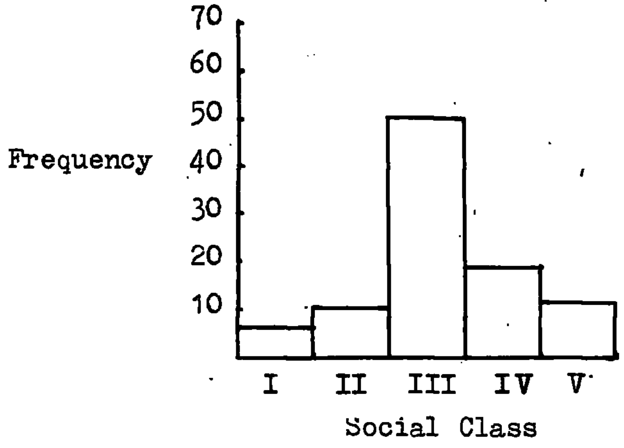


TABLE 2 Means and Standard Deviations of the Social Class Measures

School	A	B	C
Mean Social Class value	3.11	3.03	3.21
Standard deviation	0.72	0.66	1.00

TABLE 3 Significance of Social Class differences between Schools

(For significance at the 5% level the ratio $\frac{\text{difference}}{\text{S.E.}}$ should be ≥ 1.96)

Schools	A & B	B & C	A & C
Difference of means	0.08	0.18	0.10
S.E. of differences	0.10	0.13	0.13
$\frac{\text{Difference}}{\text{S.E.}}$	0.80	1.38	0.77

In each school a considerable number of children had mothers who go out to work. The details are given in the following table, and once again illustrate the similarity of the children's home background.

TABLE 4 Percentage of Mothers working
Schools 'A', 'B' and 'C'

School	Percentage Full-time	Percentage Part-time
A	28.6	58.9
B	18.9	52.7
C	26.2	56.3

(ii) Intelligence level of the three Samples

The three schools being under the same Local Education Authority, each of them had taken part in the County's 11+ selection procedure and had sat the same tests including two Moray House tests of Verbal Reasoning, Tests 81 and 82.

The results of these tests were made available to the writer in the County records and provided the 'intelligence' measures referred to in the present study. The I.Q. distribution for a number of schools was analysed in the initial selection and in particular the results from Schools 'A', 'B' and 'C' yielded means whose differences were not significant. The largest difference, that between Schools 'B' and 'C' was not even significant at a 20% level and the other two differences were very much smaller.

The results are summarised in Tables 5 and 6

TABLE 5 **Intelligence Quotients: Means and Standard deviations Schools 'A', 'B' and 'C'**

School	A	B	C
Mean I.Q.	103.8	102.5	105.0
Standard deviation	13.5	14.3	12.1

TABLE 6 **Significance of School Differences in Mean I.Q.**

(For significance at the 5% level, the ratio, $\frac{\text{difference}}{\text{S.E.}}$ should be $\geq$ 1.96)

Schools	A & B	B & C	A & C
Difference of Means	1.3	2.5	1.2
S.E. of differences	2.07	2.03	1.76
$\frac{\text{Difference}}{\text{S.E.}}$	0.63	1.23	0.68

Summary and Hypotheses

The schools are situated in similar urban areas in each case bordering open farmland. There is a substantial proportion of children in each school from council estates but none of the schools are in anything like deprived areas. Parental background in each case is essentially working, or lower middle class. The school populations differ to no significant extent in either I.Q. or social class background.

In none of the schools is the size of classes excessive and each has a high proportion of experienced teachers. All three schools have pleasant, adequate buildings and a good sized playing field. Each school takes its pupils from a single Infants School.

The one extensive and obvious difference between the schools lies in the new approaches to Mathematics adopted in such a committed fashion by School 'C'. Compared to this the other differences, already noted in the descriptions were ones of detail. Pupil:teacher ratios were slightly different, though not greatly so. The old buildings of School 'B' were not as attractive as School 'A' or School 'C', but it had several new classrooms. The ways of streaming varied, though all stream in some way. The headmasters and teachers were bound to have their own peculiar ideas and abilities, but none were observed to be excessive.

Although these minor differences will be borne in mind when interpreting the results, the overwhelming difference remains the Mathematics emphasis in School 'C'. Here, the great emphasis on the discovery approach to Mathematics teaching, the school being a pilot member of the Nuffield Project, is a deliberate exercise to improve the mathematical, logical and creative thinking abilities of the children, as well as their attitude to mathematics. If there are significant differences between the children's performances in this school and the control schools it cannot but reflect the effectiveness of the school's implementation of the mathematics project.

In order to facilitate discussion of the inter-school differences and to focus attention on the possible effects of the discovery approach, the following hypotheses are suggested:

1. Children in School 'C' will show a more favourable attitude to mathematics than children in Schools 'A' and 'B'.

2. Scores on the Creativity tests will be higher from School 'C' than from the control schools.

3. The performance of children in School 'C' on the N.F.E.R. Intermediate Mathematics test, which stresses understanding and excludes routine calculation, will be greater than in Schools 'A' and 'B'.

4. The scores on tests designed to assess flexible and logical thinking in mathematics will be higher from children in School 'C' than from those in Schools 'A' and 'B'.

5. The attainment of children in School 'C' on the tests of Mathematical Concepts will be greater than that of children in the other two schools.

6. Performance on the N.F.E.R. test of 'Arithmetic Progress', which involves mechanical and problem arithmetic will not differ significantly between the experimental and the other two schools.

2. <u>Testing Battery and Procedures</u>

The dual nature of the present study, part exploratory and part evaluative, together with the need to allow for the appearance of as many factors of creative, flexible or original thinking as possible, implies a wide variety of assessments of the children's abilities. Four main considerations guided the choice of the testing battery:

1. The practical limitations in administering and marking the tests, the need to confine the tests to those which could be administered on a group basis, and an obligation to keep the total testing time within reasonable limits.

2. The need to make a selection of 'creativity' tests which would sample as many as possible of the dimensions hypothetically associated with creative thinking.

3. The need for a sample of mathematics tests which would not only measure computational ability but would also assess a degree of problem solving ability and understanding, and do justice to both the traditionally taught children and those working through discovery methods.

4. The need to keep a balance between tests in the interests of the subsequent factor analysis.

The complete battery of tests finally consisted of two I.Q. tests, previously administered by the County authorities in their 11+ selection procedures; a Guttman scale designed to assess the children's attitudes towards five areas of the curriculum including Mathematics; a Creativity booklet containing five separate creative thinking tasks, including a Make-up Problems section; an Arithmetic booklet in three parts including a concept test; and two standardised N.F.E.R. Mathematics tests, one designed for measuring children's progress in Arithmetic and the other of more recent origin specially intended to assess the more modern approaches to the teaching of mathematics. The total testing time amounted to 3 hours 4 minutes, excluding the time needed for preliminary instructions.

The Creativity booklet, the Arithmetic booklet and the Attitude scale are not available commercially and are reproduced in the Appendix together with samples of responses. A discussion of the tests follows:-

(i) <u>I.Q. Tests: Moray House Verbal Reasoning Test 81 and Test 82 (1968)</u>

The 1968 revision of the above standard group tests had been given as part of the County's 11+ selection procedure and were kindly made available for use by the writer. The tests are standardised to a mean of 100 and a standard deviation of 15, and the children's scores were adopted as the I.Q. measures in the present study.

It is particularly suitable, considering the weight of numerical tests in the remainder of the testing battery, that the 'intelligence' measures should be based on a verbal form of assessment.

(ii) Attitudes

In his investigation of children's attitudes to Junior School activities, Sharples (1969) suggested that young children find it diffucult to make the comparative judgements and responses necessitated by many tests of attitudes. From an extensive analysis of children's statements of their attitudes towards school activities, he consequently developed a Guttman scale which proved to be a reliable and effective instrument in his investigation, and which he has kindly supplied for use in the present study. A copy is reproduced in the Appendix.

Eight statements are presented to the subjects as being views expressed by other children and they are asked to indicate which statement agrees best with how they feel about each of five school acitivites. The statements are numbered from 1 to 8, from "I hate it" to "I love it" respectively, and the five activities considered were Reading, Mathematics, Writing Stories, Art, and P.E.

Each child thus had five separate scores, from 1 to 8, indicating his attitude to each of the school subjects. His total score was also recorded as an overall measure of his attitude to school work in general.

(iii) Creativity Booklet

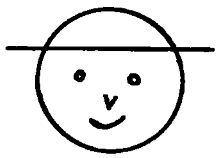
(a) Circles Game

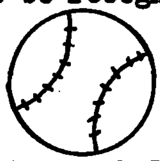
This test is an established part of the Test of Imagination, Form D, of the Minnesotta Tests of Creative Thinking (Torrance 1962, 1965), and asks candidates to sketch in ten minutes as many objects as possible which have a circle as their main part.

Described by Guilford (1967) as a figural test of ideational fluency, it was first suggested by him in a verbal form, asking the subject to "Name all things that are round" (Guilford (1950)). Guilford has mainly used the test with adolescent and adult populations but it has been successfully developed by Torrance for use as early as kindergarten. It is a particularly good test for children, and to introduce a creativity battery, as it is well suited to group administration and to children who are slow in their verbal development.

The candidates are provided with a page of circles and told to add their lines inside or outside the circle or both inside and outside. They may label the object if they think it might not be recognised.

e.g.





tennis ball

In the present study the 'test' was entitled Circles 'Game' to further a favourable reaction to the Booklet and to reduce any test atmosphere that might arise. The time limit was also modified for in a pilot study carried out by the writer the time of ten minutes recommended by Torrance was found to be very short. When told to stop children reported that they had "only just got going", and it was felt that a more reliable measurement, particularly of the Flexibility and Originality categories would be obtained if the time was extended. In the final form of the Booklet the children were therefore allowed 15 minutes.

Reviewing some of the studies involving this test, and parts (b) and (c) of the present booklet, Torrance (1965) reports a good degree of test-retest reliability, and validation based on the criteria of other assessments of creative thinking, attitude flexibility, personality, and teacher and peer nominations. Whereas the Guilford forms of creativity tests are usually designed to identify or assess a single factor in his scheme of divergent production abilities, Torrance had adapted much of the material to allow for scoring on several factors. He has in fact gone to the other extreme and in the Circles test, for example, has used, among others, criteria of Fluency, Flexibility, Originality, Elaboration, Communicativeness, and Complexity. More recently he has reverted to only the first four criteria, and in this study only the first three, Fluency, Flexibility and Originality will be adopted.

Details of scoring procedures will be given later.

(b) Uses for Things

Originally designed by Guilford as a test of ideational fluency or flexibility according to whether marked for number of responses or categories into which the responses may be placed, this test asked the subject to give, in eight minutes, as many uses as he could for a brick. Later Guilford used the term 'spontaneous flexibility' to distinguish this sort of shift of response category by individual initiative from his later form of the test named 'Alternate Uses' which specifically requires the candidate to change to a new category with every response. (See Guilford, 1950, 1959b, 1967a).

With the substitution of 'tin-cans' for 'bricks' the original form of the test was incorporated by Torrance in his Minnesotta Creativity Battery

(Torrance 1962, 1965), and in one of its various forms the test has since become almost a classic in a collection of divergent thinking tests particularly when children are being tested (Getzels and Jackson 1962, Wallach and Kogan 1966, Hudson 1966, Lovell and Shields 1968, Child 1968).

In the adaptation used for the present battery, subjects were asked to write down as many different uses as they could think of for each of the three stimulus objects: a newspaper, a spoon, and a piece of string. They were given a total time of fifteen minutes, and scored for fluency, flexibility and originality.

(c) Consequences

Once again used extensively since Guilford's early hypotheses on the nature of creative thinking, this test had its origin as a test of 'Fluency of Inferences' and was later incorporated into Guilford's more sophisticated battery of tests of divergent thinking as a test of the Semantic Transformation or Originality factor. In the latter form it is intended to assess a subject's ability or disposition to produce rare, remotely associated, or clever responses. In his experiments, Guilford found that all three criteria isolated the same factor which he termed 'originality' (Guilford 1950, 1959b 1967a.).

Torrance's adaptation of the test has been used extensively with children though his time limit of five minutes for responses to three situations such as "What would happen, if man could be invisible at will?" appeared once again, from the writer's pilot study, to be too severe. Accordingly in the present form of the test, ten minutes was allowed for the children to write down consequences to two hypothetical situations:

(i) "If we had no hair on our heads"

and (ii) "If we did not need to eat or drink".

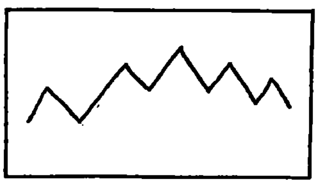
The responses were scored for fluency and originality.

(d) Pattern Meanings

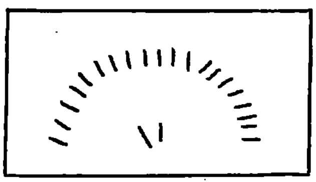
This test was adapted from Wallach and Kogan (1966) and incorporated items from their test of "Pattern Meanings" and from that of "Line Meanings". The test was designed to stimulate the child "to generate possible meanings or interpretations for each of a number of abstract visual designs" so as to assess his imagination and his power of making uncommon associates. The responses are therefore scored for fluency and originality respectively, the latter being assessed by the relative infrequency of a response.

This is the second test using a visual stimulus and with the circles test provides a pair of tests which might aid the identification of any appropriate factor which might appear in the factor analysis.

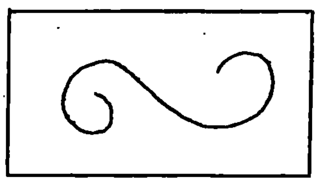
Twelve minutes were allowed for the responses to the three figures reproduced below:-



(i)



(ii)



(iii)

(e) Make-up Problems

'Sensitivity to problems' was the first of the thinking factors hypothesised by Guilford (1950) and as an example of a possible test he suggested that one might present the examinee with a short paragraph of expository material and instruct him to ask as many questions as he can that are suggested by the statements, with relatively liberal time allowed. Guilford himself later developed other 'Seeing problems' tests of his factor of Semantic Implications, but his original suggestion was incorporated by Getzels and Jackson (1962) in a test of 'Make-up Problems'.

The test aims in particular at assessing the subject's ability to translate the information given in each paragraph into a more concise symbolic form and to create new arrangements of these symbols in the form of mathematical problems. The subjects are asked to make up as many problems as they can from the material given in four fairly complicated paragraphs. Although no time limit was specified, Getzels and Jackson report that the test was usually completed in 30 minutes.

Even without the American terminology, the original paragraphs are too difficult for pre-adolescents and they have been adapted for use with younger children by Lovell and Shields (1968). The present test asks for make-up problems from the information given in one paragraph only, and is adapted, in turn, from the latter investigators.

A time of 10 minutes was allowed and the results scored to reflect both the number of problems invented and their degree of complexity.

A Note on Time Allowances

In describing the creativity tests used it has been noted above that the times allowed for certain of the tests are greater than those given by some investigators. There is, as Guilford (1950) observes "a general problem to be investigated, apart from Creativity, whether many of the primary thinking abilities have both a power and a speed aspect somewhat independent of each other". Wallach and Kogan (1966) have emphasised that there should be no time constraint whatever, but even their tests, conducted in a "gamelike and relaxed context" had the implicit limitations of boredom, frustation and fatigue.

The writer's pilot study showed that children can produce a seemingly unending supply of figures made from circles until overcome by one or other of the latter. The problem has still to be investigated, but for the purpose of the present study, the criterion of fluency has been incorporated as a creativity measure with an acknowledged speed factor.

Scoring Procedures

The automatic, objective scoring procedures which facilitate the marking of standardised tests of attainment and intelligence have gradually dictated a form of testing in which the right answer, arrived at by a 'convergent' thinking process is of paramount importance. This is not the case with tests of divergent thinking and it leaves the experimenter with the problem of maintaining a balance between subjective and objective methods, to credit what Getzels and Jackson term the "richness and uniqueness" of a subject's response, without sacrificing scoring reliability. It is also necessary to specify the precise method of scoring adopted, for although inter-scorer reliability is usually high when the method of scoring is stipulated (Yamamoto 1965b) variations in scoring procedures can produce quite different results.

The following methods of scoring have been adopted in the present Creativity battery:

(a) Circles Game

(i) Fluency

One mark was given for each recognisable response.

(ii) Flexibility

One mark was awarded for each different category of response (see below)

(iii) Originality

Marks were awarded to each unique item or to categories which were included by less than 19 children (6%). Exceptional answers in larger categories such as "top view of a yoghurt carton", "a ginger-bread man", or "coconut on stand", were also credited, although they were placed in the respective categories of 'containers', 'human figures', and 'fruits' for the purposes of the flexibility score. The following scale was adopted for awarding originality marks:

Frequency	1	2–5	6–10	11–18
Originality Mark	6	3	2	1

Response Categories

In order to credit the responses of nearly 300 children according to the above scheme it was necessary to tabulate the data very systematically. Torrance (1962, 1965) has illustrated the type of categories that are usually formed, and several 'obvious' categories were readily apparent, for example:

Animal faces, human faces, animal figures, human figures, planets (including sun, moon, etc), clocks and watches, fruits, coins, symbols (letters, numbers), and containers.

Such categories formed the basis of a frequency distribution, the number of responses made by each child in any particular category being tabulated. New categories were added to the distribution as they occurred. Rather than limit the categories, and hence the degree of flexibility, to large and ill-defined categories, a large number of answers were given categories of their own. It would, for example, have been possible to have created a 'household' category to include such diverse items as 'a cushion', 'T.V. set', 'electric fan', 'toilet roll' and 'tea cosy'; but where the defining concept was not obviously similar the articles were awarded a separate category. This resulted in a very large frequency distribution, samples of which are included in the Appendix, but it was decided that it would be the most reliable means of analysing the data in this test.

(b) Uses for Things

(i) Fluency

One mark was given for each relevant response

(ii) Flexibility

One mark was awarded for each different category of response.

(iii) Originality

Marks were awarded on the basis of statistical infrequency. A use given by not more than 20% of a sample of 100 subjects was regarded as uncommon and credited according to the following scale:-

Percentage frequency in sample	1	2-3	4-9	10-20
Originality Mark	5	3	2	1

Samples of the distrubion obtained are given in the Appendix.

Example: A newspaper: "To read, make a paper hat, put on floor to stop the floor from getting dirty, to make darts, make a paper boat, read about football, wrap fish and chips in, stop draughts."

Scoring: Fluency 9

Flexibility 6

('make a paper hat', 'make darts', 'make a paper boat' are in the same category)
(   )
('read', 'read about football' are in the same category

Originality 4

('Put on floor' is given by 11% of the sample and thus scores 1 originality mark
('Stop draughts' is given by 3% of the sample " " " 3 " marks
(The other items were common and received no originality marks

The scores for each of the objects was added, to give a total score for each scoring category.

(c) Consequences

(i) Fluency

One mark for each sensible response.

(ii) Originality

Marks were awarded for remote responses on the basis of a frequency distribution of the replies given by a sample of 40 children. The experience of marking for 'Circles' and 'Uses' suggested that a random sample of 40 children out of 300 would give a reliable frequency distribution of responses to this test.

A response which was unique in the sample was classed as 'very uncommon', as was any other reply not recorded by the sample. These relatively unique replies scored 2 marks. Other responses given up to 8 times in the sample (20%) were regarded as 'uncommon' and scored one mark. (A sample of the data is given in the Appendix).

The following example shows the frequency, f, of a response as given by the sample, and the marks consequently awarded for originality:

Example: 'If we did not need to eat or drink'

"food shops would have to close down (f = 11, no marks), there would be no meal times (f = 6, 1 mark), reservoirs would not be needed (f = 2, 1 mark), we could live in the desert (f = 1, 2 marks), no need for knives and forks (f = 13, no marks)

Score: Fluency 5 Originality 4

The scores for replies to the two hypothetical situations were added to give a total score in each category.

(d) Pattern Meanings

(i) Fluency

(ii) Originality

Both scores were awarded after exactly the same procedure as for the Consequences Test.

The scores for the three patterns were added to give a total score in each category.

(e) Make-up Problems

Full details of a scoring procedure is given by Getzels and Jackson (1962), in which each problem is marked for the number of ELEMENTS and OPERATIONS contained in it. One mark was awarded for each ELEMENT, i.e. each piece of numerical information (e.g. the number of girls, 60, who went on the trip), and one or two marks for each OPERATION, i.e. addition and subtraction (1 mark), or multiplication and division (2 marks).

The procedure is easier once the data given in the paragraph is summarised with a symbol assigned to each numerical element e.g.

Total number of school pupils	(a)	and so on up to element (l)
Total number of 10 year olds	(b)	
Number of girls	(c)	

Scoring then proceeded as follows:-

1. How many boys went? ≡ $\begin{matrix} b & - & c \\ 1 & 1 & 1 \end{matrix}$ = 3 marks

2. How much bus fare altogether for the pupils ≡ $\begin{matrix} b & \times & e \\ 1 & 2 & 1 \end{matrix}$ = 4 marks

3. How much pocket money is left after a pupil has gone in everything? ≡ $\begin{matrix} i & - & e & + & f & - & j & + & k & + & l \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{matrix}$ = 11 marks

If a piece of information arrived at in one problem was used in another it was credited only one mark as one element in the new problem.

This scoring procedure was initially adopted in the present study but a number of factors led to its abandonment in favour of an alternative scheme.

Implicit in Getzels and Jackson's method of scoring is the belief that the children (adolescents in their case) appreciate the implications of the questions they ask in terms of the number of arithmetic operations.

Consequently, a large number of operations leads to a large score even if the question itself is a fairly simple one. This is particularly possible in the nature of the paragraph used in this study where a fairly obvious question such as "How much was spent altogether?" results in 23 marks.

It was felt by the writer that the 11-year-old children in the present investigation would not be likely to grasp all the implications when they made up such a question. This consideration, and the fact that a simpler procedure would considerably facilitate the scoring, led to the formulation and adoption of an alternative scheme.

In this method of scoring, the following marks were awarded:

1 mark for a question involving 1 operation

2 marks for a question involving 2 or more operations.

As a comparison between the two procedures a Spearman's Rank Correlation was carried out between the scores of a sample of 21 children marked by both methods. A value of R= 0.98 was obtained, significant at more than a 0.1% level and this confirmed the writer in adopting the second procedure.

<u>Addenda to the Scoring Procedures</u>

1. In any group test the ability of a candidate to understand and follow directions is part of the ability tested so that, in general, where subjects departed from the requirements of the tests, their responses were not credited.

2. Some subjectivity inevitably arose when a judgement of feasibility had to be made regarding the admissibility of a response, as, for example, in the following uses for a newspaper: "to stuff down a Russian's throat to choke him" (allowed) or "to put under cushions to make the room tidy" (Not allowed).

3. In the case of the Make-up Problems test two additions were made to the scoring procedure

(a) A question involving a single numerical answer obtainable from the information without the need to apply any 'operation' was credited with ½ mark and the subsequent total rounded <u>down</u> to the nearest whole number.

Thus "How many girls went?", although verbally similar to the problem "How many boys went?", is answerable without any computation and was credited ½ mark for the single <u>element</u> of information required.

(b) As possible exceptions to Addendum 1 above, seventeen scripts were put aside for review on the grounds that they might deserve some credit although the instructions had not been followed exactly. Of these, eight were given no credit according to the original criteria, but the remaining nine were awarded ½ mark for problems clearly indicating a make-up problem ability though not directly applicable to the material provided. They might for instance contribute their own information followed by a sensible question. The maximum score awarded to these exceptions was 3 marks. They were distributed amongst the three schools.

(iv) <u>Arithmetic Booklet</u>

<u>PART 1</u>

<u>Concept Test (N.F.E.R.)</u>

This test is part of the Concept Arithmetic test specially designed for the N.F.E.R. study of Arithmetic in the Primary School conducted by Biggs (1967). Although not commercially available, permission from the N.F.E.R. was granted for its reproduction in the present study. It was designed to measure the child's conceptual understanding of Arithmetic, the usual forms of problem test not being considered adequate for this purpose. Biggs gave two reasons for this belief, firstly problem tests may be so stereotyped that sets of rules can be learned to cope with most of the items without real understanding, and secondly that even if the items did present genuine problems, the element of computation required between 'seeing' the problem and producing the answer could be irrelevant to the factor of understanding itself.

The first part of Biggs' test, Concept A, was an attempt to assess the childs ability to apply his knowledge of already learned concepts to problem situations without involving him in computation, and, as such, is considered very suitable for the present study where a test of computation would favour the more 'traditional' approaches.

The second part, Concept B, emphasised the child's ability to recognise certain basic arithmetic concepts when they are presented to him in an unusual or unfamiliar way, and to see if he can relate the unconventional presentation to the more familiar symbolic representation of the concept.

Biggs (1967) reports that both parts of the test are reliable (Kuder-Richardson coefficients of 0.84 and 0.97 respectively) but although Concept A discriminated between the various 'method groups' in his study, Concept B was unsuccessful and played little part in the results of his investigation. In fact the differences between 'method group' means on Concept B rarely achieved significance and Biggs acknowledged that it is questionable whether, in the form he used it, it was a valid measure of number understanding. The presentation is exceedingly 'wordy' and would involve a good degree of verbal ability to understand. It was therefore decided to omit most of the Concept B test but to incorporate the Concept A test as the first part of the writer's Arithmetic Booklet, separate norms being available.

The timing of Concept A in the N.F.E.R. presentation, however, included a page, one sixth, of the Concept B test, and this page, designed to test understanding of the concept of mensuration, was kept in the present battery and scored separately as a measure of the mensuration concept.

Examples

(i) Concept A

Item 5, Tick the number which is one more than 999

100   10100   9991   1000   9910

Item 9, 246 people paid 2/9d. each to see a football match. Tick what you do to find out how much they paid altogether.

ADD   SUBTRACT   MULTIPLY   DIVIDE   NONE OF THESE

(ii) Concept B (PART 2)

"At the top of the page you will see pictures of a square fip and of a square yog. A square fip is one fip along each of its sides. A square yog is one yog along each of its sides.

Item 5, How many square fips do you need to cover the whole of

ONE SQUARE YOG? .... "

PART 2

Filling Spaces

(i) Series Completion

Studies reported by Lovell (1968), Lovell and Shields (1968), and Lunzer (1965) have indicated that while the ability of children to deal with problems involving the second-order relations (relations between relations) of proportionality rarely develops until the Piagetian stage of formal operational thought, problems involving numerical series are a good test of the flexibility of first order relations (relations between elements) involved during the stage of concrete operations.

Lovell (1968) suggests that when gifted children reach the stage of concrete operational thought they are able to transfer their thinking to a greater variety of situations and tasks than is the case with ordinary pupils at first. "It is", he observes "as if they possess sub-schemas of much greater generality which permits transfer to new situations". Accordingly a test was devised by the writer to include ten items requiring the completion of a sequence, confining the types to those which could be answered without necessitating a grasp of the relation of proportionality. Following Lunzer (1965) the following types of sequence were included within this criterion:

(a) Additive sequence: Involving addition or subtraction of a constant

e.g. Item 2 21, 16, 11, 6, –,

(b) Sequential differences:

(i) Involving addition e.g. Item 3 15, 14, 12, 9, –,

(ii) Involving subtraction e.g. Item 9 1, 11, 20, 28, –,

(iii) Involving multiplication e.g. Item 7   1, 3, 7, 15, -,

(c) Simple Geometric Sequence: Involving multiplication or division by a constant,

e.g. Item 6   80, 40, 20, 10, -,

Item 10   81, 27, 9, -, 1

Scoring: 1 mark for each correct answer.

(ii) Gap filling

Bartlett (1958) in his experiments on thinking has interpreted the process of thinking as essentially "filling the gap" between information presented and goal desired. He devised a number of experiments, chiefly intended for adult subjects, which had numerical items requiring that spaces be filled. Some of the material can be compared with the previous test of sequence completion and other parts suggested the present test of 'gap-filling'.

Some subjects who attempted Bartlett's problems persistently attempted to apply a 'method' of solution, others proceeded by trial and error, whilst some people relied on a leap of 'intuition' to fill the gap. A significant observation noted by Bartlett was the comment by one of his subjects that "It was hard to break away from an approach which nevertheless was leading to nothing definite".

For success in the tests, a subject therefore required a certain amount of flexibility in his thinking, and needed to vary his approach and try different methods of solution. Bartlett's case of "Simple Arithmetic in Disguise" is a good example, in which an addition 'sum' is given as

```
  DONALD
+ GERALD
  ROBERT
```

The exercise is to find the number corresponding to each letter, given that D = 5, and that every number from 0 to 9 has a corresponding letter.

In the present test, more appropriate to 11 year olds, the sums were not 'disguised' but sufficient gaps were left in the working to demand a degree of flexibility and understanding in their completion. The test is reproduced in the Appendix

<u>Example</u> Item 14

```
              □ □ 3 □
Subtraction     9 □ 1
              -------
                  9 5
              -------
```

Scoring: One mark was awarded for each gap filled.

<u>PART 3</u>

<u>Easy Ways of Solving Problems</u>

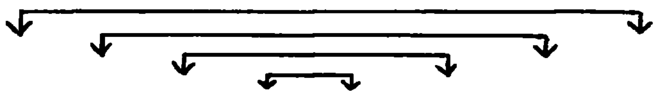
In this part of the Arithmetic Booklet the subject is first given two examples, involving the summation of a series, in which a new way of looking at the problem provides a key to its 'easy' solution. The emphasis is on the principle that the whole sum of the series can be seen as a number of separate parts which can be reorganised into a new form whilst retaining the original sum.

For ease of solution the subject needs to achieve a 'good gestalt', by a procedure which "goes from viewed whole-quantities to the items viewed as parts of the whole" (Wertheimer 1961). The preliminary explanation of the test includes the following example:-

Add: 96 + 97 + 98 + 99 + 101 + 102 + 103 + 104

Can you see an easy way to do it?

Pair the numbers again, as shown by the arrows:-



96 + 97 + 98 + 99 + 101 + 102 + 103 + 104

we get 96 + 104 = 200

97 + 103 = 200

98 + 102 = 200

99 + 101 = 200

Therefore TOTAL = 800

Many of the examples set were taken from Wertheimer; with one exception they were all what he terms A-tasks, i.e. they are best solved by understanding the structure of the problem and applying a "productive process" rather than by simply applying a blind 'method'. The key to the problems lay in some application of the hints provided in the introductory examples, though in some cases in a disguised form.

The test was tried out in the writer's pilot study and a time limit of ten minutes made it unlikely that a candidate would gain a high mark unless he had grasped the principle involved and had an insight into the nature of the problem.

Examples

Item 4 $196 + 77 - 134 - 77 + 134 =$ ....

Item 13 $83\frac{1}{3} + 83\frac{2}{3} + 84 + 84\frac{1}{3} + 84\frac{2}{3} =$ ....

Item 24 $1 \times 2 \times 3 \times 10 \times 15 \times 30 =$ ....

Scoring:- One mark was given for each correct answer.

The complete test is given in the Appendix.

(v) N.F.E.R. Arithmetic Progress Test C1

This test, available through the N.F.E.R., (Test 89), was designed to enable the teacher to estimate the progress made by his pupils during the last two years of the Junior School course. There are two sections, each of 15 minutes duration, separately timed.

The first section consists of computation involving knowledge of the four rules and simple exercises in money, weights and measures. The second section consists of problems requiring similar knowledge. The scores in the two sections were recorded separately as 'Mechanical' and 'Problem' scores respectively, together with the total score standardised according to the manual provided.

The test aims to measure general attainment in Arithmetic, and standardised in 1952, is essentially traditional. Its emphasis is therefore likely to favour the 'control' schools, but the balance is maintained by including the next test which, in contrast, has been recently designed to follow the new approaches.

(vi) N.F.E.R. Intermediate Mathematics Test 1

This is a new N.F.E.R. test (No.228), provisional norms for which were only completed in January 1969, and is primarily designed for use in the fourth year of the Junior School. The content follows the more recent approaches to the teaching of mathematics, and was designed to test understanding of mathematical concepts and involve almost no mechanical computation.

It includes questions on number, the four rules, measurement of length and area, shapes and fractions. The questions are presented in a non-traditional form, with no time limit. The test is normally completed in about 50 minutes.

Administration of the Tests

The two I.Q. tests had been administered as part of the County's 11+ selection procedure at the beginning of the pupils' fourth year in November 1968. The other tests were all given by the schools during the first week of July 1969.

In order to keep the testing conditions as uniform as possible, the writer prepared a 'manual' of test procedures giving the sequence and duration of the tests, general notes on preparation and administration, and specific details for each of the tests. Each headmaster and all the teachers involved were provided with a copy which is reproduced in the Appendix. At the same time, the headmasters were provided with the sets of testing material, appropriately parcelled and labelled for the three days of testing.

The test procedures asked the teachers to keep to the order of testing days as given and to the order of tests within each day. This ensured that the attitudes scale and the creativity tests were given at the beginning of the testing week when they could be expected to be least coloured by any test atmosphere. The schools were asked not to tell the children that there would be more tests later in the week, and to introduce the first day by reading the following explanation:-

"Three schools in this County have been asked to take part in a survey of children's attitudes, work and imagination. This school is one of them and it is hoped that you will enjoy answering the questions, which have nothing to do with the 11+"

The writer is indebted to the headmasters and teachers for carrying out the administration of the tests and for their interest and co-operation though-out the experiment. It was good to learn that in spite of the heavy testing load of 3 hours 4 minutes, it was generally reported that both teachers and children had enjoyed the exercise.

Summary of the Tests, their Sequence and Duration

DAY 1

(i) Attitude questionnaire "Things you do at School"		Time: Approximately 3 minutes
(ii) Creativity Booklet		Total time: 62 minutes (excluding the reading of instructions)
(a) Circles Game	15 minutes	
(b) Uses for things	15 minutes	
(c) Consequences	10 minutes	
(d) Pattern Meanings	10 minutes	
(e) Make-up Problems	10 minutes	

DAY 2

(i) Arithmetic Booklet		Total Time:29 minutes (excluding the reading of instructions
(a) PART 1 (Concept Test)	12 minutes	
(b) PART 2 (Filling Spaces)	7 minutes	
(c) PART 3 (Easy Ways of Solving Problems)	10 minutes	
(ii) N.F.E.R.Arithmetic Progress Test C1		Time 30 minutes

DAY 3

N.F.E.R. Intermediate Mathematics Test 1	No time limit (50-60 minutes approximately)

CHAPTER 6

RESULTS

Introduction

Complete scores on the 31 variables were available for 265 out of the 297 children who took some part in the testing. The variables consisted of the scores on two I.Q. tests, seven 'Mathematical' thinking tests, five 'creativity' tests, an attitude scale, and a 'measure' of the children's sex. With the exception of the latter the scores were not markedly skewed or multimodal and were considered to give sufficiently normal distributions for the purpose of intercorrelation and factor analysis. In a battery of 31 variables the factor analysis is unlikely to suffer from the inclusion of a single bi-modal score and it was felt that in the absence of a separate boy/girl analysis of the data, this variable should be included on an exploratory basis.

The other consideration to be borne in mind in discussing the results is the presence in the battery of a number of linearly or experimentally dependent scores such as the standardised total score for the N.F.E.R. Arithmetic test together with its separate scores for mechanical and problem arithmetic. The pupil's standardised scores for the Intermediate and Concept 'A' tests were also included being corrected for age and irregularity in their distributions, according to the manuals provided.

As Fruchter (1954) points out, the extent to which time limits and test reliability influence the loadings in a subsequent factor analysis has received attention by the more sophisticated experimenters, but in view of the generous time limits allowed in the present study and following common practice, none of the existing 'correction' formulae have been applied in the present analysis.

The significance of the difference between means is easily ascertained from the calculation of standard error and reference to tables giving the percentage points of the t-distribution, and the significance of a correlation coefficient is also provided for in appropriate tables. In the factor analysis components were retained for all eigenvalues greater than or equal to the arbitrary, but widely accepted value of 1.0. In each case this criterion resulted in the extraction of a large proportion of the variance.

There are a number of criteria for estimating the significance of factor loadings (Harman (1960), Burt (1952), Rippe (1953)) but they are difficult to compute, or else, where a table of standard errors of factor loadings is compiled, as by Harman, it is acknowledged that they are not entirely reliable. As Butcher (1969) observes "No very satisfactory answer appears to have been found to the problem of determining the statistical significance of a rotated factor loading". Butcher adopts an arbitrary figure of 0.35 to distinguish high loadings which, with 70 variables and a population of 1,000 he also considers likely to be a conservative estimate of significance. Vernon (1965) adopts a rather lower level with a battery of 13 tests and 100 subjects and suggests that with such a population, loadings of 0.20 upwards are likely to be statistically significant. However, as he infers, loadings are often more profitably seen as groupings of psychological interest rather than as items of statistical significance. The analyses in the present investigation are reproduced in full though factor loadings of below 0.20 have been omitted, for convenience, in some of the duplicated tables.

Product moment intercorrelations of the 31 variables were calculated and both a Principal Components solution and a Varimax rotation of the factor matrix were performed using the IBM 360/67 computer of the University of Durham Computer Unit. The Principal Components solution is that traditionally favoured by the British school with the first component almost inevitably indicating a large common or 'g' factor. The rotation to the Varimax criterion on the other hand is claimed by Kaiser (1958) to give results approximating to Thurstone's 'simple structure' and is therefore more typical of the American solution in which the method of rotation tends to spread loadings more evenly between the factors. Both solutions are discussed.

The analysis of the results falls into two main sections as dictated by the design of the experiment. Firstly an investigation into the relation between the tasks of Creative Thinking, Mathematics and Intelligence, and secondly, the comparison of the experimental with the control schools in their respective performances on the range of tests included in the battery.

Part 1

Dimensions of Performance

Although the factor analysis is itself an analysis of the intercorrelation matrix an overall view of the relation between test performances can quickly be seen by considering the intercorrelations directly. The complete table (TABLE 7) is given at the end of this section, and the subsections are reproduced for convenient analysis.

I <u>Intercorrelation Analysis</u>

(a) <u>Intercorrelations, Tests 1-13; Intelligence and Mathematics Measures</u>

<u>TABLE A</u>

			1	2	3	4	5	6	7	8	9	10	11	12	13
I.Q.1		1	1	94	82	82	64	68	69	69	69	67	69	67	69
I.Q.2		2		1	84	84	67	70	71	69	70	66	70	68	68
Intermediate Mathematics	Raw Score	3			1	98	76	81	83	77	75	70	77	70	70
	Standard Score	4				1	75	80	82	75	75	68	75	70	68
Arithmetic Progress	Mechanical	5					1	87	94	61	64	61	65	69	57
	Problem	6						1	96	72	73	66	75	67	61
	Standard Score	7							1	71	72	65	73	70	62
Arithmetic Concept A	Raw Score	8								1	96	66	69	53	62
	Standard Score	9									1	65	67	55	60
Mensuration Concept		10										1	67	52	56
Series Completion		11											1	59	63
Filling Spaces		12												1	62
Easy Problems		13													1

This block presents the intercorrelations between the first thirteen tests, being those of intelligence and mathematical thinking. All these tests intercorrelate very highly with each other far in excess of the .01 significance level at which r = 0.16. The lowest value of 'r' is 0.52 between the N.F.E.R. test of the Mensuration concept and the writer's test of space filling in arithmetic problems. (Decimal points are omitted in the tables). An average 'r' for this block would be deceptively high as it would include the intercorrelations between Raw and Standard Scores

---

r = 0.16.

The highest correlations occur, as expected, among the different scoring procedures for a single test, although, in the case of the Circles Test, the correlation of 0.66 between its Fluency and Originality scores is equalled by a number of independent correlations. In particular it is less than and between parts scores and total scores. However, there is a very strong intercorrelation between the different categories of test. The highest independent correlation being between I.Q. and the N.F.E.R. Intermediate Mathematics test. The I.Q. tests themselves have an intercorrelation of 0.94, and, discussing I.Q.2 for convenience, it is particularly noteworthy that it should correlate so highly, r = 0.84, with the N.F.E.R. Intermediate Mathematics test. The latter is designed especially to test understanding of mathematical concepts and involves almost no mechanical computation yet it has its highest correlations with intelligence and the traditional Arithmetic Progress test.

While all the intercorrelations in this section are high, the independent correlations ranging from 0.52 to 0.84, the predominance of the lower correlations chiefly among the concept and non-commercial tests suggests that though they may not be as reliable as the standardised tests, they might give rise to different patterns of loadings in the factor analysis.

(b) Intercorrelations, Tests 14-24; Creativity Tests.

The intercorrelations between the eleven creativity measures are shown in Table B. All are positive and highly significant though in general they are lower than the correlations between the convergent tests in Table A. The lowest value of r =.27 is still well beyond the 1% significance level at r = 0.16.

The highest correlations occur, as expected, among the different scoring procedures for a single test, although, in the case of the Circles Test, the correlation of 0.66 between its Fluency and Originality scores is equalled by a number of independent correlations. In particular it is less than the coefficient of 0.68 between the Flexibility score for the Uses Test and the Originality score for the test of 'Pattern Meanings'.

TABLE B

			14	15	16	17	18	19	20	21	22	23	24
Circles	Fluency	14	1	86	66	53	49	41	47	41	47	47	34
	Flexibility	15		1	79	55	55	46	52	45	48	51	38
	Originality	16			1	41	40	34	40	40	34	34	27
Uses	Fluency	17				1	95	83	64	48	65	66	50
	Flexibility	18					1	84	66	48	65	68	55
	Originality	19						1	52	41	56	62	47
Consequences	Fluency	20							1	79	54	57	54
	Originality	21								1	39	44	45
Pattern Meanings	Fluency	22									1	90	41
	Originality	23										1	48
Make-Up Problems		24											1

Throughout this block of tests in fact the originality score for the figural Circles Test consistently involves the lowest values of 'r'. Particular attention will be given later to the factor loadings for this score.

The correlations between the different scoring procedures in a particular test are summarised in tables B (i), (ii), (iii), (iv). With the exception of that already mentioned, they range from 0.79 to 0.95 and for many procedures one score only would be sufficient. It is possible however that, though highly correlated, they may owe the correlation to different combinations of factors which might be revealed in the factor analysis.

TABLES B (i), (ii), (iii), (iv) Intercorrelations between different scoring procedures on a single test

(i) Circles Test

	Flu.	Flex.	Orig.
Fluency	1	86	66
Flexibility		1	79
Originality			1

(ii) Uses Test

	Flu.	Flex.	Orig.
Fluency	1	95	83
Flexibility		1	84
Originality			1

(iii) Consequences

	Flu.	Orig.
Fluency	1	79
Originality		1

(iv) Pattern Meanings

	Flu.	Orig.
Fluency	1	90
Originality		1

(c) Intercorrelations, Scores 25-30: Attitudes TABLE C

As can be expected with a section of affective scores reflecting liking for certain school subjects, there is no overall relationship other than between the summed score and the five sub-scores. There is however some pattern apparent in the relationship of certain of the scores, two correlations being significant at the .05 level and one at the .01 level.

TABLE C

			25	26	27	28	29	30
Attitudes	Reading	25	1	-06	09	-17	-09	33
	Mathematics	26		1	-12	-02	-07	39
	Writing Stories	27			1	-03	-11	44
	Art	28				1	-12	48
	P.E.	29					1	37
	Summed Score	30						1

'Reading' and 'Writing Stories' are positively correlated but without reaching a significant level; while the other correlations with 'Reading' are all negative. In particular, that between 'Reading' and 'Art' is the only score significant at the .01 level. Liking for Mathematics has a slight negative correlation with everything else and in the case of 'Mathematics' and 'Writing' it reaches a .05 level of significance. 'Art' and 'P.E.' are the only preferences which are positively correlated at a significant level and each of them is negatively correlated with liking for all the other subjects. 'Art' contributes the highest correlation with the summed score partly reflecting its positive correlation with 'P.E.'.

It will be particularly interesting to see later if the overall pattern reflects the attitudes of the general population tested, or whether differing School influences are greater than any 'subject' pattern.

(d) <u>Intercorrelations between the thirteen Intelligence/Mathematics measures and the eleven Creativity scores</u> <u>TABLE D</u>

The block of scores in Table D clearly indicates that, with only a few exceptions, performance on the mathematics/intelligence tests is directly related to that on the creativity tests. There are no negative correlations and most of the correlations are far beyond even a 0.1% level.

TABLE D

		Circles			Uses			Consequences		Pat-tern-meanings		
		Flu.	Flex.	Orig.	Flu.	Flex.	Orig.	Flu.	Orig.	Flu.	Orig.	Make Up Problems
		14	15	16	17	18	19	20	21	22	23	24
I.Q.1	1	24	32	22	40	49	48	45	37	32	38	61
I.Q.2	2	24	32	22	41	50	46	46	35	31	37	64
Intermediate Mathematics (Raw Score	3	16	28	18	43	52	47	47	35	33	39	63
Intermediate Mathematics (Standard Score	4	16	27	18	42	50	46	45	34	31	37	62
Arithmetic Progress (Mechanical	5	05	13	02	43	49	45	36	23	30	34	54
Arithmetic Progress (Problem	6	03	12	01	42	48	44	36	24	32	34	53
Arithmetic Progress (Standard Score	7	03	12	01	43	49	45	36	23	30	33	54
Arithmetic Concept A (Raw Score	8	12	20	12	38	43	40	38	28	26	28	49
Arithmetic Concept A (Standard Score	9	10	17	10	37	42	39	34	24	25	27	49
Mensuration Concept	10	13	24	17	33	40	35	37	30	26	29	46
Series Completion	11	12	19	07	41	46	40	41	30	31	33	54
Filling Spaces	12	25	30	16	38	44	37	36	26	32	33	47
Easy Problems	13	24	30	19	36	42	38	45	34	28	30	49

Having said this, however, there are a number of observations and considerations which must be noted.

(i) The results are obtained from the whole continuum of abilities, ranging on the I.Q. scale from 70 to 140. With such a general sample of the population, it would be unlikely that overall correlations would be other than positive.

(ii) The values of 'r' in the block are uniformly lower than those between the set of mathematics and intelligence measures in table A. This suggests that after a certain factor in common there may well be secondary factors which are peculiar to one of the sets.

(iii) Test 24, Make-up Problems, stands out as having in every case, higher correlations with the set of tests in TABLE 'A' than its companion tests in TABLE 'B'. Although they are not quite as high as those between the tests in table 'A' they are consistent enough to delineate test 24 as one extreme of the creativity battery, with a value of r = 0.64 between it and the second I.Q. test.

(iv) At the other extreme are the most noteworthy features of this table, namely the relationships between the Circles Test and those from table A. Three measures, fluency, flexibility and originality, were obtained from the Circles Test and these consituted the only exceptions to the significant correlations between the rest of the tests. In general they indicate a far more tenuous relationship to the tests of TABLE 'A' than do the other creativity measures and in particular there is a negligible correlation between the fluency and originality scores and each point of the N.F.E.R. Arithmetic Progress Test.

This is the first definite indication of a dichotomy between mechanical and imaginative thinking and it will be discussed more fully later.

(e) <u>Intercorrelations between the thirteen Intelligence/Mathematics Measures and the six attitude scores.</u>

TABLE E

			Attitudes					
			Reading 25	Maths 26	Writing Stories 27	Art 28	P.E. 29	Summed 30
I.Q.1		1	20	06	-08	-22	01	-05
I.Q.2		2	23	07	-08	-20	03	-01
Intermediate Mathematics	Raw Score	3	26	10	-11	-20	07	03
	Standard Score	4	26	10	-13	-20	07	02
Arithmetic Progress	Mechanical	5	33	17	-08	-21	07	11
	Problem	6	30	16	-10	-17	11	11
	Standard Score	7	32	17	-12	-19	10	10
Arithmetic Concept A	Raw Score	8	16	17	-08	-05	07	10
	Standard Score	9	19	15	-07	-05	05	10
Mensuration Concept		10	17	14	00	-06	02	12
Series Completion		11	23	16	-10	-08	06	12
Filling Spaces		12	24	01	-01	-22	08	02
Easy Problems		13	14	11	-01	-15	06	05

This block of correlations is best analysed in terms of the subjects covered in the measure of attitudes.

(i) Liking for Reading carries the highest correlations, though being of the order of 0.25 they are not excessively so. Nevertheless its correlations with the 13 measures from TABLE A are all positive and significant, twelve of them at the.01 level. It is interesting that the highest values of'r'occur between liking for Reading and performance on the mechanical Arithmetic test.

(ii) Of the thirteen correlations with liking for Mathematics, all are positive, five are significant at the .01 level and two at the .05 level. In comparison with the scores of liking for Reading it is noteworthy that although liking for Mathematics also has its highest correlations with the test of Arithmetic Progress, they are not so high as the corresponding correlations between liking for Reading and the Arithmetic test.

(iii) Liking for Writing Stores is negatively correlated with all the 'academic' measures of table A except with the mensuration concept for which 'r' is zero. However, only two of the correlations are significant, those with the Intermediate Mathematics test and the test of Arithmetic Progress, and those only at the .05 level.

(iv) All the correlations of the academic measures of Table A with liking for Art are negative, eight at the .01 level of significance.

(v) None of the correlations with liking for P.E. are significant, although once again those with the test of Arithmetic Progress are the highest, almost significant at the .05 level.

(vi) As might be expected from the variation in the pattern of the individual correlations, the summed score is only significantly correlated with the academic means in two cases and then only at the .05 level. The writer's 'Series' test and the N.F.E.R. Mensuration concept being those which are just significantly correlated with the overall attitude score.

It seems that the population of children tested had no overall attitude to school subjects but that their preferences were strongly subject orientated. It will be interesting to see how this conclusion compares with the analysis of the individual schools.

(f) <u>Intercorrelation between the eleven Creativity measures and the six Attitude Scores</u>

TABLE F

			Attitudes: Reading 25	Maths 26	Writing Stories 27	Art 28	P.E. 29	Summed 30
Circles	Fluency	14	03	01	08	06	05	11
	Flexibility	15	03	-03	07	03	07	08
	Originality	16	00	03	08	05	00	08
Uses	Fluency	17	19	05	04	-05	02	10
	Flexibility	18	19	02	02	-05	03	08
	Originality	19	17	02	-03	-10	-03	-00
Consequences	Fluency	20	15	06	09	-07	-00	09
	Originality	21	07	10	10	-07	-03	08
Pattern Meanings	Fluency	22	15	03	03	10	-00	14
	Originality	23	17	-03	05	07	01	12
Make-Up Problems		24	28	04	02	-20	02	05

This block of correlations is marked by its lack of significant values. Apart from a single negative correlation, significant at the .01 level, between liking for Art and performance on the Make-Up Problems test, and two correlations at the .05 level with the summed score; only liking for Reading is significantly correlated with any of the creativity scores.

Including the results from section (e) it is seen that liking for Reading is positively correlated with all 24 cognitive test scores, with only four scores, three from the Circles Test and the Originality score for Consequences, not reaching significance.

The Pattern Meanings test which might have been thought more allied to liking for Art than Reading is in fact only significantly related to the latter.

Attitude to Writing Stories which is often believed to be allied to the 'imaginative pole' of children's ability is rather surprisingly insignificantly related to any of the creativity tests, but is at least not negatively correlated as it is with the academic tests. Once again, however, it must be remembered that the whole range of ability is represented and creative writing ability will be seriously limited in those children in the 70 to 90 I.Q. range.

(g) Correlations with Sex

(i) Cognitive performance

With only one exception, all the measures of cognitive performance are negatively correlated with sex. As the convention applied was that boys were given the score of 1 and girls 0, this means that there is a definite tendency for boys to perform less well than girls on the tests of intelligence, mathematics and creative thinking, although fourteen out of the twenty-four correlations were not significant and only three were significant at the .01 level.

The largest correlation was with the Make-up Problems test for which $r = -0.23$.

The only positive correlation is non-significant, r = 0.07, but indicates that the boys performed better on the originality measure in the non-verbal Circles Test.

(ii) Attitudes

Three of the six correlations in this section are positive, but only one is significant, revealing the not unexpected result that boys rate Art more highly than do girls. On the other hand, again at the .05 level, liking for Reading is correlated with being a girl. Attitude to Writing Stories also favours girls but is not significant.

II Factor Analysis of the Whole Sample

Having noted the significant features of the intercorrelation matrix one is now in a better position to consider the factor analysis itself. The essential feature of the factor analysis technique being that successive extractions of communality relate together test scores in factors which, because of their decreasing proportion of the total variance, are not always apparent in the original correlation but which are nevertheless of psychological significance.

Complete results of the factor analysis by both Principal Components and Varimax rotation are tabulated at the end of this section, Tables 8 (a) and 9 (a). Tables 8 (b) and 9 (b) which follow reproduce, for ease of discussion, those factor loadings which were not less than 0.20.

Factor Analysis of the Whole data (31 variables, 265 cases)

Principal Components Analysis — TABLE 8 (b) | **Varimax Analysis — TABLE 9 (b)**

		I	II	III	IV	V	VI	I	II	III	IV	V	VI
I.Q.1	1	84						85				-23	
I.Q.2	2	85	-20					86				-21	
N.F.E.R.Intermediate	3	90	-28					92	20				
" " Std.Score	4	88	-29					91					
" Arith.Mechanical	5	80	-34					81	29			(17)	
Problem	6	83	-38					87	25			(15)	
Std.Score	7	84	-39					88	27			(18)	
" Concept Raw "	8	78	-30					84					
Std.Score	9	77	-33					84					
" Mensuration	10	73	-23					76					
Series	11	79	-27					81	20				
Blanks	12	74					-20	74					
Easy Problems	13	74						74				-25	
CIRCLES (Fluency	14	39	71		-29				37			-79	
CIRCLES (Flexibility	15	48	68		-33				37			-83	
CIRCLES (Originality	16	33	63		-41	-23			21			-82	
USES (Fluency	17	69	50		23	23		28	82			-27	
USES (Flexibility	18	75	44		22	22		37	81			-25	
USES (Originality	19	68	38		20	27		34	76				
CONSE-QUENCES (Fluency	20	66	44					33	53			-47	
CONSE-QUENCES (Originality	21	52	42			-23	29	23	36	20		-52	26
PATTERNS (Fluency	22	56	52		23	30			81			-21	
PATTERNS (Originality	23	60	52		24	26		20	81			-23	
MAKE-UP PROBLEMS	24	73						57	35		23	-26	
Interests (Reading	25	30			51	-28		24			62		
Interests (Maths	26			-38			73						83
Interests (Writing	27		21	-33	29	-64					73	-25	
Interests (Art	28		20	-61	-23	34		-20		-71			
Interests (P.E.	29			-41	-21	21	-60			-69			-34
" Summed	30			-95						-73	51		42
Sex	31				-46	21					-44		
Percentage of Total Variance		40.6	12.9	6.1	5.0	4.4	3.7	32.7	14.8	5.6	5.1	10.4	4.2

The Principal Components analysis yielded six factors with eigenvalues greater than one, accounting for 72.7% of the total variance. The percentage variance of each factor being, 40.6, 12.9, 6.1, 5.0, 4.4 and 3.7 respectively. After Varimax rotation to simple orthogonal structure the six factors obtained had percentage variances of 32.7, 14.8, 5.6, 5.1, 10.4 and 4.2 respectively.

Similarities between both analyses are particularly noteworthy, the abilities sampled by the testing battery obviously being well defined in certain areas of performance.

In most cases factors are easily identifiable in both sets of results and where they complement each other in this way they will be jointly discussed in the results which follow. The letters 'P' and 'V' will be used to identify the origin of factors, factors PI and VI for example being Principal Components factor I and Varimax factor I respectively.

Factors PI and VI

In each analysis this factor is clearly a general ability factor with very high loadings on intelligence and all the tests with a Mathematical bias including the 'Creativity' test of Make-up Problems. In view of the large number of mathematics tests all loading heavily on this factor it is obviously more than a pure 'g' factor and fits what Vernon (1961) terms a 'g + v:ed' factor including 'g' and a verbal-numerical-educational ability 'v:ed'. It indicates an ability to perform well on the intelligence tests, Mechanical tests of Arithmetic, and on those designed to test concepts or understanding. The new N.F.E.R. Intermediate test has in fact the highest loadings on both factors, with intelligence and Arithmetical progress close seconds.

In the Principal Components analysis, all the creativity measures also load on factor PI, though not to such a high degree as the other cognitive measures. In the Varimax analysis the distinction is more marked for though most of the creativity measures have positive loadings on VI they are only of the order of 0.30, and four of the eleven measures are less than 0.20. In particular the Circles Test, which was often an exception in the correlation pattern already analysed, contributes a negligible amount to factor VI. The Pattern Meanings test also has low loadings on this factor and there is consequently some evidence to support the view that ability on the figural tests of creativity is not to be linked with a general ability factor.

The attitude loadings on this factor appear to support this view, for, though small, both PI and VI have negative loadings for 'liking for Art', positive loadings for reading and small positive loadings for Mathematics. There is also a low negative loading for sex.

It appears that girls perform better than boys on this dimension of ability, are generally keen on reading and do not mind mathematics. On the other hand, boys who do not do well on this factor, are more likely to find refuge in a non-academic subject such as Art.

<u>Factors PII and VII</u>

Considering the whole range of ability sampled, this factor confirms the belief that there is a dimension of performance peculiar to tests of creativity, though in both analyses it has a much smaller percentage of the total variance than the general factor. Although both PII and VII, broadly conceived, locate this same factor they do so with some distinct differences which I shall note separately.

(a) Principal Components II

A creativity dimension is indicated by a bipolar factor having 12.9% of the total variance and clearly separating the negatively loaded 'academic' tests from those of creativity. The latter having, with the exception of the Make-up Problems Test, the more substantial loadings.

In contrast to the Varimax factor II, this factor is best defined by the loadings on the Circles Test (0.71, 0.68, 0.63), contrasted with N.F.E.R. 'formal' Arithmetic test loading -0.39 on its standardised score. From the attitudes section it has positive loadings of 0.21 and 0.20 from Writing Stories and Art respectively, but is slightly negatively loaded on the academically orientated preferences for Reading and Mathematics. The loading on the Make-up Problems Test is an exception to the significant loadings on the other tests in the Creativity battery, but its small positive loading is on the 'creative' side of the creativity versus academic balance.

There are, therefore, strong grounds for interpreting this factor in terms of a creative fluency/flexibility/originality factor particularly strong on figural tests, and opposed to academic tests particularly 'formal' arithmetic. This interpretation is supported by the relatively small loadings on the tests of intelligence, 'Easy' problems and Filling Spaces, which, though placing these tests in the negative side of the 'balance' do not overemphasise their significance.

(b) Varimax II

Apart from some negative loadings on the affective variables the

Varimax rotation results in all the other tests having positive loadings. It is clear that the interpretation of the factor however lies in the particularly large loadings on the creativity tests. Predominant among these is the Uses Test with loadings of 0.82, 0.81 and 0.76, and the Pattern Meanings test (0.81 and 0.81).

The Circles Test on the other hand has relatively small loadings for the creativity battery and while both PII and VII are clearly located in the same overall dimension it seems that they must have somewhat different interpretations. A comparison of the loadings of the Arithmetic Progress Test on Factors PII and VII confirms this.

In PII the Arithmetic test had loadings which placed it at an extreme of the 'academic' battery furthest from the creativity tests. In contrast, on the factor VII, it is the 'academic' test with loadings nearest to those of the creativity battery.

It is not difficult however to explain the relation between the Circles Test and that of formal Arithmetic in a way which can illuminate the obvious 'creativity' bias of both PII and VII. In PII there is an antithesis between those tests interpreted in terms of 'formal' arithmetic versus the 'freedom' of figural expression. This antithesis is also present in the Varimax analysis and is predominant in factor V.V. It is also likely however that in a formal Arithmetic test, set out in the traditional pattern, there is a marked proportion of obvious answers that are easily elicited - in a way related to the early responses that occur in the response pattern to any of the creativity tests. In this sense one might expect some common loadings on the two types of test.

On PII both the test of Pattern Meanings and the Circles Test have high loadings but in VII, while Pattern Meanings has an even higher loading, the loading on Circles Test is much lower. Both tests are similar in having figural stimulae but only the latter is answered in the same medium, the former needing written answers. PII therefore seems to emphasise the figural nature of the Circles test, while factor VII is more biased towards the ability to reproduce responses in a written form.

In support of this interpretation it should be noted that, again in contrast to PII, VII has a slight positive loading on liking for reading and a small loading indicating a better performance by girls.

It is slightly disappointing that the 'Easy' problems test, designed to assess a measure of flexibility of thinking, while located on the 'creativity side' of the academic battery in PII, is not significant in the interpretation of VII. At the same time, it is encouraging to observe that it does appear, coupled to the creativity block of tests in factor V.V

Factors PIII and VIII.

Factors PIII and VIII having respectively 6.1% and 5.6% of the total variance both define the first clear 'attitude' factor by far the greatest proportion of the variance of each factor being contributed by attitude loadings which, particularly for Art and P.E., are large and negative.

It is not easy to relate this 'anti-school-subjects' attitude with the other loadings as the latter are consistently low even before rotation. Bearing in mind, however, that a large proportion of the variance has already been extracted it seems that there is a residual 'intellectual' ability, as reflected by the positive loadings on the I.Q. tests in both factors, and on the tests of Consequences and Make-up Problems in factor VIII; which, outside the attitude block, provides the major source of co-variance with attitude in the residual matrix.

In PIII the -0.95 loading reflects the strong intercorrelation of attitudes after the extraction of preferences for Reading and Mathematics in factor PI and for Writing and Art in factor PII. It must be noted that though there may be overall positive correlations between tests as shown by the intercorrelation table, extraction of communality, due to 'g' say, may result in residues being negatively correlated, or vice versa.

Rotation for VIII emphasises the loadings for Art and P.E. -0.71 and -0.69 respectively, and the predominance of girls on this factor.

On PIII the creativity tests, with the exception of the Pattern meanings test, have low positive loadings, while the loadings on the 'academic' tests of I.Q. and Mathematical thinking are divided into positive and negative groups. The poor attitudes are coupled with negative loadings on the mechanical and concept tests of mathematics in contrast to the positive I.Q. loadings. It suggests the presence of some pupils, more likely to be girls, who have a dislike of Art and P.E., and a tendency not to understand numerical Mathematics or Arithmetical concepts, but who have a certain intellectual ability to score on certain items in an I.Q. test, on tests of originality (In PIII on Uses and in VIII on Consequences and Make-up Problems), and even in the N.F.E.R. Mathematics test.

It is impossible to dwell on the nature of this 'intellectual ability', as the testing battery, designed to incorporate creative thinking, Mathematics and I.Q. tests, is not equipped to reveal other well-known factors such as those of spatial or mechanical ability. Nevertheless it is interesting to note the presence of negative attitudes with an indication not only of inability to perform on some arithmetic tests but with positive performance on verbal as opposed to numerical tests.

Factor PIV

This factor is best regarded in terms of its high negative loading in favour of girls related to a liking for Reading and Writing Stores, loading 0.51 and 0.29 respectively, and a tendency to dislike Mathematics, Art and P.E. It is divisive of both the mathematics and creativity tests, being, in particular, predominatnly negative on the Circles test and positive on the verbally answered creativity tests of Uses and Pattern meanings. It has 5 per cent of the total variance.

Much of the verbal communality of the I.Q. and Mathematics tests has already been extracted and it might be expected that some figural or spatial loading would remain to correlate negatively with girls' preference for reading and a verbal format. Enlarging on the personification of this factor it appears that the girls in question enjoy reading and can respond positively to a mechanical arithmetic test but are not very able at grasping mathematical concepts or certain items present in I.Q. tests.

Factor VIV

This factor is in many ways similar to PIV although its highest affective loading is liking for Writing Stories, loading 0.73. This is coupled to liking for Reading 0.62 and is again strongly related to girls, loading -0.44. There are few loadings in the cognitive domain which are likely to be significant although there are once again some positive loadings which suggest that there is a supplementary factor for girls, independent of intelligence, which helps them on Make-Up Problems, Consequences and some of the questions on Mechanical Arithmetic. The heavy loadings on preference for writing suggest a possible verbal facility factor which is least 'anti-mathematics' in the case of the well known arithmetic-type test. It will be worth noting whether such a factor is present in the inter-school analysis, though with only 5.1 per cent of the total variance it can easily be lost if conditions favour other factors.

Factor PV

The cognitive tests fall into a pattern on this factor which is very similar to that of PIV, with negative loadings on I.Q., Circles Test and Easy Problems and positive loadings on Pattern Meanings, Uses, and the N.F.E.R. Arithmetic Test. On the other hand it has a negative loading on Make-Up Problems, a slight positive loading on the Concept Arithmetic test and, for the first time, a significant loading favouring boys. The factor is consequently interpretable in terms of boys who like Art and P.E., don't very much mind Mathematics but strongly dislike Writing, loading -0.64, and Reading (-0.28). The largest positive loadings, on liking for Art and both parts of the Pattern Meanings test therefore support an interpretation of the factor as a weak visual imagination factor favouring boys.

Factor VV

Varimax factor five shows a clear dichotomy between the N.F.E.R. Arithmetic Test and all the other cognitive tests. The group of Creativity Tests are well defined with significant negative loadings throughout and very high negative loadings on the Circles Test (-0.79, -0.83, -0.82) which contribute a good proportion of the 10.4 per cent of the total variance represented by this factor. The second Principal Components factor had loadings which emphasised the 'opposition' of the Circles Test and the formal Arithmetic test but this is the first time in the rotated factors that the Circles Test has stood out so much.

The most obvious explanation is that this is a 'numerical calculation' factor in contrast to spontaneous flexibility and imagination, particularly when the latter is not dependent on verbal fluency. The most significant loading outside the creativity battery is a negative loading on the Easy Problems Test. This test was designed to assess a degree of flexibility in applying a 'Key' to solve certain problems - in opposition to learned techniques or methods of numerical calculation, and consequently supports the above interpretation of this factor. The only significant attitude is a dislike of Writing Stories which accords with the figural bias indicated by the loadings on the Circles Test.

Factors PVI and V VI

Both these factors are open to the same interpretation having predominant loadings on liking for Mathematics, 0.73, and 0.83 respectively; and on liking for P.E. which loads negatively on both factors.

Although in both cases there is little evidence of any marked relationship with the cognitive loadings, the Consequences test carries the largest cognitive loadings on both factors which, though relatively small, 0.29 and 0.26 respectively, are large enough to be significant and reflect perhaps a degree of deductive and imaginative reasoning. Coupled with the small positive loadings on the tests of Mathematical Concepts and Series Completion, it is therefore likely that liking for mathematics is correlated to reasoning ability and understanding, particularly for boys. There is also a marked tendency it seems, for such pupils to be those who dislike P.E.

Interim Conclusion

Before discussing these results further one conclusion can be made from the composition of factors I and II on both the Principal Axis and the Varimax analyses. It is clear that, as Burt (1962) observed of divergent thinking tests in general, that the creativity tests in the present study "have succeeded in eliciting supplementary activities that are rarely tapped by the usual brands of intelligence tests".

At the same time, though they all consistently indicate some creativity factor, substantial loadings on the creativity tests are by no means confined to this factor. They have positive loadings, usually very significant on both PI and V I and they also contribute significant loadings to other factors. It appears that the creativity tests certainly locate an appropriate factor, but are also indicative of other diverse abilities that are by no means similar in all respects.

Focusing attention on the high loadings of the creativity tests on factors PII and V II however, an interim conclusion might be that:-

Over the whole range of intelligence there is evidence of a dimension of ability as measured by tests of creative thinking which, though not independent of intelligence, exists as a consistent complementary activity.

Considering the almost certain effect of any intellectual ability over a complete range of intelligence, the above conclusion points to a dimension of ability which might be more marked in a restricted range of I.Q. Yamamoto (1965b) has already demonstrated this, showing that correlations between I.Q. tests and creativity decrease in the higher ranges of intelligence and giving support for the idea of a 'threshold of intelligence' above which, as Mackinnon (1962) suggests, "It just is not true that the more intelligent person is necessarily the more creative one". As I have observed earlier Hudson (1966) puts the theory into a classroom setting by his contention that "a knowledge of a boy's I.Q. is of little help if you are faced with a formful of clever boys".

The design of the present experiment provides an opportunity for a separate analysis which could be carried out on the results of the group of children with a high level of I.Q. Such an analysis, by intercorrelations and factor analysis, was therefore carried out in order to contribute evidence on the question of a 'threshold of intelligence'.

The question is whether, given a certain substantial I.Q., children of the highest intelligence are more likely to perform well on creative thinking tests than those children with I.Q.'s nearer the threshold. For the present study an I.Q. of 115 is to be taken as the threshold level, and the hypothesis made is the null one, namely that:

<u>Above an I.Q. of 115 there is no relationship between children's performance on tests of creativity and tests of I.Q.</u>

<u>High I.Q. Analysis</u>

The High I.Q. sample was chosen from the population of the present study by selecting those children who had registered an I.Q. of 115 on at least one of the Moray House tests. As these tests were part of the County's 11+ selection procedure the seventy-one children obtained in this way were virtually those selected for a Grammar School education. In fact only 8 out of the 71 children were not awarded a Grammar School place and only 6 of the remaining 194 succeeded in gaining a place.

Thirty-one test results were available for each of the 71 children in the High I.Q. sample and, using the university computer, product-moment intercorrelations of these results were calculated. A factor analysis of the resulting matrix of intercorrelations was carried out by both the Principal Axis and Varimax methods although, for simplicity, the six attitude scores and the one boy/girl measure were omitted for this analysis.

The following results were obtained.

a. Intercorrelations. High I.Q. sample (I.Q. $\geq$ 115)

The complete table of intercorrelations of the 31 variables is reproduced at the end of this section, TABLE 10. The following blocks of intercorrelations, TABLES 10 (a), 10 (b), 10 (c) however are of particular relevance to the question of any relationship between the academic and the creativity measures.

Table 10 (a) shows the correlations among the eleven creativity measures for the high I.Q. sample. There are very strong intercorrelations between the variables, 52 of the 55 coefficients being significant beyond the 0.05 level and 42 of these significant beyond the 0.01 level. 'Originality of Uses' is a score which produces two of the non-significant results though both are positive. The only other exception is marginally so, the coefficient of 0.22 being just short of the 0.05 significance level of 0.23.

TABLE 10 (a)

Correlations among the eleven creativity tests for the High I.Q. Sample

			14	15	16	17	18	19	20	21	22	23	24
Circles	Fluency	14	1	87	67	48	48	28	45	31	52	53	39
	Flexibility	15		1	78	44	46	27	46	36	50	54	44
	Originality	16			1	26	26	08	31	35	27	25	22
Uses	Fluency	17				1	97	85	55	23	71	71	50
	Flexibility	18					1	86	55	24	73	70	51
	Originality	19						1	41	13	63	63	35
Consequences	Fluency	20							1	73	55	56	62
	Originality	21								1	23	29	38
Pattern Meanings	Fluency	22									1	90	47
	Originality	23										1	55
Make-Up Problems		24											1

Table 10(a) shows ample evidence for a belief in some ability which is consistent and general throughout the battery of creativity tests, and present in both visual and verbal items. In fact comparison with Table 10 (b) shows that it is in fact more consistent than the 'academic' ability which is assumed to load tests 1-13.

Tests 1-13 do nevertheless provide grounds for assuming some common 'academic' ability, particularly present in the standardised tests of I.Q. and Mathematical ability. In fact, of the 36 coefficients of correlation between the first 9 tests only 2 are not significant and 29 of them are significant beyond the .01 level. Tests 10 and 13, the Mensuration Concept test and the Easy Problems Test respectively, are however, less well correlated than the others, with the latter test correlating as well with the creativity tests as with those in its own section. It was designed as a test of flexibility of thought and though its success was not so apparent from the general analysis it is now revealed as having something in common with a set of creative thinking tests. I shall return to this later.

TABLE 10 (b)

Correlations among the thirteen Intelligence and Mathematics tests for the High I.Q. Sample

Test			1	2	3	4	5	6	7	8	9	10	11	12	13
I.Q.1		1	1	57	36	41	29	28	32	16	14	26	35	40	39
I.Q.2		2		1	49	52	38	26	35	23	24	22	16	35	38
Intermediate Mathematics	Raw Score	3			1	95	66	60	65	36	31	29	39	56	34
	Standard Score	4				1	60	56	62	33	32	25	35	55	26
Arithmetic Progress	Mechanical	5					1	86	97	49	44	26	45	56	25
	Problem	6						1	94	50	44	20	44	50	22
	Standard Score	7							1	49	45	21	44	57	21
Arithmetic Concept A	Raw Score	8								1	96	17	31	24	11
	Standard Score	9									1	12	28	26	01
Mensuration Concept		10										1	27	08	18
Series Completion		11											1	28	21
Filling Spaces		12												1	26
Easy Problems		13													1

Having established that the 13 'academic' tests, with two possible exceptions, are very well correlated, it is reasonable to infer that they measure some common general ability. In contrast to this it is also well established that the 11 creativity measures have a common variance which, for the time being, will be referred to as 'creativity'. The interim conclusion of the last section is therefore verified and its use as a premise for the hypothesis being tested is reaffirmed.

The question of relationship between the children's performance on tests of creativity and tests of I.Q. can now be directly answered from Table 10 (c).In a more general form, the question is whether or not there exists, in the present high I.Q. sample, a relationship between 'creativity' and 'academic' ability.

Of the 22 correlations between the two I.Q. tests and the 11 creativity tests, only 2 are significant - and then only at the 0.05 level. Both of these correlations occur with test I.Q.2 and may well contain factors of the retest situation. None of the correlations with I.Q.1 even approach significance.

Excluding for the moment test 24, 'Make-up Problems', which was noted earlier as being most likely to cross any creativity/I.Q. boundaries; the remaining 10 tests of creativity have 130 intercorrelations with the 13 'academic' measures. Only 20 of these are significant - and five of these are negative. Only 3 are significant at the 1% level and one of these is negative. It therefore seems appropriate to make the following conclusion:

<u>CONCLUSION:</u> <u>The 22 correlations between the I.Q. and Creativity measures provide no evidence on which to reject the hypothesis and,</u>

considering the correlation matrix as a whole, the conclusion must be that the creativity and academic dimensions already located are relatively independent in a high I.Q. sample

TABLE 10 (c)

Intercorrelations between the 11 creativity tests and the 13 'academic' tests for the High I.Q. sample

			14	15	16	17	18	19	20	21	22	23	24
I.Q.1		1	00	04	07	-01	02	04	10	12	07	06	11
I.Q.2		2	13	26	20	05	09	-02	14	05	12	12	26
Intermediate Mathematics	(Raw Score	3	06	27	03	18	23	10	27	10	10	17	38
	(Standard Score	4	06	17	03	12	16	05	23	06	12	14	37
Arithmetic Progress	(Mechanical	5	-15	-07	-21	25	30	24	18	02	19	21	38
	(Problem	6	-28	-21	-30	15	20	20	10	02	10	10	31
	(Standard Score	7	-20	-12	-25	22	27	24	15	01	16	17	38
Arithmetic Concept A	(Raw Score	8	-19	-18	-23	18	16	05	-12	-15	06	06	08
	(Standard Score	9	-20	-20	-23	12	11	-00	-19	-22	04	02	04
Mensuration Concept		10	-09	-07	09	-17	-07	-12	-07	01	-08	-11	-10
Series Completion		11	-08	-05	-02	07	09	01	15	18	04	00	17
Filling Spaces		12	10	13	06	15	15	07	25	16	20	23	23
Easy Problems		13	23	25	19	20	22	07	30	23	18	15	32

(b) Factor Analysis High I.Q. Sample

The complete factor analyses of the correlations obtained from the High I.Q. sample are shown at the end of this section of the results in tables 11 (a) and 12 (a). These merit some discussion in view of the above conclusion and in order to examine further those tests which were exceptions in the intercorrelation analysis. The following tables reproduce, for ease of discussion, both sets of factors with loadings less than 0.20 omitted.

TABLE 11 (b)
Principal Components Analysis
High I.Q. Sample

		I	II	III	IV
I.Q.1	1	39	30	-43	
I.Q.2	2	48	25	-46	31
Intermediate	3	69	44	-27	
" Standard Score	4	65	44	-30	
Arithmetic Progress (Mechanical	5	70	57		
Arithmetic Progress (Problem	6	59	64	(19)	-23
Arithmetic Progress (Standard Score	7	68	61		
Concept (Raw Score	8	37	55	33	47
Concept (Standard Score	9	31	56	33	53
Mensuration	10		34	-32	
Series	11	39	38		
Blanks	12	58	31	-20	
Easy Problems	13	45		-38	
CIRCLES (	14	40	-69	-27	29
CIRCLES (	15	47	-64	-36	29
CIRCLES (	16	24	-56	-51	30
USES (	17	69	-46	43	
USES (	18	73	-43	40	
USES (	19	57	-38	53	
CONSEQUENCES (	20	63	-45		-42
CONSEQUENCES (	21	36	-35	-32	-47
PATTERNS (	22	65	-49	26	
PATTERNS (	23	67	-49	25	
Make up Problems	24	69	-22		-21
Percentage of Total Variance		29.9	21.7	10.4	6.2

TABLE 12 (b)
Varimax Analysis
High I.Q. Sample

	I	II	III	IV
1		61	-22	
2		64	-40	
3		85		
4		83		
5	29	78	36	
6	21	74	49	
7	27	79	42	
8		42		74
9		37		79
10	-25	41		
11		57		
12		68		
13		48	-30	
14	46		-75	
15	43		-79	
16			-81	-20
17	93			
18	92			
19	86			
20	59	26		-58
21	25	21		-67
22	82		-24	
23	83		-23	
24	57	39		-28
Percentage of Total Variance	22.2	24.0	12.5	9.5

Four Principal Components factors were obtained before Kaiser's criterion was reached, and accounted for 29.9, 21.7, 10.4 and 6.2 per cent of the total variance respectively. After rotation by the Varimax method the percentage variances of the factors were respectively 22.2, 24.0, 12.5 and 9.5.

Principal Components Analysis   Factors I and II

Factors I and II appear at first sight to follow the general pattern, established for the whole population, of a general factor identified mainly by the academic measures and a second bipolar factor dividing the academic from the creativity measures. A number of differences however are very significant. The first factor is not easily identified by the academic tests but is equally well loaded on the creativity side of the 'balance'. The test of the mensuration concept is the only test not to load significantly but I.Q. is not prominent nor is the N.F.E.R. test of arithmetical concepts. The highest loading is due to the Uses test and other high loadings are contributed by Make-Up Problems, Pattern Meanings, Arithmetic Progress and Intermediate Mathematics.

The intercorrelation analysis revealed that the two main blocks of tests correlate highly among themselves and, although very small, the correlations between both sets of tests are usually positive (109 times out of 143). Using the Principal Components method of solution this is sufficient to expect the presence of a general factor and Factor I is of this 'general' nature. At the same time, any deeper psychological significance inherent in the intercorrelations is not readily apparent from such a factor. It is worth noting that the test of the Mensuration concept which has the lowest loading on this factor was noted in the intercorrelation analysis as having the lowest correlations within the academic battery, and it also has the largest number of negative correlations with the eleven creativity tests, nine being negative.

The most likely interpretation of Factor I seems to be in terms of a certain 'general facility' linked to an element of fluency of response. This acknowleges the high I.Q. level of the subjects and suggests that a large number of responses to both academic and creativity tests, will be quickly elicited. This interpretation might account for the larger loading on the mechanical than the problem section of the N.F.E.R. Arithmetic test, in contrast to the overall analysis, and is supported by the relatively low loadings on the tests of arithmetic and mensuration concepts which are less likely to stimulate 'obvious' responses.

Factor II also differs from that in the general analysis for, though an equally well defined bi-polar factor, it is positive on the side of the academic tests. The Easy Problems Test, noted from the intercorrelation as being a possible exception in the academic battery, is now clearly seen to be placed midway between the poles of this factor, with a loading, just positive, of 0.02.

Varimax Factors I and II

A study of these factors is seen to emphasise the orthogonality of the academic versus the creativity measures and attributes to the creativity tests 22.2 per cent of the total variance, and to the second academic factor

24.0 per cent. They clearly support the conclusion arrived at from studying the intercorrelations in the High I.Q. sample, namely, that performances on the creativity and academic batteries are relatively independent. At the same time, it is apparent from these factors that not all the tests fit into a single 'creative' or 'academic' domain for, as already noted, some tests have significant loadings on both the 'creativity' and 'academic' factors. In particular the 'creativity' tests of Make-Up Problems and Consequences have moderate loadings on factor II and the N.F.E.R. Arithmetic test moderate loadings on factor I. In general however Factor I has very significant loadings on the creativity tests, that of 'Uses' having loadings of 0.93, 0.92 and 0.86. The 'creativity' label for Factor I is justified in so far as it reflects the loadings on the so called creativity tests but it is worth observing that, as in the case of the Principal Components Factor I it seems likely from its composition that it owes a good deal of its variance to a 'fluency' ability.

Factor II, is clearly a mathematical/academic factor with high loadings on all thirteen academic tests. The N.F.E.R. Intermediate Mathematics Test has the highest loading of 0.85 and only two of the creativity tests make significant contributions. That of the Make-Up Problems Test once again indicating its natural leanings towards the mathematics tests.

<u>Principal Components Factors III and IV</u>

Both these factors, having respectively 10.4% and 6.2% of the total variance illustrate further that the testing battery is not to be divided too rigidly into categories of academic and creativity tests. There are dimensions of performance which cross over these divisions and which indicate that there are abilities and modes of thought pervading both sets of tests.

On Factor III the I.Q. tests are coupled with five significant mathematics loadings and four significant creativity loadings, all negative, in opposition to the positive loadings on the test of Concept Arithmetic, the Uses Test and the test of Pattern Meanings. The highest positive loading is 0.53 on the originality score for the Uses Test and the greatest negative loading on the originality score for the Circles Test. The intercorrelation analysis has already noted that the Uses Test did not correlate well with the originality scores for the Circles Test and Consequences Test and this is again reflected in the opposite sign of their loadings on this factor. The N.F.E.R. tests of concept attainment also diverge on this factor, the Arithmetic Concept loading 0.33 and the Mensuration Concept -0.32.

Much of the common variance of the tests has already been extracted and this being acknowledged, it appears that some ability, or lack of it, affects performance on both creative and academic tests. Several of the tests in both sections contain figural/spatial items and a verbal versus figural element would seem to account for many of the loadings on this factor, reflecting a verbal v. figural bias in the children's abilities. The loadings of opposite sign on the Circles Test and Pattern Meanings Test appear to contradict this explanation but these tests have showed a common variance on the earlier factors and the difficulty can be resolved in terms of the responses to the tests, which are figural and verbal respectively.

Factor IV also crosses the boundaries between the academic and creativity sections of the tests, relating understanding of Arithmetic to performance on the second I.Q. test and the Circles Test, but separating these from the tests of Consequences, Make-Up Problems, and Problem Arithmetic.

Varimax Factors III and IV

The pattern of loadings on these factors supports the general interpretation of the last section in reflecting abilities common to both creativity and academic tests.

Factor III has predominantly negative loadings, those on the Circles Test being particularly significant, but quite high positive loadings on the test of Arithmetic Progress. It appears that an ability to perform the rather routine procedures of elementary arithmetic are in opposition to the more imaginative, certainly more figurally loaded, abilities involved in the Circles Test.

Factor IV also has some strong bi-polar loadings; in this case separating the Arithmetic Concept Test from those of Consequences, Make-Up Problems, and Circles (originality). This indicates that understanding arithmetical concepts might not be a criterion for originality even in the mathematical context of Make-Up Problems, and particulary in a consequences test.

The result of the High I.Q. factor analysis clearly indicates that neither creativity tests nor academic tests rely entirely on a single, individual mode of thinking, but can involve elements of ability which are often common to both sets.

At the same time the relative orthogonality of factors I and II supports the conclusion made from considering the intercorrelations; namely that the two respective groups of tests locate two principal dimensions of performance which, in a High I.Q. sample are relatively independent.

PART 1 SUMMARY AND CONCLUSIONS

The data analysed in this section of the results consisted of 31 scores for each of the 265 children for whom complete results were available; the scores having been obtained from tests of intelligence, divergent thinking, mathematical ability and attitudes and a score denoting the pupils' sex. The purpose of the analysis was largely to prepare for the subsequent inter-school results by investigating the modes of thinking which would be indicated by the different sections of the testing battery. There have been many precedents, however, a number of them reviewed in Chapter 4, which have focussed on the relation of the so-called creativity tests to other variables, and the present results have a bearing on many of these experiments.

1. Intercorrelation Analysis

The results of the overall intercorrelation analysis showed significant correlations both within and across the academic and creativity sections of the tests. In particular the two I.Q. tests and the eleven mathematics tests correlated very highly and suggested a fairly cohesive 'academic' section of the tests. All eleven creativity scores also correlated, well beyond the .01 level.

The correlations between the sections were generally lower, although most of them were significant and clearly indicated that with few exceptions performances on the two sections of the testing battery are not independent. Considering the complete range of intelligence covered by the sample however this is not unexpected. The uniformly lower values of r in the set of cross-correlations suggested that, in fact, there are likely to be secondary factors which do not correlate across the sections.

This latter fact, and the nature of those tests, particularly 'Circles' and 'Make-Up Problems', which showed themselves to be exceptions to the above summary are best interpreted by means of the subsequent factor analysis.

The attitude scores, reflecting the pupils' liking for school subjects, showed no tendency for a pupil to like all school subjects, in fact eight out of the ten intercorrelations were negative. Only three correlations were significant, an inverse correlation at the .01 level between liking for Art and liking for Reading and at the .05 level between Mathematics and Writing Stories, and a positive correlation at the .05 level between Art and P.E. Two significant sex scores in relation to attitudes throw further light on these preferences, girls tending to like Reading, and boys Art.

These findings are in line with what Sharples (1969) terms the "general assumptions about 'girls' subjects' or 'boys' activities'", but are contrary to his results which suggested that such assumptions are not well founded. The present results however are arrived at after grouping together the children from three different schools while Sharples' results were confined to a within-school analysis. Interpretation of this section of the results must bear in mind that in some ways the results represent an 'average' of different levels of attitude and ability, which are likely to occur in the separate schools. This procedure might be quite valid, especially if, as Sharples found, the patterns within schools are generally similar. However, if, as might be the case in the present study, the pattern of attitudes and performance is markedly different between schools the present interpretations might have to be accepted with some caution.

On the other hand, for a reliable analysis the population needs to be fairly large. Guilford (1954) suggests that "a minimum N of 200 is good policy", and it is therefore likely that the present overall sample of 265 children will be well founded in a way in which a small population from a single school could not achieve.

Liking for Reading is the only score to correlate consistently with both the academic and creativity tests. It clearly reflects a verbal ability, and fails to correlate significantly only on the completely figural 'Circles Test' and on the originality score for Consequences.

Liking for Mathematics correlates significantly with seven of the academic tests but with none of the creativity tests.

Here again the pattern may change within schools, particularly as the present results indicate that the most favourable attitudes to Mathematics are related, not to the new N.F.E.R. Intermediate test, the writer's tests of flexible application of mathematical ideas, or Make-Up Problems, but to the traditional Arithmetic Progress Test and the tests of the Arithmetical and Mensuration concepts. It seems to indicate that for many pupils, liking for Mathematics is dependent on success in Arithmetic calculation.

Although few of the correlations between liking for Writing and the cognitive tests are individually significant, the general pattern of the scores is worthy of note; all 13 of the correlations with the academic tests being negative but only one correlation being negative in the creativity section. It supports the belief that children's attitude to writing stories is related to their 'imaginative' ability. Whether or not this is indeed the ability which influences their performance on the creativity tests is a question which merits a separate study.

The final column of the intercorrelation matrix clearly indicated that boys performed less well than girls on most of the test items, significantly so on 10 out of the 24 tests, but at the .01 level on only 3 of these. The only test favouring boys was the Circles test of originality, although even this was not statistically significant. Nevertheless, it reflects the boys' preference for non-verbal items as shown by the attitude scale.

Cronbach (1968) in his reappraisal of the Wallach and Kogan data on creativity, suggests that it is often more profitable not to follow their procedure of separating the sexes unless a demonstrable interaction is present. Such a separate analysis cuts the number of degrees of freedom in half and thereby discards much of the power of the investigation. Moreover he warns that it leads one to draw different conclusions about boys and girls where perhaps no difference exists.

There are a number of studies of creative and mathematical thinking, particularly when a large number of gifted subjects are needed, which have not separated the results for boys and girls. Lovell and Shields (1968) worked with a combined group and Getzels and Jackson (1962) designed their experiment to incorporate roughly equal proportions of boys and girls in both of their experiment groups. Other studies have conducted separate sex analyses and have found no significant differences in performance even in Mathematical items. Kellmer Pringle and McKenzie (1965) in their study of rigidity in problem solving in a population of 11-year-olds, similar to that used in the present experiment, found that "None of the sex differences, either within each of the schools or between the sexes combined, proved to be significant." In a very extensive study incorporating about 77 per cent of the 9,750 children in their fourth year in Junior schools in Staffordshire, Eysenck and Cookson (1969) also found that the results of a Moray House Mathematics test "fail to show any difference between the sexes". On verbal tests however they found significant sex differences in favour of girls, and there are other studies, such as that of Biggs (1959), that extend the sex differences to include performance in Mathematics; the latter usually favouring boys. Although Biggs found only slight differences between the performances of boys and girls, particularly in the cognitive section of his tests, and although in certain of his factors "slight rotation minimises sex differences", he concluded that "sex differences while slight, are psychologically meaningful".

The evidence of the extra variable used in the present study to identify the sexes suggests that different patterns of attitudes and performance would occur if the samples were confined to one of the sexes. Some further study designed within the sexes might therefore be profitable.

2. <u>Factor Analysis</u>

The modes of thinking covered by the tests and the nature of the tests used were well illustrated by the two factor analyses. The following conclusions summarise the identification of the factors, the percentage of the total variance contributed by each factor being shown in brackets.

I. Principal Components Factor I (40.6) and Varimax Factor I(32.7)

This was clearly a general factor which, in view of the mathematics bias in the testing battery is interpreted as a g + v:ed factor including 'g' and a verbal-numerical-educational ability v:ed. The creativity battery contributed less to V.I than to P.I.

II Principal Components Factor II (12.9) and Varimax Factor II (14.8)

This factor, identified by strong bipolar loadings in PII and by predominantly highloadings on the creativity tests on VII clearly confirms the belief in a dimension of performance peculiar to tests of creativity, though not confined to these tests nor completely absent in others.

Though broadly in the same dimension the factors PII and VII were observed to have a number of significant differences. P.II was interpreted as a creative fluency-flexibility-originality factor, particularly strong on the figural tests of Circles and Pattern Meanings, but in opposition to academic tests, particularly formal arithmetic. The emphasis on factor VII also lay with the creativity tests but was more marked by performance on the verbal rather than the figural tests.

In contrast to its loadings on PII, the test of Arithmetic Progress was the 'academic' test nearest to the creative pole of factor VII, and this indicated the dual nature of the test which was discussed in relation to factors P.II and VII.

III Principal Components Factor III (6.1), and Varimax Factor III (5.6)

Factor III in both analyses is clearly an attitude factor, with loadings, particularly for Art and P.E., which are large and negative. The cognitive loadings are uniformly low but their pattern suggests that there are pupils whose dislike of Art and P.E., coupled on PIII to a dislike of Mathematics, Writing and Reading, is related to a certain verbal intellectual ability as reflected by items in the I.Q. tests and tests of originality, and to a tendency not to understand arithmetical concepts.

IV <u>Principal Components Factor IV (5.0), and Varimax Factor IV (5.1)</u>

Both analyses clearly indicate that Factor IV is a Sex Attitude factor reflecting that girls have a strong preference for Reading and Writing Stories, a tendency to dislike Art, P.E. and Mathematics, and a bias towards verbal rather than figural test items.

V (i) <u>Principal Components Factor V (4.4)</u>

This was interpreted as a weak visual imagination factor favouring boys. It is the first factor to load significantly in favour of boys and reflects strong dislike of Writing Stories and Reading, but a marked preference for Art and P.E. The highest cognitive loading on the test was on the test of Pattern Meanings.

NOTE: Macfarlane Smith (1964) suggests that tests with spatial loadings show marked sex differences in favour of boys and this factor, coupled with factor IV suggests such a sex difference. The present testing battery is not well enough equipped with spatially orientated tests to reveal any such tendency in the intercorrelations but the small percentage of variance extracted by factors IV and factor PV might be relevant to Macfarlane Smith's observations.

V (ii) <u>Varimax Factor V (10.4)</u>

The Varimax rotation results in this factor having as much as 10.4 per cent of the total variance, and it was interpreted as a factor reflecting methods of numerical calculation in opposition to a spontaneous ability to think imaginatively and flexibly, particularly when the latter is not dependent on verbal fluency. The creativity tests carry the largest negative loadings but even the academic tests, except for the Arithmetic Progress test, all load negatively.

VI Principal Components Factor VI (3.7) and Varimax Factor VI (4.2)

In view of the large numbers of Mathematics tests it is not surprising that at some stage after extraction of some of the more obvious sources of intercorrelation, a liking for mathematics factor should be extracted. Factor VI, in both analyses, is such a factor. It contrasts liking for Mathematics with a dislike of P.E. and is biased towards boys. On the cognitive side it has low but probably significant loadings on the test of Consequences which might indicate a degree of deductive reasoning. This is supported by low positive loadings on the test of Series Completion.

Having identified the above factors it remains to summarise the insight which they have given to the composition of the testing battery. This can be considered in two parts, conclusions from the interpretation of factors I and II in terms of the two main sections of the testing battery, and conclusions about the nature of some of the tests which did not fit, indeed were not designed to fit, exactly into any one section.

3. Dimensions of Performance as Indicated by Factors I and II

(a) Overall Analysis

The evidence presented by the compostion of Factors I and II on both the Principal Components and the Varimax analysis was summed up in an Interim Conclusion, that over the whole range of intelligence there is evidence of a dimension of ability as measured by tests of creative thinking which, though not independent of intelligence, exists as a consistent complementary activity.

This conclusion does not subscribe to the more extreme 'American' view of creativity as a "dimension of individual differences....... quite independent of the traditional notion of general intelligence" (Wallach and Kogan 1966), but it acknowledges an internal consistency in the creativity battery which reflects an ability common to all the tests of creativity.

Factor analyses of Wallach and Kogan's original data have tended to support their general results but modify their claim to have established dimensions that are "quite independent". Fee (1968) suggests that they are only "relatively independent" and Ward (1967) that though their second factor is clearly one of creativity it has a low correlation with the first factor reflecting performance on 'g' tests.

The creativity dimension located by the present study, when taken over the whole population, is clearly not independent of intelligence and moreover results of the creativity tests are not confined to this dimension but contribute significant loadings to other factors. Considering that the creativity section of the testing battery was deliberately designed to include figural, verbal and mathematically biased items however, the fact that it nevertheless locates a definite 'creativity' factor to which all the tests contribute is a very significant feature of the results. That the range of creativity tests also indicates other supplementary abilities not confined to the creativity battery but often shared with the academic tests is not surprising, though it reinforces the multidimensional view of creativity which suggests that more than one factor is needed to account for the different abilities tapped by the usual forms of creativity test. (Burt 1962, Lovell and Shields 1967).

(b) High I.Q. Analysis

A separate analysis of the results of those pupils with an I.Q. of not less than 115 reinforced the last conclusion that the creativity tests are by no means unidimensional; with regard to the question of independence of the academic and creativity dimensions, however, the results go further than the interim conclusion reported earlier. Designed primarily to test the concept of a "threshold of intelligence" (Yamamoto (1964) McNemar (1964)) it upheld the hypotheses, (Page 173), that "Above an I.Q. of 115 there is no relationship between children's performance on tests of creativity and tests of I.Q.". The 22 correlations between the I.Q. and Creativity measures provided no evidence on which to reject this hypothesis and when extended to cover the whole range of 'academic' tests it was concluded, in only slightly weaker terms, that "the creativity and academic dimensions already located are relatively independent in a high I.Q. sample" (Page 178).

Both Principal Components and Varimax factor analyses confirmed this result and threw light on the nature of some of the experimental tests. The Varimax analysis in particular emphasised the orthogonality of the academic versus the creativity measures and attributed to the creativity tests almost as great a proportion of the extracted variance as to the academic tests.

The results of the High I.Q. analysis are particulary relevant to what Burt (1962) terms "useful creative abilities" for most psychologists and educators would agree with him that "'useful creativity' must involve the ability to deal, not only inventively, but also rationally with the material supplied". His assertion that general intelligence is not only an essential but also the most important constituent of such activities, however, is questionable. Reports of experiments on creative individuals such as those of Roe (1953) and Mackinnon (1962) have indicated that, given a minimum level of intelligence, there is something more than intelligence that is needed to achieve success. The extra something no doubt depends largely on personality attributes, though as noted in an earlier chapter the ability to think flexibly and divergently is often related to personality and has often been revealed in persons regarded as creative.

The independence of the academic and the creativity measures as demonstrated in the present sample could be expressed in terms of McKinnon's (1962) conclusion that "above a certain required minimum level of intelligence ...., being more intelligent does not guarantee a corresponding increase in creativeness". Or as Hudson, talking of the results of creativity tests, expresses in a different way; in a formful of clever boys "the boy with the lowest I.Q. in the form is almost as likely to get the top marks as the boy with the highest" (Hudson 1966). The conclusions from both the Overall Analysis and that of the High I.Q. sample can finally be summarised as follows:-

> Over the whole range of intelligence there is evidence of a dimension of ability as measured by tests of creative thinking which, though not independent of intelligence exists as a consistent complementary activity.
>
> Furthermore, given a minimum I.Q. of 115 the creativity and academic dimensions are relatively independent.

There is also evidence that the ability to perform well on creativity tests is not entirely confined to one factor, that is, it is not a unidimensional ability. It appears that creativity tests are also indicative of a number of other abilities that are by no means similar and are often shared with tests of a more academic nature.

4. The Testing Battery

The preceding discussion of the results of the intercorrelations and factor analyses has allocated the tests to two categories which have been labelled 'academic' and 'creativity' respectively, and these are generally well defined by the matrix of correlations and, more markedly, by the factor analyses.

There are a number of tests, however, which have shown themselves in some cases to differ from the general pattern of tests in their category. It would have been disappointing if this were not the case, for several of the tests were designed by the writer to test for aspects of thinking not emphasized in the more conventional mathematics tests, and the choice of the creativity battery deliberately included both verbal and figural tests and also the mathematically biased test of Make-Up Problems. The following notes on these tests summarises their earlier discussion in the context of the intercorrelation and factor analyses.

(a) Mensuration Concept Test

This part of the N.F.E.R. Concept 'B' test as used by Biggs (1959), although rarely an extreme when discussed in relation to the general population, is significantly different in the High I.Q. analysis. In this analysis it does not correlate at a significant level with 7 out of the other 12 academic tests, is the only test not to load significantly on factor PI, and has the only significant negative loading on V.I.

In spite of the fact that it was part of the same N.F.E.R. test as that of the Arithmetic Concept, the Mensuration Concept is not significantly correlated with the latter in the High I.Q. analysis, and is on the opposite side of the bipolar factor P.III. This suggests that there is an element of a spatial or other factor which separates the mensuration from the arithmetic sections of the N.F.E.R. Concept test, and that it is appropriate to score them separately.

(b) Series Completion

Generally this test is well designated in the academic/mathematics section of the testing battery and there are only slight indications that it assesses any degree of logical or flexible thinking different from the set of mathematics tests in general. A loading of 0.20 on the Varimax 'creativity' factor II for the general population is however just significant. It is also an exception, with the other two experimental mathematics tests, in having a negative loading on the High I.Q. factor V IV, inclining it to the creativity side of this factor.

(c) Space Filling

Although once again firmly in the academic section of the testing battery, this test, with that of 'Easy Problems', is furthest to the creativity side of the academic section as indicated by the bipolar factor P II in the general analysis, and also has a tendency in this direction on P II for the High I.Q. sample. It was not an easy test for those children used to routine arithmetic calculations and is the only test to have substantial, though possibly not significant, negative loadings in opposition to liking for mathematics in factors P VI and V VI of the general analysis.

(d) Easy Problems

In the academic section this is the test most often an exception to the general pattern or at an extreme of the academic category. On the bipolar factors factors P II of the High I.Q. analysis and P II and V $\overline{V}$ of the general analysis, it is clearly the academic test nearest to the creativity side of the balance. In the latter factor it has a loading (-0.25) in opposition to the test of Arithmetic Progress and in line with the ability to think flexibly suggested by the other loadings.

In the table of intercorrelations for the High I.Q. sample it is the test most consistently correlated with the creativity battery and six out of 12 of its correlations with the academic battery do not reach significance. Although its general correlations and factor loadings are substantially in the academic section its leanings on the factors mentioned indicate that it is to some degree successful in assessing a wider range of abilities than the more conventional tests, and that the rationale behind it is not without some foundation.

(e) Make-Up Problems

This test, deliberately included to give a mathematical slant to the creativity section,clearly involves modes of thinking typical of the two sections of the testing battery. In the whole sample its correlations with the 13 academic tests are in each case the largest of any of the creativity tests, and although this is not so marked in the High I.Q. analysis, it is once again the creativity test most biased towards the academic section. Eight out of 13 of its correlations with the academic tests are still positive and significant while only 15 of the remaining 130 correlations between the academic and creativity sections are similarly so.

At the same time its correlations with the other creativity tests are generally higher than those achieved by the academic tests. This dual nature of the test is seen in the overall factor analysis where it just loads the creativity side of the bipolar factor P II and is the only creativity test to load more strongly on V I than on V II, that is, more strongly on the academic factor than on that located by the other creativity tests. In the High I.Q. analysis it becomes more stable as a creativity test, in particular showing more communality with the creativity factor V I than the second 'g' factor V II.

(f) Circles Test

This is the only completely figural test in the creativity battery and necessitates some special mention. In the overall population each of its three scores correlates well with the other creativity measures, all being significant beyond the .01 level, and even in the High I.Q. sample 25 out of 27 of its correlations with the other creativity tests are significant at the .05 level. Its correlations with the academic tests, in contrast, are often non-significant, and in the High I.Q. analysis especially over half are negative and five significantly so. In particular it either fails to correlate or has significant negative correlations with the Arithmetic Progress Test. The latter is an example of the traditional type of Arithmetic test in which the correct application of routine methods ensures a good performance. That the results of the Circles Test do not correlate with this test is in accord with the belief that some sort of imaginative and flexible ability is not related to mechanical application of techniques.

Not depending on verbal ability it is clearly less dependent on I.Q. and g + v : ed ability than the other creativity tests. This is also very obvious in the overall factor analysis where it has the lowest loadings of the creativity battery on both 'academic' factors PI and VI. It also figures predominantly in factors PIV and V V, the latter confirming a non-verbal ability to think flexibly and imaginatively in opposition to routine numerical calculation. This conclusion is strongly supported by factor V III in the factor analysis of the High I.Q. sample.

It has been essential, in view of Part II of the results of this study, to have summarised the nature of the tests used, for although the evidence of the first part clearly supports two general sections of academic/mathematics and creativity tests respectively, differing patterns of school performances on individual tests may be enlightening. The performances of the experimental and the control schools can now be more readily discussed.

TABLE 7

INTERCORRELATION TABLE FOR ALL VARIABLES FROM THE COMPLETE POPULATION (N = 265)

Variable	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I.Q.1	1	1	94	82	82	64	68	69	69	69	67	69	67	69	24	32	22	40	49	48	45	37	32	38	61	20	06	-08	-22	01	-05	-06
I.Q.2	2		1	84	84	67	70	71	69	70	66	70	68	68	24	32	22	41	50	46	46	35	31	37	64	23	07	-08	-20	03	-01	-12
Intermediate Mathematics (Raw Score	3			1	98	76	81	83	77	75	70	77	70	70	16	28	18	43	52	47	47	35	33	39	63	26	10	-11	-20	07	03	-14
(Standard Score	4				1	75	80	82	75	75	68	75	70	68	16	27	18	42	50	46	45	34	31	37	62	26	10	-13	-20	07	02	-14
Arithmetic Progress (Mechanical	5					1	87	94	61	64	61	65	69	57	05	13	02	43	49	45	36	23	30	34	54	33	17	-08	-21	07	11	-18
(Problem	6						1	96	72	73	66	75	67	61	03	12	01	42	48	44	36	24	32	34	53	30	16	-10	-17	11	11	-11
(Standard Score	7							1	71	72	65	73	70	62	03	12	01	43	49	45	36	23	30	33	54	32	17	-12	-19	10	10	-15
Arithmetic Concept A (Raw Score	8								1	96	66	69	53	62	12	20	12	38	43	40	38	28	26	28	49	16	17	-08	-05	07	10	-06
(Standard Score	9									1	65	67	55	60	10	17	10	37	42	39	34	24	25	27	49	19	15	-07	-05	05	10	-08
Mensuration Concept	10										1	67	52	56	13	24	17	33	40	35	37	30	26	29	46	17	14	00	-06	02	12	-11
Series Completion	11											1	59	63	12	19	07	41	46	40	41	30	31	33	54	23	16	-10	-08	06	12	-07
Filling Spaces	12												1	62	25	30	16	38	44	37	36	26	32	33	47	24	01	-01	-22	08	02	-09
Easy Problems	13													1	24	30	19	36	42	38	45	34	28	30	49	14	11	-01	-15	06	05	-11
Circles (Fluency	14														1	86	66	53	49	41	47	41	47	47	34	03	01	08	06	05	11	-01
(Flexibility	15															1	79	55	55	46	52	45	48	51	38	03	-03	07	03	07	08	-04
(Originality	16																1	41	40	34	40	40	34	34	27	00	03	08	05	00	08	07
Uses (Fluency	17																	1	95	83	64	48	65	66	50	19	05	04	-05	02	10	-15
(Flexibility	18																		1	84	66	48	65	68	55	19	02	02	-05	03	08	-17
(Originality	19																			1	52	41	56	62	47	17	02	-03	-10	-03	-00	-07
Consequences (Fluency	20																				1	79	54	57	54	15	06	09	-07	-00	09	-13
(Originality	21																					1	39	44	45	07	10	10	-07	-03	08	-07
Patterns (Fluency	22																						1	90	41	15	03	03	10	-00	14	-10
(Originality	23																							1	48	17	-03	05	07	01	12	-10
Make-Up Problems	24																								1	28	04	02	-20	02	05	-23
Attitudes (Reading	25																									1	-06	09	-17	-09	33	-13
(Mathematics	26																										1	-12	-02	-07	39	04
(Writing	27																											1	-03	-11	44	-09
(Art	28																												1	-12	48	14
(P.E.	29																													1	37	01
(Summed Score	30																														1	-00
Sex	31																															1

NOTE: for 263 d.f. values of r of 0.12 and 0.16 are significant at the .05 and .01 levels respectively. Decimal points are omitted in the table

FACTOR LOADINGS

TABLE 8 (a)
Factor Analysis of the Whole data (31 variables, 265 cases)

Principal Components Analysis

		I	II	III	IV	V	VI
I.Q.1	1	84	-19	15	-18	-10	-04
I.Q.2	2	85	-20	12	-14	-12	-07
N.F.E.R.Intermediate	3	90	-28	05	-08	-03	-05
" " Std.Score	4	88	-29	06	-09	-03	-05
" Arith.Mechanical	5	80	-34	-06	19	07	-02
Problem	6	83	-38	-09	10	11	-02
Std.Score	7	84	-39	-07	13	11	-02
" Concept Raw	8	78	-30	-11	-19	05	08
Std.Score	9	77	-33	-11	-15	04	06
" Mensuration	10	73	-23	-10	-14	-09	06
Series	11	79	-27	-09	-06	05	05
Blanks	12	74	-18	06	-03	-10	-20
Easy Problems	13	74	-15	02	-18	-15	-01
(Fluency	14	39	71	01	-29	-14	-12
CIRCLES (Flexibility	15	48	68	04	-33	-16	-16
(Originality	16	33	63	03	-41	-23	-04
(Fluency	17	69	50	02	23	23	05
USES (Flexibility	18	75	44	05	22	22	01
(Originality	19	68	38	13	20	27	06
CONSE- (Fluency	20	66	44	04	04	-12	18
QUENCES(Originality	21	52	42	05	-05	-23	29
PATTERNS (Fluency	22	56	52	-08	23	30	01
(Originality	23	60	52	-03	24	26	-03
MAKE-UP PROBLEMS	24	73	09	09	11	-17	-03
(Reading	25	30	-08	-19	51	-28	-12
(Maths	26	13	-10	-38	-15	-05	73
Interests (Writing	27	-04	21	-33	29	-64	-04
(Art	28	-16	20	-61	-23	34	-09
(P.E.	29	06	-03	-41	-21	21	-60
" Summed	30	11	11	-95	09	-16	00
Sex	31	-16	01	-08	-46	21	14
Percentage of Total Variance		40.6	12.9	6.1	5.0	4.4	3.7

TABLE 9 (a)
Factor Analysis of the Whole data (31 variables, 265 cases)

Varimax Analysis

		I	II	III	IV	V	VI
I.Q.1	1	85	15	14	-02	-23	-06
I.Q.2	2	86	15	11	03	-21	-07
N.F.E.R.Intermediate	3	92	20	06	03	-10	-03
" " Std.Score	4	91	18	06	02	-10	-04
" Arith.Mechanical	5	81	29	01	16	17	01
Problem	6	87	25	-04	08	15	03
Std.Score	7	88	27	-02	10	18	02
" Concept Raw	8	84	13	-07	-06	-07	16
Std.Score	9	84	12	-07	-04	-03	14
" Mensuration	10	76	09	-02	06	-13	13
Series	11	81	20	-04	01	-02	11
Blanks	12	74	15	03	11	-14	-18
Easy Problems	13	74	09	05	04	-25	02
(Fluency	14	04	37	-10	-00	-79	-07
CIRCLES (Flexibility	15	14	37	-08	-02	-83	-11
(Originality	16	05	21	-05	-06	-82	01
(Fluency	17	28	82	01	-07	-27	02
USES (Flexibility	18	37	81	02	07	-25	-03
(Originality	19	34	76	09	-02	-18	-01
CONSE- (Fluency	20	33	53	14	16	-47	16
QUENCES(Originality	21	23	36	20	13	-52	26
PATTERNS (Fluency	22	16	81	-11	05	-21	02
(Originality	23	20	81	-08	08	-23	-03
MAKE-UP PROBLEMS	24	57	35	15	23	-26	-05
(Reading	25	24	16	-00	62	13	-06
(Maths	26	15	-00	-05	-08	04	83
Interests (Writing	27	-14	-11	-05	73	-25	11
(Art	28	-20	08	-71	-16	-03	19
(P.E.	29	13	-05	-69	-05	-03	-34
" Summed	30	05	03	-73	51	-07	42
Sex	31	-09	-16	-17	-44	-11	19
Percentage of Total Variance		32.7	14.8	5.6	5.1	10.4	4.2

TABLE 10

INTERCORRELATION TABLE FOR ALL VARIABLES FROM THE HIGH I.Q.SAMPLE (N=71)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I.Q. 1	1	1	57	36	41	29	28	32	16	14	26	35	40	39	00	04	07	-01	02	04	10	12	07	06	11	-27	15	-23	-11	05	-20	07
I.Q. 2	2		1	49	52	38	26	35	23	24	22	16	35	38	13	26	20	05	09	-02	14	05	12	12	26	15	07	-13	-02	-00	03	-19
Intermediate Mathematics (Raw Score	3			1	95	66	60	65	36	31	29	39	56	34	06	17	03	18	23	10	27	10	10	17	38	17	03	-11	-05	19	08	-23
(Standard Score	4				1	60	56	62	33	32	25	35	55	26	06	17	03	12	16	05	23	06	12	14	37	13	04	-13	-03	16	05	-18
Arithmetic Progress (Mechanical	5					1	86	97	49	44	26	45	56	25	-15	-07	-21	25	30	24	18	02	19	21	38	29	07	-11	-14	19	11	-15
(Problem	6						1	94	50	44	20	44	50	22	-28	-21	-30	15	20	20	10	02	10	10	31	24	03	-12	-21	25	04	-03
(Standard Score	7							1	49	45	21	44	57	21	-20	-12	-25	22	27	24	15	01	16	17	38	27	06	-14	-21	21	05	-09
Arithmetic (Raw Score	8								1	96	17	31	24	11	-19	-18	-23	18	16	05	-12	-15	06	06	08	17	01	-08	13	04	12	-13
Concept A (Standard Score	9									1	12	28	26	01	-20	-20	-23	12	11	-00	-19	-22	04	02	04	19	02	-08	13	06	15	-10
Mensuration Concept	10										1	27	08	18	-09	-07	09	-17	-07	-12	-07	01	-08	-11	-10	09	14	12	08	-09	19	01
Series Completion	11											1	28	21	-08	-05	-02	07	09	01	15	18	04	00	17	18	24	-09	09	16	29	19
Filling Spaces	12												1	26	10	13	06	15	15	07	25	16	20	23	23	15	-09	08	-13	08	02	02
Easy Problems	13													1	23	25	19	20	22	07	30	23	18	15	32	-01	06	06	-03	09	08	-12
Circles (Fluency	14														1	87	67	48	48	28	45	31	52	53	39	-16	-05	20	21	02	13	-11
(Flexibility	15															1	78	44	46	27	46	36	50	54	44	-16	-04	20	15	09	13	-11
(Originality	16																1	26	26	08	31	35	27	25	22	-24	05	15	17	-03	08	11
Uses (Fluency	17																	1	97	85	55	23	71	71	50	00	-03	-13	04	06	-04	-18
(Flexibility	18																		1	86	55	24	73	70	51	-03	-02	-14	05	10	-03	-17
(Originality	19																			1	41	13	63	63	35	-02	-02	-16	-02	02	-11	-13
Consequences (Fluency	20																				1	73	55	56	62	-00	15	15	-19	-05	04	-11
(Originality	21																					1	23	29	38	-13	14	21	-19	-08	01	01
Pattern Meanings (Fluency	22																						1	90	47	03	04	02	10	06	13	-12
(Originality	23																							1	55	11	-08	07	08	05	10	-19
Make-Up Problems	24																								1	10	10	08	-13	09	11	-15
Attitudes (Reading	25																									1	-03	19	02	-13	49	-16
(Mathematics	26																										1	-07	-09	-26	39	22
(Writing Stories	27																											1	01	-25	49	-09
(Art	28																												1	-03	50	-05
(P.E.	29																													1	03	09
(Summed Score	30																														1	02
Sex	31																															1

NOTE: for 69 d.f. values of r of 0.23 and 0.30 are significant at the .05 and .01 levels respectively. Decimal points are omitted in the table b

FACTOR ANALYSIS: HIGH I.Q. SAMPLE (24 variables 71 cases)

Table 11 (a) Principal Components | Table 12 (a) Varimax

		PC I	PC II	PC III	PC IV	Varimax I	Varimax II	Varimax III	Varimax IV
I.Q.1	1	39	30	-43	08	-11	61	-22	00
I.Q.2	2	48	25	-46	31	-04	64	-40	15
Intermediate	3	69	44	-27	-01	13	85	-04	04
" Standard Score	4	65	44	-30	03	08	83	-08	07
Arithmetic Progress (Mechanical	5	70	57	14	-15	29	78	36	15
Arithmetic Progress (Problem	6	59	64	19	-23	21	74	49	14
Arithmetic Progress (Standard Score	7	68	61	16	-19	27	79	42	15
Concept (Raw Score	8	37	55	33	47	16	42	16	74
Concept (Standard Score	9	31	56	33	53	11	37	14	79
Mensuration	10	13	34	-32	13	-25	41	-12	11
Series	11	39	38	-13	-15	02	57	14	-03
Blanks	12	58	31	-20	-07	14	68	-01	-03
Easy Problems	13	45	02	-38	00	10	48	-30	-16
CIRCLES (	14	40	-69	-27	29	46	-04	-75	-16
CIRCLES (	15	47	-64	-36	29	43	07	-79	-18
CIRCLES (	16	24	-56	-51	30	16	01	-81	-20
USES (	17	69	-46	43	08	93	05	-12	05
USES (	18	73	-43	40	07	92	10	-12	04
USES (	19	57	-38	53	-05	86	-03	08	01
CONSEQUENCES (	20	63	-45	-13	-42	59	26	-16	-58
CONSEQUENCES (	21	36	-35	-32	-47	25	21	-17	-67
PATTERNS (	22	65	-49	26	10	82	06	-24	-02
PATTERNS (	23	67	-49	25	05	83	08	-23	-06
MAKE-UP PROBLEMS	24	69	-22	-03	-21	57	39	-12	-28
Percentage of Total Variance		29.9	21.7	10.4	6.2	22.2	24.0	12.5	9.5

PART 2

COMPARISON OF SCHOOL PERFORMANCES AND DISCUSSION OF THE EFFECTS OF THE DISCOVERY APPROACH IN SCHOOL 'C'

The previous section has established that the range of scores available for the subjects taking part in this experiment can generally be allocated to two main categories, one containing academic and mathematical measures and the other the results of the creativity tests. In addition there were some tests which had properites peculiar to themselves. In this final section of the results the performance of the 'experimental' school will be compared to that of the other two schools on each of the experimental measures and the effects of the discovery approach discussed. Comparison is possible on a good deal of objective data; means, standard deviations, product moment intercorrelations, and factor analyses having been calculated for each school. The complete data is reproduced at the end of this chapter, TABLES 13 to 18, and throughout this part of the results reference will be made to these tables and to those which have been discussed earlier.

The numbers of children in each school, 102, 71 and 92 respectively are large enough to achieve roughly normal distributions and permit reasonable significance criteria, and, although factor analyses normally require several hundred subjects to achieve reliable results, the nature of the testing battery in the present study, in which a number of factors are well defined by a group of tests, enables some valid conclusions to be made from the individual school analyses. In particular the results of the present section will derive from an analysis of the levels of performances and attitudes, as shown by the differences between the means for each school on each test. The significance of any such differences will be assessed by means of the 't' test and discussed in terms of the hypotheses relevant to this section.

On a preliminary investigation of the intercorrelation tables and the factor analyses, patterns of performance appear to vary between schools, with School C, conveniently, appearing on most scores to lie between the other two, with the exception of variable 31 denoting the children's sex. In view of the differing attitudes and performances which we have already noted to be associated with sex differences, the latter will need further scrutiny in this section. In fact a number of features peculiar to the individual schools can profitably be discussed before proceeding to the main comparison.

<u>School A</u>

In School A the intercorrelations (Table 13) both within and between the academic and creativity sections of the testing battery are uniformly high, none falling below the .01 level of significance, and the majority, even between the sections, being decidedly higher. It indicates a more substantial relationship between creative and academic performance than was indicated by the overall analysis in the last section, and although both factor analyses of the data from School A (Table 14) still provide two factors which, from their major loadings, can be identified with the academic and the creativity tests respectively, neither factor is exclusive to one of these categories. The Principal Components analysis allocates

50.7% and 9.4% of the total variance to factors I and II and this stresses the importance of the g + v:ed factor. Two other features of performance in School A are worth noting at this stage; the significant correlations ($p < 0.01$) between liking for Reading and all the cognitive scores, and the consistent correlations in favour of girls on all the test performances including the creativity section.

These two trends are reflected in the factor analysis for School A. Factors I and III in the Principal Components analysis have loadings of -0.31 and -0.20 towards girls, and factor IV has a strong 'boy' loading indicating boys' dislike of Reading, Mathematics and Writing Stories, and preference for Art and P.E. The Varimax analysis stresses these differences, V IV showing boys' dislike of Reading and Writing Stories and V V girls' liking for Mathematics in this school. The importance of these trends will be discussed shortly after the predominant features of Schools B and C have been noted.

School B

From the intercorrelation analysis for School B (Table 15) it can be seen that although the academic tests are all very highly correlated, there is less of a cohesive creativity dimension that has been seen previously, and a smaller number of significant correlations between the sections. Only 39 out of the 143 correlations between the sections are significant at the .01 level, and this includes all 13 in the case of the Make-Up Problems test. Excluding the latter, however, there are, in general, higher correlations among the creativity scores than between the creativity and academic sections.

The Circles Test in this school has a definite role, largely confined to itself, for although it is reasonably correlated with the other creativity tests, (once again excluding the Make-Up Problems Test), it is negatively correlated on at least one of its scores with each of the academic tests. It is the test which most markedly defines the second factor on both Principal Components and Varimax factor analysis of School B, and though sharing communality with the other creativity tests on factor PII, it is largely on its own in factor VII. The Varimax analysis for this school is particularly illustrative of the multidimensional nature of the results of creativity tests, as was suggested in Part I of this study. The eight factors extracted in the factor analysies of Schools B and C provide more convincing evidence of this than the five factors obtained for School A, though they also reduce the amount of variance represented by the first 'general' factor.

Liking for Reading in School B is once again positively correlated with the academic measures though rarely significantly, and in contrast to School A it is often negatively correlated with the creativity scores. Correlations with sex are also less marked than in School A and even include significant positive correlations favouring boys' preference for Art and better performance on the fluency score for the Circles Test.

School C

The general pattern of results in both the intercorrelation table (Table 17) and the factor analysis (Tables 18a,b) appears to place School C in a mid-way position between Schools A and B. There are substantial correlations within both creativity and academic sections of the testing battery and 75 out of the 143 intercorrelations between the two sections are significant at the .01 level or better. This compares with all such correlations being significant in School A and only 39 in School B. The majority of non-significant correlations, as in School B. involve the Circles test or the test of Pattern Meanings.

The factor analysis resembles that of School B in having eight factors, but factors I and II are in some ways more like those in the analysis of School A than School B. Factor I in both Principal Components and Varimax analyses having substantial correlations, especially in the former, from both academic and creativity sections. On the other hand, Varimax factor II is more exclusively a creativity factor than it is in School A and is loaded more uniformly by the creativity tests than in School B.

The trends noted as being very significant in School A, and very much less so in School B have now, however, been taken a step further in School C. Correlations with sex differences are now generally positive, that is, in favour of boys, and correlations with liking for Reading, which were very marked and positive in A, are now insignificant and occasionally even negative. There are two noteworthy correlations on variable 31; one, as in School B indicates boys' superiority on the Circles test, this time predominantly on the Originality score, and the other, significant at the 0.01 level, showing boys' liking for mathematics.

The patterns of performance in the schools under review have so far been discussed in terms of the intercorrelation tables and their subsequent factor analyses. Before these are discussed further however, it must be noted that they tell one nothing about the level of performance achieved by a school and can give only a picture of the relations between tests.

The conclusions of Part I of these results confirmed that the testing battery can profitably be seen as two sections which, though not independent, comprise the academic tests of intelligence and mathematical thinking, and the creativity tests respectively. This pattern is repeated in the inter-school analysis but to varying degrees; the two sections being most dependent in School A and least dependent in School B. While these differences can be seen as modifications of the overall pattern however, two markedly different trends were observed to characterise the individual schools and these necessitate further investigation.

Variable 31 indicating the sex of the pupils has distinctly different correlation patterns in Schools A and C, and variable 25, indicating the pupils liking for Reading, is also very different.

The correlations in School A clearly indicate that girls were primarily responsible for high scores on all the tests, creativity, intelligence and mathematics and that they have better attitudes to school subjects than boys, except in Art. School B tended, with a number of exceptions, to follow this pattern to a lesser degree but in School C the tendency was in the opposite direction favouring boys and indicating in particular a significant correlation between liking for Mathematics and boys.

In view of the care which was taken to match the three schools in as many variables as possible except for their approach to mathematics, one is tempted to interpret the difference in terms of the methods employed in the mathematics teaching. On the other hand, further scrutiny of the populations reveals different distributions of boys and girls which even if not statistically significant are likely to have an effect on the results from School A.

There are no significantly different proportions of girls in the overall populations from the three schools, though School A does have the greatest number, as shown in Table 19(i). The High I.Q. groups however, are made up as shown in Table 19(ii) and it can be seen that School A now has a far greater proportion of girls:-

TABLE 19

Numbers of Boys and Girls in each School

	School	Number of Boys	Number of Girls	Totals
(i) Whole Population	A	46	56	102
	B	37	34	71
	C	44	48	92
(ii) High I.Q. Groups	A	9	17	26
	B	9	9	18
	C	14	13	27

There is generally a tendency for girls to do better than boys on verbal tests of I.Q. and the distribution of boys and girls, with ten more girls than boys emphasises the effect of sex differences and the chance of girls appearing in the high I.Q. group. In relation to the whole school population the 9:17 ratio is in fact equivalent to 10.4:15.6 were there equal numbers of boys and girls from which to choose a sample. If a random sample of 26 pupils was taken from a large population having equal numbers of boys and girls a distribution of 10:16 is not significant even at a 15% level and the high I.Q. sample in School A is therefore quite likely a matter of chance, particularly in view of girls general slight superiority on verbal I.Q. tests.

However, given that School A has a natural bias towards girls there is also the likelihood that the tendency is self-perpetuating in the sense that the activities of the school will tend to be orientated towards girls' interests. The type of streaming in force in School A was to have one 'top' class and two equal 'B' classes and with the large proportion of High I.Q. girls in the 'A' class such a system must tend to further the interests of girls. There is a significant correlation indicating that girls rather than boys in School A have a liking for Reading and this attitude correlates well beyond the 1% level with all 24 cognitive test scores.

That sex differences are a major influence on School A's pattern of ability and attitude to school subjects, is further emphasised by the consistent negative correlations of all the cognitive test scores with liking for Art, the latter being the only measure in School A on which boys score more highly than girls.

The overall effect on School A, apparent from the correlation table and particularly from the factor analysis, in which factor PI has over 50% of the total variance, is that general verbal ability plays a very substantial part in all the test scores, including those of creativity, and is associated with girls while boys take some refuge in liking for Art.

Sex differences in School B are in evidence with a significant liking for Art in favour of boys and a corresponding performance on the Circles Test which boys perform significantly better than girls. At the same time, however, School B's performance on the Circles Test is lower than that of both A and C though School B has the highest level of liking for Art. These results might well be related, for over-emphasis on the artistic decoration of the Circle drawings, which is possibly related to liking for Art, would gather no extra marks and reduce the fluency of response. It has already been noted that the performance on the Circles Test in School B follows a different pattern than in the other schools and, unlike A or C, it has negligible loadings on the first general ability factor in the Principal Components Analysis.

While the overall pattern of results in School C falls largely between that of Schools A and B the sex differences go further in the direction of boys than in School B and consequently contrast markedly with School A. Liking for mathematics appears correlated to sex for the first time and although it is, very surprisingly, at its lowest level in School C, it is most favoured by boys. There is no significant correlation in School C between any of the cognitive scores and liking for reading, although in School A it was noted that all such correlations were significant at the 1% level.

It appears that if the most intelligent pupils are predominantly girls, as in School A, then their general verbal reasoning ability also makes them superior to boys both in the mathematics tests and those of creativity. On the other hand in School C the boys are slightly, though not significantly the most intelligent and the correlations between sex and the other tests are usually negligible though just positive.

A chance distribution of high intelligence among girls, reinforced by lessons orientated towards them in the top stream, could together account largely for the pattern of results in School A. In School C however there is a better distribution of numbers and intelligence between the sexes but a definite leaning towards better performance by boys. It is quite likely that the emphasis on mathematics in School C encourages boys rather than girls to work at the subject, although in the case of their attitudes their scores are not as high as in the other schools.

Although this discussion of the dex differences between schools has been necessary to explain some of the pattern differences, real distinction between School performances is best seen in terms of the level of their performance on the tests administered and these will now be discussed individually.

Comparison of Levels of Attainment

Means and standard deviations for each of the 31 variables are shown in Table 20 at the end of this chapter, together with the 't' value of the differences between the means of the three schools. The level of 't' necessary for significance between the means is also shown. The results are discussed individually and are related to the experimental hypotheses when appropriate.

(1) I.Q. Tests Moray House Verbal Reasoning Tests 81 and 82

The three schools were matched for I.Q. level when the experiment was set up and this ensured that the original populations did not differ significantly. In fact the differences were not significant at even a

20% level. Elimination of certain pupils because of incomplete data however changed the composition of the samples slightly. Even so intelligence levels still do not differ significantly at a 10% level though School C has a higher level which is almost significant at this level.

This fact would have been awkward had School C performed significantly better on most of the other variables but as we shall see this is not the case. This means that if Schools A and B exceed School C in some performance, they are doing so against the trend of intelligence.

One must consider, however, that, to some extent, the discovery approach, with its encouragement of the pupil to think for himself, might result in the pupils in School C developing their potential ability to a higher degree than pupils in the other schools, thus enabling them to gain higher marks on an I.Q. test. This possibility cannot be answered from the present study but needs a longitudinal experiment. Investigation of the trend in previous years however showed that it is not unusual for School C to have had a population which, when tested at 11+, showed a higher level of intelligence than those children in the present sample.

The following table (TABLE 21) shows the percentage of pupils passing from each of the three Schools to the Grammar School over the past four years, and as the main placement criterion is I.Q. it gives an indication of the variation of intelligence both between schools and within any single school from year to year.

TABLE 21

Percentage of Children passing to Grammar School, 1966-1969

	School A	School B	School C
1969	23.3	26.7	27.5
1968	25.8	25.6	13.6
1967	38.0	26.3	39.4
1966	27.2	25.0	33.3

(2) N.F.E.R. Intermediate Mathematics Test 1

This test has only recently been standardised by the N.F.E.R. and is designed to test understanding of mathematical concepts and involve almost no mechanical computation. It follows the more recent approaches to the teaching of mathematics, presents questions in a non-traditional form and has no time limit.

It would seem to favour the approach adopted in School C but in fact both School A and School B attain better results, School A being significantly better than School C at well beyond the 1% level. This result, considering the design of the test and the higher level of intelligence in School C, is very surprising and in direct contradiction to hypothesis 3, which suggested that the performance of children in School C on this test, specially designed to stress understanding and avoid routine calculation, would be greater than in Schools A and B. The hypothesis is thus rejected.

It is worth noting for discussion later that School A also attains a higher result than School B on this test, which is significant at a 10% level.

3. N.F.E.R. Arithmetic Progress Test C1

(a) Mechanical Arithmetic

This section comprises exercises in computation involving knowledge of the four rules and simple exercises in money, weights and measures. The aim of the test is to measure general attainment but it is set in a traditional form which is likely to benefit the control schools. Even so their superiority over School C is very great, with the mean scores in A and B being over 10 points greater with t = 6.59 and 5.75 respectively. Performance in Schools A and B does not differ significantly.

It must be repeated that School C, in its discovery approach, does not aim to give the children rigorous methods and routine practice in computation, and the practical interpretation of this result will be discussed further later. It is likely to be of less educational significance than appears at first sight, although its degree is disturbing to those who believe that the children taught by discovery methods attain by the age of eleven roughly the same level of computational attainment as their more traditionally taught counterparts.

Hypothesis 6 was worded to allow a certain degree of superiority on this test in the control schools, but the performance of School C on this part of the test is so very significantly lower, that the hypothesis, which suggests that any differences will not be significant, has to be rejected.

(b) Problem Arithmetic

This section of the test consists of problems in Arithmetic, based, as in part (a) on knowledge of the four rules and of money, weights and measures, and is again basically traditional. As might be expected from the results of part (a) of this test, Schools A and B are once again very significantly superior to School C on this section, the values of 't' for the differences being 5.91 and 6.21 respectively.

(c) Overall Standard Score

The N.F.E.R. manual for this test provides a standard score based on the sum of the scores in the two separate sections. This confirms the results of the two sections separately with the value if 't' increasing slightly. Its most interesting feature is that it shows the level of attainment in School C to be not only very much lower than that in the similar Schools A and B, but also significantly lower than the standardised average in spite of the fact that its mean I.Q. is above the national average.

The combined results for this test confirm that hypothesis 6 must be rejected.

(4) N.F.E.R. Concept 'A' Test

This test is part of that designed for the N.F.E.R. by Biggs (1959, 1967) to measure children's conceptual understanding of Arithmetic. This part, Concept A, endeavours to avoid the use of rules which could have been learned by rote and attempts to assess the child's ability to apply his concepts to problem situations without involving him in computation. As such it was felt to be particularly suitable for the present study, putting School C at no obvious disadvantage.

School C nevertheless fares badly once again, Schools A and B, and particularly the latter, attaining significantly higher levels of performance. The 't' level for the differences in standard scores between

A and C, and B and C, being 2.51 and 4.98 respectively.

The only slightly encouraging feature for School C is that its mean score of 99.6 is almost the national average so that although children in School C do not achieve their full potential on Arithmetical understanding their performances do not fall significantly below the average. At the same time it is disappointing that although their I.Q. level shows that they are of equal, if not higher intelligence than children in Schools B and C, their arithmetical understanding is very much lower in spite of the emphasis in School C on mathematical activity and understanding.

Hypothesis 5 refers to both this test and that of the Mensuration Concept. As far as this test is concerned the evidence must reject it.

(5) N.F.E.R. Mensuration Concept

This test is another part of the testing battery used by Biggs in the study already referred to (1959, 1967), and is designed to assess understanding of the concept of mensuration. It was not, like Concept A, a separately standardised test and consequently only Raw Scores are recorded. The format of the test, with a diagrammatical representation of 'fips' and 'yogs' is certainly not in a traditional pattern and children in School C perform relatively better on this section. Their performance however, is still below that of children from Schools A and B, though not significantly so in the case of School A, and only at the 10% level in the case of School B.

Hypothesis 5 however asserts that School C should reach a higher level of attainment than A and B on tests of mathematical concepts and, these results, in conjunction with those of the Concept A test are such that the hypothesis must be rejected.

(6) Tests of Logical and Flexible Thinking in Mathematics

Designed as a test of flexibility of thinking involved in relations between elements, this test followed the example of tests used by Lunzer (1965) and Lovell (1968). Schools A and B once again achieve a higher degree of success than School C. The differences being significant at levels of 6% and 7% respectively. The test involved little knowledge of rules of arithmetic but demanded a certain ability to manipulate numbers and relate them in different ways. The results are contrary to hypothesis 4, which suggests that School C should have the best performance on such tests.

(b) Space filling

Following Bartlett (1958) this test was designed to leave gaps in mathematical statements which would demand a degree of flexible and logical thinking for completion.

School A attained the highest level on this test with School C again lowest but only just behind School B. The relatively poor performance of School B seems surprising in view of its performance on the Arithmetic Progress and Concept Tests but, as noted in Part I, the present test has some features which place it at the creativity side of the academic tests, and it was deliberately designed so as to necessitate more flexible and constructive thinking than is involved in just applying a rule.

It is encouraging to find that School C is not so far behind the others on this test, but the initial hypotheses were posed with the superiority of C in mind and this is certainly not the case.

(c) Easy Ways of Solving Problems

This test consisted of 25 numerical problems which were most easily solved if the subject applied a procedure, illustrated in two examples, which necessitated him looking at the problems in a 'new' way and reorganising the problem into a new form so that the solution could be seen more easily. In order to attain a high score the subject therefore needed to be willing and able to vary his approach, and to attain an insight into the real nature of the questions.

The performance of children in School C is, for the first time, better than in Schools A and B, though only by a very small and not significant margin. The result is not sufficient to claim that the children in School C are better at this type of thinking than those in A or B for the 't' ratios of the difference to standard error are only 0.41 and 0.55.

Hypothesis 4 maintained that scores on the tests designed to assess flexible and logical thinking in mathematics would be higher from children in School C than from those in Schools A and B. While the results of these three tests do not directly contradict this hypothesis to the extent that other hypotheses have been contradicted, they give no support to the hypothesis and it must consequently be rejected.

The present results will be summarised later but it is appropriate to note at this stage that all four hypotheses so far examined have been rejected. This shows that in none of the cases was there any support for a belief that the mathematical ability of children in School C would be of a higher level than in the more traditional schools. In fact the contrary was often established.

It is worth noting, however, that School C's performance has improved as the tests have changed their character so as to emphasise flexibility and reduce the part played by techniques. In particular the factor Analysis frequently showed the Easy Problems Test to be the academic test with loadings nearest to the creativity side of a number of bipolar factors, and it is significant that it is the only mathematically orientated test on which School C performs slightly better than the other two schools.

Discussion of the results of the Creativity tests follow.

(7) Creativity Tests

(a) Circles Test

This is the only completely figural test in the creativity battery and as might have been expected, it was shown by the factor analysis to be less dependent on I.Q. and general ability than the other creativity tests. It was noted earlier in this section that School B's performance on this test is of a different pattern than that in the other Schools, but it is School C's performance however which stands out. For the first time it is significantly better than that in both control Schools, and not only is it better but to a very significant level and on each of the scoring procedures.

One of the features of the intercorrelation analysis for the whole population was the non-significance of the correlations between the scores for Circles Test and those for Arithmetic Progress. In the High I.Q. Analysis they were significantly negatively correlated, and it was suggested that performance on the Circles Test involves some imaginative and flexible ability which is not related to mechanical application of techniques. School C's superiority on this test is therefore of particular significance for it shows a degree of imagination and creative ability on this test much higher than in either School A or School B. The pattern of School C's performance is somewhere between that of A and B. Boys perform better than girls, as in School B, but the correlations with the other scores are all positive and often significant as is the case for School A.

It has already been suggested that School B's poor performance might be linked with their strong liking for Art which might encourage over-emphasis on irrelevant artistic detail and a consequent reduction in fluency. School B's level of performance is however similar to that of School A, both being significantly lower than that in School C.

Before making any conclusion about the evidence of creative ability in School C however, the remaining Creativity tests need discussing.

(b) Uses Test

Three scoring procedures were also adopted for this test, reflecting a subject's fluency, flexibility and originality in producing ideas for the use of various objects. School A has the best level of performance in each of the measures, significantly better than School B at a 1% level, but only better than School C at a 10% level. School C is not significantly better than School B.

The factor analyses of each School reveal that this test is well defined by the creativity factors but also has substantial loadings on the first general factor in each analysis. It is a completely verbal test and its scores are well correlated with intelligence. School A however overcomes its slight disadvantage with regard to intelligence to attain its moderately significant level of superiority over School C.

(c) Consequences Test

The test was designed to assess originality in thinking of possible consequences of a number of hypothetical situations. It was scored for fluency and originality, and School C had the highest mean score for each category. In neither case however was it significantly better than School A though it was superior to School B at the 5% level. On the measure for fluency School A's performance was significantly better than that of School B but only at a 10% level

(d) Pattern Meanings

Although this is another test designed, like the Circles Test, to assess a subject's imaginative ability given a figural stimulus, it had to be answered in a verbal form and this partly explains the fact that its results differ from those of the Circles test. Although it has some loadings in most of the factor analyses which are similar to those of the Circles Test it has others such as VII and PIV in the overall analysis which are markedly different or even of opposite sign. School A has the highest level of performance with School B slightly better than School C on the fluency score but not on that of originality. The only significant difference in performance is School A's superiority over School B on the Originality score.

(e) Make-Up Problems

This test was deliberately included to give a mathematical slant to one of the creativity tests and was often well correlated with the academic tests. It also contributed substantial loadings to those factors mainly located by the academic tests and in a number of ways indicated modes of thinking common to both creative and academic sections of the testing battery. Schools A and C perform significantly better, at a 5% level, than School B, and School A attains a slightly higher performance than School C though the latter is not significant.

Hypothesis 2 claimed that scores on the Creativity tests would be higher from School C than from the control schools. This can now be evaluated in terms of the above results on the Creativity tests.

Although a dimension of Creativity was established in Part I of these results, it was observed to be multi-dimensional, and the Circles Test was often observed to carry loadings peculiar to itself. It is certainly the creativity test which discriminates most highly between the levels of performance in the three schools, School C being very significantly superior to the others.

As far as this test of creativity is concerned the hypothesis is therefore verified.

However on six out of the remaining eight creativity measures School A has the highest score, significantly better than School C, though only at the 10% level, on the three scores for the Uses Test.

In general therefore the hypothesis must be rejected although the educational and psychological significance of School C's marked superiority on the Circles Test will be discussed further in the final conclusion.

7. Attitudes

For the purpose of this study the most significant feature of the attitude results is that mathematics is the subject least highly regarded in each of the schools, and in particular that its lowest rating should occur in School C.

The mean scores, taking all the schools together, place the subject preferences in the order P.E., Art, Reading, Writing Stories and Mathematics, and this is the pattern in each of the schools except for the reversal of Reading and Writing Stories in School C.

The fact that Writing Stories is preferred to Reading in School C might suggest that the children, used to writing accounts of their discovery work consequently prefer active participation in Writing Stories rather than Reading. This writing aspect might be worth pursuing further though School C's level of preference for Writing Stories is not exceptional being below that of School B. An alternative investigation might focus on its comparatively poor attitude to Reading significantly lower than that in School B.

School B's attitudes are particularly pleasing for in spite of its slightly lower level of intelligence it has the best attitudes to school on four out of the five subjects and the best overall attitude. The latter is significantly better than that of School C at the 5% level and so is its preference for Reading. Its liking for Mathematics is higher than in either School A or School C and though it is not very significant, it is superior to that in School C at a 16% level. This is in contrast to Hypothesis 1 which suggested that children in School C would show a more favourable attitude to mathematics than children in Schools A and B.

School C never attains the highest attitude score in comparison with the other two schools but it takes second place on three occasions, above

A on Writing Stories and Art, and above B on liking for P.E. In none of these instances however are the differences significant.

It appears that the widespread impression that children using discovery methods in mathematics are liking and enjoying the work to a greater extent than those using more conventional methods is not well founded. The present evidence suggests that children may well prefer routine success and computational ability. From the evidence of this section it is clear that hypothesis 1 must be rejected.

Summary and Discussion

The purpose of this final section of the results was to compare the performance of the experimental school, School C, with that of the other two schools on each of the experimental measures and to make conclusions with regard to the validity of the hypotheses made earlier concerning the discovery approach.

The pattern of School C's performance, as shown by the intercorrelation table and its factor analysis, was in many ways similar to that of A and B and generally mid-way between them. It indicated a less consistent relation between creativity and the intelligence/mathematics measures than in School A but a greater degree of consistency than in School B.

Two features however contrasted with School A, and followed a trend already noted in School B. Boys in School C generally performed better than girls and the score reflecting liking for Reading was not correlated with the other variables. The boys in School C did particularly well on the Circles Test and liked the Mathematics more than did the girls. In Schools A and B on the other hand girls favoured mathematics to a higher extent than did boys, and in School A girls were primarily responsible for high scores on all the tests.

Investigation of these features revealed differences in the proportions of boys and girls, particularly in School A, where there were 46 boys and 56 girls. Of the 26 pupils in the High I.Q. group in School A only 9 were boys. This difference is not statistically significant, even at a 15% level, but it is bound to have a bearing on the pattern if not the level of the results, and on the emphasis of the teaching methods employed.

It appeared that in School A, girls' g + v:ed ability is orientated towards their verbal facility and liking for reading, while in School C the emphasis on mathematics, results in boys rather than girls having both the higher attainment and better attitude to mathematics.

The conclusions regarding the hypotheses are summarised as follows:

1. Children in School C will show a more favourable attitude to mathematics than children in Schools A and B.

   Rejected: School C had the least favourable attitude to Mathematics

2. Scores on the Creativity tests will be higher from School C than from the control schools.

   The conclusions regarding this hypothesis were divided:

   (a) Confirmed in the case of the Circles Test: School C superior at a very significant level.

(b) Rejected in the cases of the other four Tests: School C was less successful than School A on six out of eight of the scores on these tests and not significantly better on the other two.

3. The performance of children in School C on the N.F.E.R. Intermediate Mathematics test, which stresses understanding and excludes routine calculation, will be greater than in Schools A and B.

   Rejected: Both School A and School B have a better performance than School C, the former beyond the .01 level of significance.

4. The scores on tests designed to assess flexible and logical thinking in mathematics will be higher from children in School C than from those in Schools A and B.

   Rejected: Of the three tests covered by this hypothesis, School C had the lowest level of attainment in two of them, significantly so in the Series Test, but was just superior, though not significantly on the Easy Problems Test.

5. The attainment of children in School C on the tests of Mathematical Concepts will be greater than that of children in the other two schools.

   Rejected: School C has the lowest performance in both Concept A and the Mensuration Concept, the former being particularly significant.

6. Performance on the N.F.E.R. test of "Arithmetic Progress" which involves mechanical and problem arithmetic will not differ significantly between the experimental and the other two schools.

   Rejected: Schools A and B are very significantly superior to School C in each section of this test.

TABLE 22

Order of Precedence of Schools A, B and C on each of the 31 Variables

			1st	2nd	3rd
I.Q. 1		1	C	B	A
I.Q. 2		2	C	A	B
Intermediate Mathematics	(Raw Score	3	A	B	C
	(Standard Score	4	A	B	C
Arithmetic Progress	(Mechanical	5	A	B	C
	(Problem	6	B	A	C
	(Standard Score	7	A	B	C
Arithmetic Concept A	(Raw Score	8	B	A	C
	(Standard Score	9	B	A	C
Mensuration Concept		10	B	A	C
Series Completion		11	B	A	C
Filling Spaces		12	A	B	C
Easy Problems		13	C	B	A
Circles	(Fluency	14	C	A	B
	(Flexibility	15	C	A	B
	(Originality	16	C	A	B
Uses	(Fluency	17	A	C	B
	(Flexibility	18	A	C	B
	(Originality	19	A	C	B
Consequences	(Fluency	20	C	A	B
	(Originality	21	C	A	B
Pattern Meanings	(Fluency	22	A	B	C
	(Originality	23	A	C	B
Make-Up Problems		24	A	C	B
Attitudes	(Reading	25	B	A	C
	(Mathematics	26	B	A	C
	(Writing Stories	27	B	C	A
	(Art	28	B	C	A
	(P.E.	29	A	C	B
	(Summed Score	30	B	A	C
Sex		31	B	C	A

A summary of the order of precedence of Schools A, B and C in each of the tests is compiled in the above table (TABLE 22). The mean levels of performance in each school and the significance of their differences were shown in TABLE 20.

DISCUSSION

It is clear from these tables that School C's commitment to the discovery approach does not lead to any general superiority over the two control schools in the items tested, in spite of its role as a pilot school in a large project and the extensive support it has received in utilising the method. There are some indications, however, particularly in the results of the Circles Test, which suggest that School C is superior in some aspects of creative thinking and that further testing in this area might reveal important developments in the children's thinking.

While, in general, the evidence of the present study indicates that teachers should view experimental approaches to mathematics teaching with some reservations, it must be emphasised once again that there are effects of the discovery approach which could not possibly be included in a study of this size. However, there are certain objectives that must be shared by all approaches to Primary School mathematics teaching, and method effects can be compared on such common objectives whatever their other aims or successes might be.

In particular, School C as pilot member of the Nuffield Foundation Primary School Mathematics Project, has adopted the discovery approach as a direct attempt to further the mathematical, logical and creative thinking abilities of the children as well as their attitude to mathematics. In addition as Matthews (1967) points out "Children of course still need certain routine skills".

The results of this study showed some signs that children's creative thinking is fostered by a discovery approach, but the mathematical attainment resulting from such an approach, is markedly lower than in the more traditional schools both in understanding and computation.

It appears that some of the fears that a discovery approach might lead to a lowering of mathematical standards are not without some foundation. Dearden (1968) has suggested that the reaction from the elementary school tradition is in danger of being altogether too indiscriminating, and as the recent Black Papers on Education (Cox and Dyson (Ed. 1969)) exemplify, there is considerable disquiet about the results of the 'progressive' movement in education which in some ways the results of the present study must support.

In mechanical and problem arithmetic both control schools are very superior to School C, though this is not entirely surprising in view of the greater attention they pay to mastery of routine skills, and the fact that teaching in School C deliberately avoids problems involving computation in complicated mensuration systems which will disappear with metrication.

Although School C is also well below the national average on the Arithmetic Progress test, it is not significantly lower than average in the Concept 'A' Test. It is however much lower than Schools A and B, and considering its above average I.Q. level, its pupils are obviously not achieving their full potential on this type of Arithmetical understanding. Though he recommends that Primary mathematics be taught in a non-authoritarian, "mutually creative" learning situation, Dienes (1960) stresses the necessity for adequate practice for the fixing and application of concepts that have been formed, and it might be suggested that while a discovery approach might bring children to the level of a new concept it does not provide sufficient reinforcement for it to be readily applied.

It is interesting to note that School B is also significantly better than School A on this Concept test and that School B is the most traditional of the three schools. This is the only test in the whole battery however on which School B is significantly better than School A.

Of the other commercial tests used, the recently published N.F.E.R. Intermediate Mathematics Test was thought to do justice to School C as it is specially designed in a non-tradional form to stress understanding and avoid routine calculation. School C, however, has the lowest performance of the three schools, though only School A is significantly better, at a 1% level. School C is not far below the national average but its failure to achieve a very good result on this test, considering its apparently suitable nature, indicates a very important shortcoming in the mathematical performance resulting from a discovery approach.

At the same time it is slightly encouraging for the protagonists of the discovery approach to see that School C's performance improved as the tests began to emphasise the less routine and the more productive aspects of mathematics. Its performance on the Series Test is still significantly lower than School B and School C, at 5% and 7% levels respectively, but it is not significantly worse on the Filling Spaces Test and it is in the first position, though not significantly so, on the Easy Problems Test.

The latter test was noted by the factor analysis to reflect a wider range of abilities than the other mathematical thinking tests and it was the academic test nearest to the creative pole on a number of factors. Though the performance of School C is not significantly better on this test, its position, in view of its poor performance on the more routine tests, is perhaps educationally significant. It is the only mathematics test on which School C attains the first position and, the test having been designed to emphasise flexibility in thinking, the results suggest that such tests might be profitably used in further investigations of the effects of the discovery approach on creative thinking. This test was devised with reference to Wertheimer's concept of productive thinking (1961).

In retrospect, it seems possible that more tests such as the latter, or others related to experimental situations and requiring more communication of mathematical generalities, might have done more justice to the beneficial effects of the discovery approach. However, as Williams (1966) points out, there are some accomplishments that we demand of the pupil whether or not such an approach specifically aims to produce them, and a good proportion of the present battery was in fact orientated towards the discovery approach.

Before proceeding to the results of the tests more specifically designed to assess creative thinking, it is appropriate to conclude the discussion of the more mathematical effects of the discovery approach with the surprising result of the attitude scale. Contrary to the widespread opinion that whatever the other effects of a discovery approach, the children would very likely enjoy it more, it appears that this is not the case. In fact it is the school most traditional in its approach that has the best attitude to mathematics and School C the worst. Although it might be an outmoded belief, it appears that children may well appreciate routine success and computational satisfaction.

It is not unusual to find mathematics the least highly regarded of Junior School Activities as Sharples (1969) found in his survey. In his study an emphasis on mathematics in the curriculum of one school did however coincide with mathematics being more highly favoured in that school than in the others. This is not the case in the present experiment, and it might be worth remembering that the attitude questionnaire was given before any of the other tests and could not therefore reflect any disillusionment of the children by the type of tests later employed.

The hypothesis suggesting that children from School C would achieve higher scores on the Creativity Tests than those from the control schools was confirmed only in the case of the Circles Test. It must be made clear however that the rejection of the hypothesis for the other four Creativity tests does not necessarily imply that School C was significantly worse than the other two schools but only that it was not significantly better. In fact School C was only significantly bettered in the Creativity Tests by School A and then only at a 10% level. Tables 20 and 22 show the relative levels and positions of the schools and it can be seen that between them Schools A and C occupy all the first positions, with School B consistently last except when it just surpasses School C on the fluency score in the test of Pattern Meanings.

Three features of these results are noteworthy:

1. The performance of School C on the figural Circles Test is very significantly higher than either of the other two schools.
2. Scores on three out of the other four tests of creativity, all involving verbal answers, are greater from School A then from the other two schools, and School A is not significantly bettered on the fourth test.

3. The performance of School B, the most traditional in its approach to mathematics teaching, is significantly below that of A or C on all but one of the eleven creativity test scores.

The first result is significant for it is the only occasion in the creativity section in which one of the schools has a very significantly better performance than both the others; and it provides the first real evidence that the thinking of children from School C is in some aspect, superior to that in the other schools. It would be wrong to give too much weight to this one test but it has stood out in the factor analysis as being in some ways the most distinctive creativity test - having in several cases the lowest correlation with intelligence and the highest loadings on a creativity factor. It has also figured predominantly in opposition to the test of Arithmetic Progress and was interpreted earlier as reflecting a non-verbal ability to think flexibly and imaginatively in contrast to routine numerical calculation.

The same test, adapted from Torrance (1962), was used by Haddon and Lytton (1968) in their evaluation of the effects of differing teaching approaches on divergent thinking abilities and it again featured, with other non-verbal tests, in showing the most significant differences, in favour of the progressive schools where the emphasis was on self-initiated learning and creative activities. Haddon and Lytton put forward two suggestions to explain the predominance of the non-verbal tests; that the effect of creative activity would be shown to a maximum on tests where no child is handicapped by having to respond in writing, and that a non-verbal medium encourages responses from boys who are less able or willing than girls to express themselves in writing.

The factor analysis of the present study is able to provide some evidence in support of these suggestions for in all three schools this is the test on which boys perform best. In Schools B and C this reaches significance at levels of 5% and 8% respectively and in School A it is one of the few tests on which girls are not significantly superior to boys.

The effects of sex differences in the three schools was discussed earlier. School A had a large proportion of girls in its High I.Q. group and a predominantly girl dominated pattern throughout the results. Girls performed better than boys in all twenty-four tests, significantly so at a 5% level in sixteen of them. The verbal influence was marked by a large g + v:ed factor and by less fragmentation of factors than in Schools B and C.

Though School B has the largest proportion of boys the male influence was less marked than in School C where boys were superior, though not significantly so, on most of the tests. The latter result, however, is against the trend in Schools A and B and might be a consequence of the discovery approach and the practical experimental work involved. If so it might be a possible means of fostering boys' abilities and interests, though it might have the opposite effect on girls. In this respect it is interesting to note that whereas in Schools A and B the correlations showed that girls tended to regard mathematics more highly than did boys, the contrary is true in School C, significantly so at 1% level.

School A's superiority on three out of the four verbal Creativity Tests must reflect to some extent the bias of that School's population towards girls' verbal ability, but it must also be remembered that intelligence was controlled in the initial selection of the Schools, that Verbal Reasoning tests were used, and that School C had the highest level.

The Circles Test remains the only Creativity Test on which one School achieved a highly significant superiority over the other two Schools and on this basis there is some evidence, supported to some extent by the result of the 'Easy Problems' test of productive thinking, that School C has developed a certain type of creative thinking to a greater extent that the two control schools. In view of the poor performance of School C on the other tests, however, this result must be seen in perspective and the main implication of School C's performance must remain one of caution, and the possible advantages of the discovery approach weighed carefully against its limitations.

The effects of the discovery approach will always be proportional to the enthusiasm and commitment of the teachers and the amount of material support given to a school. In the present study, School C was sustained by a high degree of support, both teachers and materials being well prepared. In view of this, one must be apprehensive of the wholesale adoption of discovery methods by schools less well prepared. As Brownell (1964) observed in his comparison of structural versus conventional methods of teaching arithmetic, the poor performance of the newer, structurally orientated, approaches in a group of English schools, very likely stemmed from the fact that the method was adopted by very many teachers more to be in the swim than out of any real convictions about its effectiveness. In a number of Scottish schools, however, he found that a very enthusiastic and capable band of teachers were instrumental in developing structural methods to the extent that they surpassed the conventional approaches.

Biggs (1967) in his study of mathematics in the Primary School found that the use of activity methods in the Junior School seemed clearly to produce inferior mechanical and problem results. The evidence of the present study agrees with this, and it also indicates that Biggs' suggestion that such methods might, however, have positive effects on productive and original aspects of children's thinking is not without some foundation.

As Torrance (1964) points out "we need to determine which kinds of information can be learned more economically by authority and which by creative means", and the three features noted above, together with the results of the mathematical section of the testing battery, suggest some relative merits of such teaching approaches. It appears that a compromise is likely to be the best policy.

Considering the results as a whole, School B, which has the most traditional of the approaches to mathematics teaching, often had the highest level of attainment on the mathematics tests in spite of its slightly lower level of I.Q. than the other two schools. On the creativity tests however it has the lowest score in ten of the eleven measures, in each case significantly lower than School A or School C. The pattern of its results strongly suggests that while children taught by more traditional methods can attain very good arithmetical results, both in achievement and understanding, they are not likely to make such a good response to unfamiliar test situations requiring that they use their knowledge and imagination to think creatively.

Previous studies, discussed earlier, have often focussed on the similar issue of rigidity or 'set' in problem solving, and Luchins (1942) found that the tendency to cling to once successful methods persisted more in children from formal schools than those from an informal, activity based, progressive school. Kellmer-Pringle and McKenzie (1965) however confirmed this finding only among the lowest streams in contrasted schools. To compare performances among the lowest classes in the present schools might be a profitable extension of this study, though the coincidence of School B's relatively poor performance on the creativity tests and its more traditional approach already tends to support the belief that the more traditional approaches do not foster flexibility and imagination in children's responses.

In School C on the other hand the emphasis on the discovery approach, while resulting in a very high creativity score on the Circles Test, does not appear to have been effective in developing the ability to perform arithmetical skills, to grasp concepts, or to do well on mathematical questions designed to assess understanding and the newer approaches to mathematics.

School A suffers from neither of the marked disadvantages of Schools B and C and shares their good performances on the Mathematics and the Creativity Tests respectively. Consideration of Tables 20 and 22 emphasises the all-round performance of School A, and gives weight to its headmaster's policy of 'keeping a balance', and his general aim, of helping teachers to encourage the children to find interest in their work and discipline their own efforts. There was no special emphasis on mathematics in this school and only about one fifth of the time was given to 'new approaches'. As was noted in the description of School A its ethos however was by no means formal though there is still a good deal of computation and work on the four rules. The headmaster's biannual examinations include mental, mechanical and problem arithmetic and they demand a good knowledge of basic computational techniques.

Crutchfield (1964) has warned of the inhibiting effects on an individual's creative ability of the pressure to conform with the authoritarian views of his teacher, but he also warns of the other extreme of seeking difference for difference's sake, or as Brownell (ibid) put it 'to be in the swim'. Until further evidence of the effects of various teaching methods the answer appears to be in a judicious blend of approaches, and the performance of School A in the present study provides evidence for this belief.

It might be true that by allowing children to explore a wide range of experiences for themselves, and by encouraging them to discover relationships, and think mathematically in a wide range of situations, they will be experiencing the kind of activity and enjoyment which will prepare them to think more creatively in the future. On the other hand there is the danger that unless he is firmly guided, the child will spend his time without developing any of the theoretical concepts or experiencing the computational practice which, as Bruner (1960) points out, may be a necessary step towards understanding conceptual ideas.

It is only speculative to suggest that children from School C, given a short course in computational techniques, might attain an equal level with Schools A and B; or that School B, given a short period of 'teaching for creativity', where pupils would be encouraged to contribute a free response of their own ideas, might improve greatly on creativity tests. Even a relaxation of time limit in the tests might have given a different view of the situation. The tests of creativity having a marked speed element effectively penalise those qualities of care and neatness which a traditional school might rightly emphasise, and those arithmetic tests with a time limit left little scope for children to follow more individual methods of computation. The effects of a withdrawal of time limit on such tests has not yet been studied sufficiently.

To summarise finally, the results of the last section showed that the ability to perform well on creativity tests is not entirely dependent on intelligence, even over a complete I.Q. range, and furthermore, given a minimum I.Q. of 115, the analysis revealed that the creativity dimension and that located by the academic tests were relatively independent. At the same time there was evidence that the ability to perform well on creativity tests while consistently loading a creativity factor, is not entirely confined to that factor, and in particular the completely figural Circles Test, while sharing a good deal of communality with the other creativity tests, was less related to the academic factor than the verbal tests of the creativity battery.

Having established this basis, it was particularly interesting to find that School C, reflecting the effects of the discovery approach, was very significantly better on the Circles Test than the other two Schools, though its superiority was not maintained on the verbal creativity tests nor on those of arithmetical ability and mathematical understanding. The superiority of School C on the Circles Test however when coupled with School B's relatively poor performance throughout the creativity battery appears to reflect the dichotomy in their approaches to mathematics teaching, School B being the most formal of the three schools. The difference in approach was also evident in the more mathematically orientated tasks, but here School B had a very much better performance than School C. In addition to this, and contrary to expectation, it was surprising to find that School B had the best attitude to mathematics and School C the worst. School A was notable in achieving a consistently good performance in all sections of the testing battery, surpassing School B on some of the mathematical tests and School C in sections of the creativity battery. Its performance gave weight to its headmaster's policy of 'Keeping a balance'.

Although the initiators of new methods might need to be wholly committed if their approaches are to achieve their full potential, the present study supports the view that teachers should be aware of the possible limitations of such methods, and appraise the relative values of approaches they adopt.

TABLE 13

INTERCORRELATION TABLE FOR ALL VARIABLES: SCHOOL A (N = 102)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I.Q.1	1	1	94	88	88	82	79	81	75	75	72	71	74	74	48	57	40	58	62	61	62	50	54	57	77	35	09	-14	-40	05	-09	-22
I.Q.2	2		1	87	86	86	81	84	74	75	71	71	72	71	55	64	45	61	65	63	66	50	54	58	79	44	08	-10	-38	09	-01	-30
Intermediate Mathematics (Raw Score	3			1	98	85	86	88	80	77	75	81	73	75	54	59	40	57	62	60	62	48	51	57	77	40	15	-16	-30	17	05	-27
(Standard Score	4				1	86	86	89	78	77	75	81	75	75	55	59	40	56	61	59	61	48	51	56	75	39	14	-17	-31	19	03	-26
Arithmetic Progress (Mechanical	5					1	89	95	67	69	70	73	78	70	56	60	36	64	68	65	63	45	49	54	74	41	17	-09	-39	16	06	-29
(Problem	6						1	96	73	72	70	77	76	68	51	56	36	60	63	59	61	45	49	52	72	41	14	-10	-28	29	15	-30
(Standard Score	7							1	71	71	71	77	79	71	53	57	34	62	65	62	62	44	48	51	72	42	17	-10	-35	25	12	-32
Arithmetic Concept A (Raw Score	8								1	96	68	70	60	66	41	46	35	46	49	47	54	43	38	41	62	34	17	-10	-15	19	14	-23
(Standard Score	9									1	66	69	63	66	43	47	36	46	48	46	51	40	37	39	62	32	16	-07	-11	17	15	-24
Mensuration Concept	10										1	69	64	63	37	49	29	46	49	44	57	47	35	39	61	34	08	-03	-17	26	17	-24
Series Completion	11											1	68	69	47	48	31	54	58	50	52	41	42	42	63	40	23	-12	-17	12	16	-20
Filling Spaces	12												1	72	42	46	26	52	53	48	56	47	37	39	58	31	08	-02	-33	16	05	-15
Easy Problems	13													1	43	45	25	46	47	47	54	43	37	43	56	28	08	-03	-30	14	03	-17
Circles (Fluency	14														1	86	63	72	72	67	61	51	61	68	61	41	-07	04	-00	10	21	-22
(Flexibility	15															1	79	74	77	75	68	56	65	71	67	39	-04	-02	-08	13	14	-18
(Originality	16																1	54	55	52	47	44	50	55	51	29	-05	-05	-09	04	05	-03
Uses (Fluency	17																	1	97	86	69	55	68	72	61	40	07	05	-08	10	20	-27
(Flexibility	18																		1	86	70	53	69	73	65	39	05	03	-10	11	18	-28
(Originality	19																			1	62	50	66	75	60	32	05	-07	-13	09	09	-19
Consequences (Fluency	20																				1	83	53	60	61	42	03	08	-20	17	19	-22
(Originality	21																					1	44	54	54	31	10	10	-18	10	16	-13
Patterns (Fluency	22																						1	92	54	34	01	-07	-07	01	06	-18
(Originality	23																							1	62	35	-04	-02	-12	02	06	-18
Make-Up Problems	24																								1	42	02	-10	-28	09	02	-25
Attitudes (Attitudes	25																									1	04	04	-18	-04	37	-27
(Mathematics	26																										1	-22	-16	-05	24	-14
(Writing	27																											1	19	-07	51	-12
(Art	28																												1	21	54	14
(P.E.	29																													1	43	-04
(Summed Score	30																														1	-18
Sex	31																															1

For 100 d.f. values of r of 0.20 and 0.25 are significant at the .05 and .01 levels respectively. Decimal points are omitted in the table.

TABLE 14

FACTOR ANALYSIS: SCHOOL A (31 variables, 102 cases)

			Principal Components Analysis					Varimax Analysis				
			I	II	III	IV	V	I	II	III	IV	V
I.Q.1		1	89	-25	-15	02	-09	83	38	-20	04	01
I.Q.2		2	91	-18	-09	-03	-09	81	43	-17	-04	05
Intermediate	(Raw Score	3	91	-26	01	06	02	87	36	-03	05	10
Mathematics	(Standard Score	4	91	-27	-00	08	01	88	36	-04	06	09
Arithmetic Progress	(Mechanical	5	90	-21	-01	-07	01	81	39	-10	-04	16
	(Problem	6	88	-23	12	03	03	84	35	05	-02	15
	(Standard Score	7	90	-25	08	-03	04	85	34	-01	-03	19
Arithmetic	(Raw Score	8	78	-29	18	13	02	82	22	14	02	09
Concept A	(Standard Score	9	78	-29	19	13	00	82	22	15	00	08
Mensuration Concept		10	76	-25	21	08	-12	79	21	11	-11	01
Series Completion		11	80	-25	14	01	10	78	28	07	-00	21
Filling Spaces		12	77	-28	05	01	-18	80	22	-07	-10	02
Easy Problems		13	75	-29	04	05	-17	79	21	-06	-07	-04
Circles	(Fluency	14	71	48	-03	05	-00	29	80	09	-12	-02
	(Flexibility	15	78	45	-11	13	02	34	84	07	-03	-06
	(Originality	16	56	45	-21	17	03	17	73	02	07	-12
Uses	(Fluency	17	78	43	-03	-08	12	34	81	04	-13	16
	(Flexibility	18	81	40	-04	-06	11	38	81	03	-11	14
	(Originality	19	77	36	-15	03	15	36	79	-00	04	10
Consequences	(Fluency	20	78	23	04	-07	-16	50	61	-01	-27	-01
	(Originality	21	64	25	02	-08	-17	37	54	-03	-26	-03
Pattern	(Fluency	22	67	42	-22	01	16	23	80	-04	06	09
Meanings	(Originality	23	72	45	-23	02	07	27	84	-07	00	01
Make-up Problems		24	83	01	-12	01	-07	64	53	-11	-03	00
Attitudes	(Reading	25	49	14	15	-42	-03	29	34	-09	-40	30
	(Mathematics	26	12	-26	15	-38	72	11	-08	03	18	84
	(Writing Stories	27	-07	32	48	-33	-60	-12	-02	13	-86	-19
	(Art	28	-28	41	57	39	12	-35	02	77	-08	-10
	(P.E.	29	18	-03	54	51	14	27	-01	72	11	-07
	(Summed Score	30	13	32	89	-12	12	02	10	73	-54	33
Sex		31	-31	01	-20	56	-09	-20	-12	13	39	-48
Percentage of Total variance			50.7	9.4	6.8	4.2	3.8	Total variance 74.9%				

Total variance extracted, 74.9%

TABLE 15

Intercorrelation Table for all Variables: School B (N = 71)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I.Q.1	1	1	94	81	83	76	79	81	71	74	69	72	73	61	−12	−12	−19	22	39	39	14	14	17	27	49	26	−06	−15	−14	−06	−07	−02
I.Q.2	2		1	82	84	75	81	82	74	77	67	72	74	59	−17	−18	−27	18	35	32	06	07	13	24	53	24	03	−14	−14	−06	−03	−06
Intermediate Mathematics (Raw Score	3			1	98	79	89	88	83	84	73	75	77	73	−06	−01	−05	27	43	34	23	19	17	22	59	19	05	−13	−24	−01	−05	−15
(Standard Score	4				1	74	85	85	84	86	71	75	75	70	−10	−06	−08	25	40	32	21	20	14	20	58	22	06	−15	−22	−05	−05	−11
Arithmetic Progress (Mechanical	5					1	86	95	64	66	67	66	84	65	−21	−13	−12	12	31	23	12	04	19	25	50	23	08	−16	−24	02	−02	−23
(Problem	6						1	96	74	74	76	83	80	69	−08	−06	−12	24	38	28	15	07	19	25	54	22	07	−22	−16	00	−03	−10
(Standard Score	7							1	74	75	75	79	84	68	−16	−12	−14	19	34	26	14	06	18	25	53	22	09	−22	−21	−01	−04	−15
Arithmetic Concept A (Raw Score	8								1	96	70	72	62	65	02	−02	−13	28	36	34	19	14	12	20	51	04	17	−06	−15	−01	02	−07
(Standard Score	9									1	70	70	67	65	−00	−05	−12	28	41	35	18	14	16	24	52	12	13	−06	−19	−05	−01	−07
Mensuration Concept	10										1	70	66	53	05	10	−03	31	43	41	20	11	25	35	50	02	00	−14	−19	−10	−19	−13
Series Completion	11											1	63	53	−06	−06	−17	26	31	27	16	08	22	28	52	21	05	−17	−11	03	01	−06
Filling Spaces	12												1	66	−11	−09	−06	20	38	30	05	−01	25	30	51	18	−02	−09	−20	−02	−07	−16
Easy Problems	13													1	−00	12	10	32	38	32	26	19	20	21	41	07	12	−17	−05	−02	−01	−27
Circles (Fluency	14														1	83	62	45	31	27	31	28	29	24	−01	−17	04	05	16	−13	−03	23
(Flexibility	15															1	77	37	23	19	33	34	26	25	−03	−14	10	05	19	−11	04	02
(Originality	16																1	27	14	16	31	34	20	14	−00	−02	02	12	20	−08	11	04
Uses (Fluency	17																	1	87	70	54	46	51	48	22	−10	−04	−07	−01	−21	−22	−12
(Flexibility	18																		1	70	49	40	50	50	34	−04	−12	−05	−05	−19	−24	−15
(Originality	19																			1	28	30	34	36	23	00	−16	−01	−04	−27	−25	−03
Consequences (Fluency	20																				1	75	43	41	28	10	−02	−09	02	−23	−12	−04
(Originality	21																					1	26	27	16	−00	−00	−10	−02	−17	−15	−12
Patterns (Fluency	22																						1	86	34	07	02	10	14	−08	12	−13
(Originality	23																							1	32	01	01	05	22	−11	07	06
Make-Up Problems	24																								1	34	−00	08	−19	−15	03	−29
Attitudes (Reading	25																									1	−28	14	−23	−08	22	12
(Mathematics	26																										1	−02	13	−04	47	−07
(Writing	27																											1	−04	−12	44	−10
(Art	28																												1	08	44	33
(P.E.	29																													1	43	01
(Summed Score	30																														1	12
Sex	31																															1

For 69 d.f. values of r of 0.23 and 0.30 are significant at the .05 and .01 levels respectively. Decimal points are omitted in the table.

TABLE 16 (a)

FACTOR ANALYSIS: SCHOOL B (31 variables, 71 cases)

Principal Components Analysis

		I	II	III	IV	V	VI	VII	VIII
I.Q.1	1	87	−16	−02	00	−07	20	−01	06
I.Q.2	2	87	−24	02	01	−08	13	03	11
Intermediate (Raw Score	3	94	−11	04	−10	12	01	−03	01
Mathematics (Standard Score	4	92	−14	03	−10	11	04	−05	09
Arithmetic Progress (Mechanical	5	85	−24	05	03	04	−08	−05	−20
(Problem	6	92	−17	08	−09	−01	05	−04	−11
(Standard Score	7	92	−23	06	−06	00	−00	−06	−11
Arithmetic (Raw Score	8	85	−09	13	−18	03	−05	10	24
Concept A (Standard Score	9	87	−09	09	−12	04	−01	10	22
Mensuration Concept	10	82	03	−04	−12	−04	−00	16	−08
Series Completion	11	82	−13	10	−02	−08	09	−06	−00
Filling Spaces	12	83	−15	03	04	−02	01	13	−23
Easy Problems	13	75	04	11	−17	10	−18	−05	10
Circles (Fluency	14	−02	75	20	−33	14	21	22	−08
(Flexibility	15	−01	74	29	−34	30	06	13	−22
(Originality	16	−07	65	29	−22	42	10	04	−27
Uses (Fluency	17	41	73	−21	02	−19	−08	09	06
(Flexibility	18	55	59	−25	11	−22	−05	12	03
(Originality	19	46	49	−29	04	−18	12	31	12
Consequences (Fluency	20	30	64	−11	09	14	−03	−53	19
(Originality	21	22	60	−15	−04	22	−11	−53	21
Pattern (Fluency	22	33	57	20	50	−28	−10	−04	−17
Meanings (Originality	23	39	53	19	42	−40	−04	−04	−11
Make-Up Problems	24	65	04	03	36	25	−06	−03	02
Attitudes (Reading	25	21	−17	03	52	42	53	−21	−02
(Mathematics	26	04	−03	53	−24	−01	−52	−02	42
(Writing Stories	27	−15	07	29	52	35	−03	50	21
(Art	28	−21	23	55	−10	−47	18	−13	10
(P.E.	29	−09	−28	38	−07	−19	−06	−22	−50
(Summed Score	30	−09	−11	90	26	04	−02	−04	−12
Sex	31	−18	01	21	−24	−25	77	−06	26
Percentage of Total Variance		36.8	14.5	7.2	5.6	4.7	4.5	3.9	3.5

Total variance extracted, 80.7%

TABLE 16 (b)

FACTOR ANALYSIS: SCHOOL B (31 variables, 71 cases)

Varimax Analysis

			I	II	III	IV	V	VI	VII	VIII
I.Q.1		1	87	−13	−10	11	−12	12	−03	08
I.Q.2		2	89	−19	−02	08	−08	09	01	10
Intermediate	(Raw Score	3	94	03	−01	05	−04	−08	−12	05
Mathematics	(Standard Score	4	93	−03	01	06	−00	−03	−14	09
Arithmetic Progress	(Mechanical	5	86	−09	−04	08	−09	−19	00	−17
	(Problem	6	94	−02	−06	03	−09	−01	−03	−09
	(Standard Score	7	94	−08	−05	04	−07	−08	−06	−11
Arithmetic	(Raw Score	8	87	01	16	−11	−01	03	−05	21
Concept A	(Standard Score	9	88	−01	12	−04	−05	01	03	22
Mensuration Concept		10	79	09	−13	−09	−19	−07	−05	10
Series Completion		11	82	−07	00	05	−14	08	14	−04
Filling Spaces		12	83	−00	−11	08	−18	−14	−16	−08
Easy Problems		13	74	16	04	−11	−09	−18	−16	−07
Circles	(Fluency	14	−08	83	−02	−11	−20	20	−08	17
	(Flexibility	15	−05	92	05	−09	−14	02	−14	01
	(Originality	16	−11	88	05	09	−07	−04	−17	−06
Uses	(Fluency	17	21	30	−19	−22	−62	−03	−28	35
	(Flexibility	18	36	17	−23	−14	−63	−06	−21	34
	(Originality	19	31	19	−28	−11	−48	07	−03	49
Consequences	(Fluency	20	11	21	−02	10	−33	−01	−82	13
	(Originality	21	06	23	−03	00	−17	−07	−83	15
Pattern	(Fluency	22	11	13	11	12	−87	−08	−14	−07
Meanings	(Originality	23	20	08	09	04	−86	05	−12	−05
Make-up Problems		24	56	−02	10	35	−23	−28	−15	12
Attitudes	(Reading	25	19	−09	−05	88	05	08	−09	−01
	(Mathematics	26	10	01	76	−42	12	−05	−11	02
	(Writing Stories	27	−19	12	47	45	−13	−23	36	39
	(Art	28	−19	11	35	−18	−28	58	−00	−25
	(P.E.	29	01	−02	09	−05	02	03	18	−73
	(Summed Score	30	−02	06	83	26	−08	17	15	−30
Sex		31	−09	08	−04	13	13	90	06	05

Total variance extracted, 80.7%

TABLE 17

INTERCORRELATION TABLE FOR ALL VARIABLES: SCHOOL C (n = 92)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I.Q.1	1	1	93	86	85	61	79	79	76	76	65	72	55	71	18	30	27	32	45	39	44	35	22	24	48	-00	15	01	-09	04	05	10
I.Q.2	2		1	91	90	69	79	83	77	77	66	75	59	72	16	28	26	31	43	33	45	34	20	23	51	-00	12	-02	-04	04	05	05
Intermediate (Raw Score	3			1	98	69	78	81	74	74	66	75	60	69	13	31	28	31	43	33	45	36	21	25	49	07	08	-01	-06	00	04	02
Mathematics (Standard Score	4				1	67	75	81	72	73	64	69	58	65	09	28	25	26	38	28	41	32	17	20	44	06	08	-03	-05	00	03	02
Arithmetic Progress (Mechanical	5					1	71	83	51	50	68	62	45	65	13	20	22	27	33	21	37	35	12	13	40	15	28	05	07	-02	28	06
(Problem	6						1	94	71	70	67	71	51	73	09	22	19	31	39	33	39	35	21	22	42	04	21	00	-12	02	08	13
(Standard Score	7							1	72	71	70	73	55	75	10	21	20	30	39	30	39	33	18	18	40	07	22	-05	-04	02	11	12
Arithmetic (Raw Score	8								1	98	61	66	42	63	20	35	32	42	50	40	44	31	24	25	45	-06	12	-09	05	07	05	10
Concept A (Standard Score	9									1	61	62	39	61	16	31	31	40	48	39	39	28	20	22	43	-05	11	-11	06	07	05	09
Mensuration Concept	10										1	63	30	55	12	26	32	27	36	27	34	30	19	20	34	09	26	11	08	-07	27	01
Series Completion	11											1	46	65	09	21	17	34	44	35	47	36	25	28	50	-03	15	-03	02	06	09	07
Filling Spaces	12												1	50	46	50	28	27	33	23	32	24	31	28	27	17	-02	09	-11	07	07	07
Easy Problems	13													1	18	26	20	28	39	31	43	31	24	22	47	01	15	08	-04	04	13	05
Circles (Fluency	14														1	84	59	56	51	38	44	35	58	52	27	-03	15	12	11	13	26	05
(Flexibility	15															1	75	57	57	41	46	37	54	52	29	-06	-01	14	09	14	16	05
(Originality	16																1	46	49	37	37	36	37	31	16	-09	16	16	15	-02	23	19
Uses (Fluency	17																	1	95	85	62	44	68	63	43	03	09	11	-00	02	13	-01
(Flexibility	18																		1	88	68	49	71	67	46	03	07	07	03	01	11	-02
(Originality	19																			1	52	38	58	55	34	03	12	04	-09	-05	04	08
Consequences (Fluency	20																				1	77	62	59	58	-09	15	18	05	-08	15	-08
(Originality	21																					1	41	44	49	-09	20	19	01	-10	16	01
Patterns (Fluency	22																						1	91	30	-02	06	10	25	02	23	01
(Originality	23																							1	35	05	-03	15	21	02	22	-02
Make Up Problems	24																								1	06	13	17	-07	01	16	-16
Attitudes (Reading	25																									1	-02	16	-14	-14	35	-17
(Mathematics	26																										1	-11	-02	-11	46	28
(Writing	27																											1	-25	-13	37	-07
(Art	28																												1	11	43	02
(P.E.	29																													1	28	08
(Summed Score	30																														1	10
Sex	31																															1

For 90 d.f. values of r of 0.21 and 0.27 are significant at the .05 and.01 levels respectively.
Decimal points omitted in the table

f

TABLE 18 (a)

FACTOR ANALYSIS: SCHOOL C (31 variables, 92 cases)

Principal Components Analysis

			I	II	III	IV	V	VI	VII	VIII
I.Q.1		1	86	-32	-07	-05	-05	-04	00	04
I.Q.2		2	87	-36	-06	-04	-07	03	-05	-00
Intermediate	(Raw Score	3	86	-35	-08	01	-11	04	-03	-07
Mathematics	(Standard Score	4	83	-39	-07	-01	-13	05	-03	-10
Arithmetic Progress	(Mechanical	5	72	-32	28	16	03	-00	00	-09
	(Problem	6	82	-37	01	02	04	-06	07	08
	(Standard Score	7	84	-41	07	00	02	-02	08	-00
Arithmetic	(Raw Score	8	82	-21	-08	-23	05	05	04	-04
Concept A	(Standard Score	9	80	-25	-08	-24	06	07	05	-06
Mensuration Concept		10	72	-25	23	10	08	01	00	-23
Series Completion		11	78	-26	-02	-00	12	11	-04	10
Filling Spaces		12	62	-03	-00	-01	-55	-07	06	02
Easy Problems		13	76	-25	04	06	-04	01	-05	12
Circles	(Fluency	14	42	66	17	-17	-34	-15	-07	-02
	(Flexibility	15	54	56	06	23	-43	-15	-11	-12
	(Originality	16	47	44	22	-24	-21	-35	-12	-30
Uses	(Fluency	17	63	60	-19	02	14	-01	27	06
	(Flexibility	18	72	53	-22	00	15	03	24	02
	(Originality	19	59	46	-27	01	24	-11	39	08
Consequences	(Fluency	20	68	40	-12	19	22	02	-33	05
	(Originality	21	56	32	-01	22	25	-14	-44	06
Pattern	(Fluency	22	51	68	-03	-03	09	21	08	-02
Meanings	(Originality	23	51	64	-06	05	05	27	07	-01
Make-up Problems		24	61	09	-09	31	11	12	-26	24
Attitudes	(Reading	25	03	-04	21	59	-27	15	56	-15
	(Mathematics	26	20	-02	55	03	48	-41	09	07
	(Writing Stories	27	07	22	17	62	-29	-19	-22	15
	(Art	28	02	19	45	-37	20	57	-15	-37
	(P.E.	29	03	03	24	-41	-26	36	01	69
	(Summed Score	30	20	22	87	23	02	20	07	13
Sex		31	07	-04	31	-42	14	-51	19	21
Percentage of Total Variance			38.4	13.7	6.2	5.7	4.7	4.4	3.7	3.3.

Total variance extracted, 80.1%

TABLE 18 (b)

FACTOR ANALYSIS: SCHOOL C (31 variables, 92 cases)

Varimax Analysis

Variable	No.	I	II	III	IV	V	VI	VII	VIII
I.Q.1	1	89	16	-10	05	-11	-02	-05	03
I.Q.2	2	93	11	-04	07	-10	04	-04	02
Intermediate (Raw Score	3	92	12	-04	06	-12	09	01	-04
Mathematics (Standard Score	4	91	06	-02	03	-12	10	01	-05
Arithmetic Progress (Mechanical	5	77	02	13	18	-05	-19	20	-07
(Problem	6	88	14	-10	06	-00	-14	03	02
(Standard Score	7	92	09	-02	02	-02	-13	07	-00
Arithmetic (Raw Score	8	82	26	06	-09	-11	-03	-15	03
Concept A (Standard Score	9	82	23	06	-12	-08	-03	-15	01
Mensuration Concept	10	74	08	21	12	-09	-16	15	-19
Series Completion	11	80	22	04	13	06	-04	-07	07
Filling Spaces	12	56	09	-20	02	-50	16	20	16
Easy Problems	13	77	13	-05	18	-06	-05	02	10
Circles (Fluency	14	02	43	06	16	-75	-06	01	14
(Flexibility	15	18	40	04	09	-83	06	-05	08
(Originality	16	17	26	12	06	-77	-21	-08	-17
Uses (Fluency	17	20	89	-07	07	-21	-06	03	-01
(Flexibility	18	33	88	-03	06	-20	-01	01	-03
(Originality	19	24	86	-19	-06	-07	-14	02	-07
Consequences (Fluency	20	35	58	08	54	-15	02	-20	-10
(Originality	21	28	38	05	63	-15	-11	-24	-15
Pattern (Fluency	22	08	79	24	14	-28	05	02	07
Meanings (Originality	23	11	76	22	18	-23	14	07	07
Make-up Problems	24	46	35	-03	54	05	09	-04	08
Attitudes (Reading	25	04	05	-06	-03	07	09	89	-10
(Mathematics	26	14	04	12	16	06	-82	05	-12
(Writing Stories	27	-08	-03	-22	65	-22	03	36	-02
(Art	28	-03	06	93	-13	-08	01	-07	07
(P.E.	29	03	-01	09	-06	-05	-01	-07	94
(Summed Score	30	04	06	51	34	-13	-43	53	30
Sex	31	05	-04	-15	-24	-19	-69	-17	15

Total variance extracted, 80.1%

TABLE 20

Comparison of Mean Scores between the three Schools for all 31 variables

			Means		Standard Deviations			't' value of the difference of Means		
		School A (N = 102)	School B (N = 71)	School C (N = 92)	School A	School B	School C	Schools A and B	Schools B and C	Schools A and C
I.Q.1	1	101.46	101.62	104.14	12.77	12.61	11.67	0.08	1.31	1.52
I.Q.2	2	105.34	103.97	107.46	14.32	14.36	12.62	0.62	1.62	1.10
Intermediate (Raw Score	3	28.84	26.35	24.77	10.26	9.24	9.34	1.67	1.07	2.89
Mathematics (Standard Score	4	104.30	101.01	99.46	12.96	10.86	11.27	1.81	0.89	2.78
Arithmetic Progress (Mechanical	5	9.92	9.28	4.45	7.68	6.50	3.17	0.59	5.75	6.59
(Problem	6	13.12	13.28	7.78	7.05	6.59	4.75	0.15	5.91	6.21
(Standard Score	7	106.81	105.94	94.74	15.81	13.22	8.97	0.39	6.12	6.63
Arithmetic (Raw Score	8	10.72	11.93	9.64	3.46	3.10	3.40	2.37	4.49	2.16
Concept A (Standard Score	9	103.96	108.85	99.59	13.35	12.51	10.78	2.46	4.98	2.51
Mensuration Concept	10	3.85	4.28	3.51	2.50	2.95	3.08	1.00	1.64	0.85
Series Completion	11	6.60	6.83	5.83	2.87	2.66	2.86	0.53	2.33	1.88
Filling Spaces	12	6.06	5.17	5.16	4.86	4.79	4.02	1.20	0.01	1.41
Easy Problems	13	8.93	9.03	9.29	4.62	3.45	4.58	0.16	0.41	0.55
Circles (Fluency	14	19.27	18.80	26.24	7.64	7.19	9.22	0.41	5.81	5.71
(Flexibility	15	14.02	12.93	18.09	5.91	5.36	7.10	1.27	5.32	4.33
(Originality	16	6.88	4.99	11.74	6.39	6.30	8.87	1.93	5.67	4.34
Uses (Fluency	17	23.86	21.03	21.64	10.00	5.19	8.68	2.42	0.55	1.66
(Flexibility	18	19.82	17.08	18.03	8.38	4.68	6.57	2.74	1.08	1.66
(Originality	19	23.80	19.62	20.08	17.70	11.82	13.10	1.86	0.23	1.68
Consequences (Fluency	20	9.95	9.03	10.25	4.20	2.91	4.38	1.70	2.14	0.48
(Originality	21	7.12	6.61	8.11	4.54	3.52	5.14	0.84	2.21	1.41
Pattern (Fluency	22	16.84	15.90	15.82	6.16	5.55	6.87	1.06	0.08	1.10
Meanings (Originality	23	14.73	12.34	13.28	7.35	5.30	7.59	2.49	0.92	1.34
Make-up Problems	24	7.67	6.20	7.38	4.89	3.51	3.77	2.33	2.07	0.47
Attitudes (Reading	25	5.20	5.25	4.70	1.61	1.55	1.38	0.21	2.39	2.38
(Mathematics	26	4.25	4.45	4.01	1.51	1.95	1.98	0.71	1.42	0.92
(Writing Stories	27	4.79	5.15	5.10	1.78	1.58	1.91	1.38	0.19	1.15
(Art	28	5.65	6.01	5.70	1.79	1.50	1.99	1.44	1.15	0.19
(P.E.	29	6.90	6.42	6.75	1.38	1.73	1.38	2.00	1.32	0.75
(Summed Score	30	26.84	27.30	26.25	3.46	3.37	3.36	0.87	1.98	1.20
Sex	31	0.45	0.52	0.48	0.50	0.50	0.50	0.88	0.50	0.43

NOTE: With the minimum combined population giving 161 d.f., values of 't' of 1.98, 2.61, and 3.35 are significant at the .05, .01, and .001 levels respectively

REFERENCES

Anderson, H.H. (1959) Creativity in Perspective. In H.H. Anderson (Ed) Creativity and its Cultivation, N.Y. Harper and Row.

Association of Teachers of Mathematics (1966) The Development of Mathematical Activity in Children; the Place of the Problem in this Development A.T.M. Nelson, Lancashire.

Association of Teachers of Mathematics (1967) Notes on Mathematics in Primary Schools. Cambridge C.U.P.

Ausubel, D.P. (1966) In Defense of Verbal Learning. In Anderson R.C. and Ausubel D.P. (eds). Readings in the Psychology of Cognition N.Y. Holt, Rinehart and Winston. pp 87-102

Barron, F. (1958) The Psychology of Imagination. In, Scientific American September 1958. Off-print No.432.

" (1959) Current work at the Institute of Personality Assessment Research. In C.W. Taylor (Ed.) The Third (1959) University of Utah Research Conference on the Identification of Creative Scientific Talent. Salt Lake City, University of Utah Press. pp 72-76.

Bartlett F.C. (1958) Thinking: an Experimental and Social Study, London Allen and Unwin.

Borger R. and Seaborne, A.E.M. (1966) The Psychology of Learning. England. Penguin Books.

Brownell W.A. (1964) Arithmetical Abstractions: The movement toward conceptual maturity under different systems of instruction. Co-operative Research Project No.1676 U.S. Office of Education, Berkeley University of California Press.

Brownell W.A. and Hendrickson G. (1950). How children learn; information, concepts and generalisations. In Learning and Instruction 49th Yearbook - Nat. Soc. Study of Education, Part I, pp. 92-128.

Bruner J.S. (1957) On going beyond the information given. In Contemporary Approaches to Cognition. Cambridge, Mass: Harvard Univ. Press.

" (1960) The Process of Education. Cambridge, Mass: Harvard Univ. Press.

Bruner J.S. (1961) The Act of Discovery. Harvard Educ.Review 31,21-32

" (1962) The Conditions of Creativity. In Gruber, Terrell and Wertheimer (Eds.) Contemporary Approaches to Creative Thinking. N.Y. Atherton Press pp 1-30.

Buros O.K. (1965) (Ed.) 6th Mental Measurements Yearbook. New Jersey Gryphon pp 201-205.

Burt C. (1949) The Structure of the Mind: A Review of the Results of Factor Analysis. Brit. J. Educ. Psychol. pp 19, 100-111, 176-199.

" (1952) Tests of Significance in Factor Analysis. Brit. Journal Psych. (Statistical Section) pp 5, 109-133.

" (1962) The Psychology of Creative Ability: Critical notice of 'Creativity and Intelligence' by Getzels and Jackson. Brit. J. Educ. Psychol 32 pp 292-298.

Burton W.H. (1943) Is all learning creative? Childhood Education Vol.19, 245-252.

Butcher, H.J. (1969) The Structure of Abilities, Interests and Personality in 1,000 Scottish School Children. Brit J. Educ. Psychol. Vol.39, 154-165.

Cattell R.B. (1947) General Psychology. Cambridge Mass. Sci-Art Publishers.

" (1959) The personality and motivation of the researcher from measurements of contemporaries and from biography. In C.W. Taylor (Ed.) The Third Univ. of Utah Research Conference on the Identification of Creative Scientific Talent. Salt Lake City Univ. of Utah Press. pp 77-93.

Central Advisory Council for Education C.A.C.E. (1967) The Plowden Report; Children and their Primary Schools. London H.M.S.O.

Child D. (1968) A study of some aspects of divergent thinking and their relationship to arts or science preferences in average and above average secondary schoolchildren. Unpublished M.Ed. thesis Univ. of Leeds.

Churchill E.M. (1958) The Number Concepts of the Young Child. Leeds Univ. Institute of Education. Researches and Studies. Part I No.17, Part II No.18.

Churchill E.M. (1960) Piaget's Findings and the Teacher. National Froebel Foundation. London.

Cox C.B. and Dyson A.E. (1969) (Eds.) Black Papers I and II, London. The Critical Quarterly.

Cronbach L.J. (1965) Issues Current in Educational Psychology. Monogr. of Soc. for Research in Child Devel. Serial No.99 Vol 30 No.1, 109-126.

Cronbach L.J. (1968) Intelligence? Creativity? A Parsimonious Reinterpretation of the Wallach-Kogan Data. Amer. Educ. Research J. Vol 5, 4, 491-511.

Cropley A.J. (1967) Creativity. London, Longmans

" (1968) A Note on the Wallach-Kogan Tests of Creativity. Brit J. Educ. Psychol Vol.38, 197-201.

Crutchfield R.S. (1962) Conformity and Creative Thinking. In Gruber, Terrell and Wertheimer (Eds.) Contemporary Approaches to Creative Thinking. N.Y. Atherton Press.

Davis R.B. (1964) Discovery in Mathematics. A Text for Teachers. Madison Project. Palo Alto California. Addison-Wesley

Dearden R.F. (1968) The Philosophy of Primary Education: an Introduction. London, Routledge and Kegan Paul.

Dewey J. (1933) How we Think. Boston, Heath

Dienes Z.P. (1960) Building up Mathematics. London, Hutchinson

" (1964) The Power of Mathematics. London, Hutchinson

" (1966) Mathematics Teaching in the Primary School. International Study Group for Mathematics Learning. U.N.E.S.C.O. Institute for Education. Hamburg.

Dunker K. (1945) On Problem-Solving. Psychol. Monogr. No.270.

Edwards M.P. and Tyler L.E. (1965) Intelligence, creativity and achievement in a non-selective public junior High School. J. of Educ. Psychol. Vol. 56, 96-99.

Eysenck H.J. (1967) Intelligence assessment: A theoretical and experimental approach. Brit. J. Educ. Psychol. Vol.37, 81-98.

Eysenck H.J. and Cookson D. (1969) Personality in Primary School Children. I Ability and Achievement, II Teachers' Ratings Brit. J. Educ. Psychol. Vol. 39 109-130

Fee F. (1968) An Alternative to Ward's Factor Analysis of Wallach and Kogan's 'Creativity' Correlations. Brit J. Educ. Psychol. Vol.38, 319-321.

Fruchter B. (1954) Introduction to Factor Analysis. N.Y. Van Nostrand

Freeman J., Butcher H.J. and Christie T. Creativity: A selective Review of Research. London. Soc. for Research into Higher Education.

Freud, Sigmund (1949) The Unconscious. Collected Papers IV. London. Hogarth.

Galton, Francis (1869) Hereditary genius: an inquiry into its laws and consequences. N.Y. Macmillan. Chapter 3 is reprinted in Jenkins' J.J. and Patterson D.G. 'Studies in Individual Differences'. (1961) N.Y. Appleton Century-Crofts.

Getzels J.W. and Jackson P.W. (1962) Creativity and Intelligence. N.Y. Wiley.

Ghiselin B. (Ed.) (1952) The Creative Process: A symposium. Berkeley. California. Univ. of California Press.

Ginsburg G.P. and Whittemore R.G. (1968) Creativity and Verbal Ability: A direct examination of their relationship. Brit. J. Educ. Psychol. Vol. 38, 133-139.

Goldberg, Miriam L (1965) Research on the Talented. N.Y. Bureau of Publications. Teachers College. Columbia University.

Gruber H.E., Terrell G. and Wertheimer Michael (Eds) (1962) Contemporary Approaches to Creative Thinking. N.Y. Atherton Press.

Guilford J.P. (1950) Creativity. Amer. Psychologist. 5, 444-454.

" (1954) Psychometric Methods. N.Y. McGraw-Hill.

" (1956) The Structure of Intellect. Psychol. Bull. Vol 53, 4, 267-293.

" (1959a) Personality. N.Y. McGraw-Hill.

" (1959b) Three Faces of Intellect. Amer. Psychologist. Vol. 14, 8, 469-479.

Guilford J.P. (1965) Implications of Research on Creativity. In Banks C. and Broadhurst P.L. Studies in Psychology. London. Univ. of London Press. Pp 75-90.

" (1967a) The Nature of Human Intelligence. N.Y. McGraw-Hill.

" (1967b) Intellectual Factors in Productive Thinking In Mooney R.L. and Razik T. (Eds.) Explorations in CreativityN.Y. Harper and Row. pp 95-106.

Gutman H. (1967) The Biological Roots of Creativity. In Mooney R.L. and Razik T. (Eds) Explorations in Creativity. N.Y. Harper & Row. pp 3-32.

Hadamard, Jacques (1949) The Psychology of Invention in the Mathematical Field. Princeton. Princeton Univ. Press.

Haddon F.A. and Lytton H. (1968) Teaching approach and the development of divergent thinking abilities in primary schools. Brit. J. Educ. Psychol. Vol.38, 171-180.

Hargreaves H.L. (1927) The 'Faculty' of Imagination. Brit. J. Psychol. Monogr., Supplement No.10.

Harman H.H. (1960) Modern Factor Analysis. Chicago. Univ. of Chicago Press.

Hasan P. and Butcher H.J.(1966) Creativity and Intelligence. A partial replication with Scottish children of Getzels and Jackson's study. Brit. J. of Psychol. Vol.57, 129-135.

Hebb D.O. (1958) A textbook of Psychology. Philadelphia, Saunders.

Hudson L. (1966) Contrary Imaginations. London, Methuen

" (1968) Frames of Mind. London, Methuen.

Hunt J. McV. (1961) Intelligence and Experience. N.Y., The Ronald Press Co.

Kaiser H.F. (1958) The varimax criterion for analytic rotation in factor analysis. Psychometrika. 23, 187-200.

Karve B.D. (1929) An experimental investigation of 'Fluency' (of Imagination and Association) in school children. (unpublished) M.Ed. Thesis. Univ. of Leeds.

Kellmer Pringle M.L. and McKenzie J.R. Teaching Method and Rigidity in Problem Solving. Brit. J. Educ Psychol. 35, 50-59.

Kneller G.F. (1966) The Art and Science of Creativity. N.Y., Holt, Rinehart and Winston.

Koestler A (1964) The Act of Creation. London, Hutchinson.

Köhler W. (1957) The Mentality of Apes. England, Pelican Books.

Land F. (Ed) (1965) Aspects of Education: Two. The New Look in Mathematics Teaching. The Process of Change. Institute of Education, Univ. of Hull. pp 8-31

Lovell K. (1968) Some Recent Studies in Cognitive and Language Development. Merrill-Palmer Quarterly of Behaviour and Development. Vol.14, 2, 124-138.

Lovell K. and Shields J.B. (1968) Some aspects of a study of the gifted child. Brit. J. Educ. Psychol. Vol 37, 201-208.

Luchins A.S. (1942) Mechanisation in Problem Solving: the effect of Einstellung. Psychol. Monogr. No.248.

Lunzer E.A. (1965) Problems of Formal Reasoning in Test Situations. Monogr. of Soc. for Res. in Child Devel. Serial No.100. Vol 30, 2, 19-46.

Macfarlane Smith (1964) Spatial Ability. London. Univ. London Press.

MacKinnon D.W. (1962) The Nature and Nurture of Creative Talent. Amer Psychologist. 17, 484-495.

McKellar P. (1957) Imagination and Thinking. London, Cohen and West.

McNemar Q. (1964) Lost: Our Intelligence? Why? Amer. Psychologist. 19, 871-882.

Maier N.R.F. (1930) Reasoning in Humans. J. Comp. Psychol. 10, 115-143.

Marsh R.W. (1964) A statistical re-analysis of Getzels and Jackson's data. Brit. J. Educ. Psychol 34, 91-93.

Mathematical Association (1956) The Teaching of Mathematics in Primary Schools. London, Bell.

Matthews G. (1967) Evaluation. Nuffield Foundation Mathematics Teaching Project. Bulletin No.12.

Matthews G. (1969) Mathematics in the Middle Years. In Schools Council, The Middle Years of Schooling from 8 to 13. Working Paper 22. London, H.M.S.O. pp 64-66.

Mead M. (1959) Creativity in Cross-Cultural Perspective. In H.H. Anderson (Ed) Creativity and its Cultivation. N.Y. Harper & Row. Pg.223.

Mednick S.A. (1962) The Associative Basis of the Creative Process. Psychol Review, 69, 220-232.

Miller K.M. (1957) Einstellung rigidity, intelligence and teaching methods. Brit. J. Educ. Psychol. 27, 127-134.

Mooney R.L. (1967) Creation in the Classroom Setting. In Mooney R.L. and Razik T. Explorations in Creativity. N.Y. Harper & Row. pp 206-215.

Moustakas C. (1967) Creativity and Conformity in Education. In Mooney R.L. and Razik T. Explorations in Creativity. N.Y. Harper & Row pp 173-184.

Nunnally J.C. (1964) Educational Measurement and Evaluation. N.Y. McGraw-Hill.

Parnes S.J. and Brunelle E.A. (1967) The Literature of Creativity. J. Creative Behaviour Vol 1 No.1.

Patrick, Catharine (1935) Creative thought in Poets. Archives of Psychol. Vol.26. 178, 1-74.

" (1937) Creative thought in Artists. J. Psychol. 4, 35-73.

" (1938) Scientific thought. J. Psychol. 5, 55-83.

Peel E.A. (1960) The Pupils' Thinking. London, Oldbourne.

Piaget J. (1950) The Psychology of Intelligence. London, Routledge & Kegan Paul.

" (1953) The Origin of Intelligence in the Child. London, Routledge & Kegan Paul.

Poincaré, Henri (1906 (1968)) Mathematical Creation. Lecture to the Psychological Society. Paris. (Reprinted (1968) in, Mathematics in the Modern World. Scientific American.)

Polya G. (1954) Mathematics and Plausible Reasoning. Vols. I and II, London, O.U.P.

" (1962) Mathematical Discovery. Vol.I, N.Y. Wiley.

" (1965) Mathematical Discovery. Vol. II, N.Y. Wiley.

Registrar General (1960) Classification of Occupations. London, H.M.S.O.

Roe A. (1953a) Making a Scientist. N.Y. Dodd, Mead & Co.,

Roe A. (1953b) A Psychological study of eminent Psychologists and Anthropologists and a comparison with Biological and Physical Scientists. Psychol. Monogr. 67, 352.

Rogers C.R. (1962) Toward a theory of creativity. In Parnes S.J. and Harding H.F. (Eds). A Source-book for Creative Thinking. N.Y. Scribners. pp 63-72

Ross A. (1969) Round-up on the whole curriculum. In Schools Council. The Middle Years of Schooling from 8 to 13. Working Paper 22, London, H.M.S.O. PP 76-83.

Rossman J. (1931) The Psychology of the Inventor. Washington D.C. Inventors Publishing Co.

Rippe D.D. (1953) Application of a large sampling criterion to some sampling problems in factor analysis. Psychometrika. 18, 191-205

Schools Council (1965) Mathematics in Primary Schools. Curriculum Bulletin No.1 London H.M.S.O.

Sears P.S. and Hilgard .E.R. (1964) The teacher's role in the motivation of the learner. In Theories of Learning and Instruction. 63rd Yearbook. Nat.Soc. for Study of Educ. Chicago. Univ. of Chicago Press.

Sharples D. (1969) Children's attitudes towards Junior School activities. Brit. J. Educ. Psychol. 39, 72-77.

Skemp R. (1965) Concept formation and its significance in mathematics teaching and syllabus reform. In Land F. (Ed) Aspects of Education: Two. Institute of Education, Univ. of Hull. pp 59-70.

Spearman C. (1930) The Creative Mind. London, Nisbet & Co.

Spearman C. and Wynn Jones Ll. (1950) Human Ability, London, MacMillan

Spielman and Gaw (1926) Special Abilities. In, A Study in Vocational Guidance. Nat. Institute of Industrial Psychol. Ch.5.

Stein M.I. (1967) Creativity and Culture. In Mooney, R.L. and Razik T. (Eds) Explorations in Creativity. N.Y. Harper & Row. pp 109-119.

Taylor I.A. (1959) The Nature of Creative Process. In P. Smith (Ed) Creativity. N.Y., Hastings House. pp 51-82.

Taylor C.W. (1954) Introduction. In C.W. Taylor (Ed) Creativity: Progress and Potential. N.Y. McGraw Hill. pp 1-14.

Terman L.M. (1906) Genius and stupidity - a study of some of the intellectual processes of seven 'brighter' and seven 'stupid' boys. Pedag. Sem. 13, 307-373.

Terman, L.M. and Oden, Melita (1959) The Gifted Group at mid-life: 35-year follow-up of the superior child. Stanford, California. Stanford Univ. Press.

Thomson R. (1959) The Psychology of Thinking. England, Pelican Books.

Thouless R.H. (1960) General and Social Psychology. London. Univ. Tutorial Press.

Thurstone L.L. (1932) The Theory of Multiple Factors. Extracts in J.J. Jenkins and D.G. Patterson (Eds) (1961) Studies in Individual Differences. N.Y., Appleton-Century Crofts. pp 351-367.

Thurstone L.L. (1952) Creative Talent. In L.L. Thurstone (Ed) Applications of Psychology. N.Y. Harper & Row. pp 18-37.

Torrance E.P. (1959) Explorations in creative thinking in the early school years IX, Res. Monogr. 59/12. Minneapolis, Univ. of Minnesota.

" (1962) Guiding Creative Talent. Englewood Cliffs, N.J. Prentice-Hall.

" (1963) Education and the Creative Potential. Minneapolis, Univ. of Minnesota Press.

" (1964) Education and Creativity. In C.W. Taylor (Ed) Creativity: Progress and Potential. N.Y. McGraw-Hill. pp 49-128.

Torrance E.P. (1965) Rewarding Creative Behaviour. Englewood Cliffs, N.J., Prentice-Hall.

Vernon P.E. (1961) The Structure of Human Abilities. London, Methuen.

" (1964) Creativity and Intelligence. Educ.Res. 6, 163-169

" (1965a) The Measurement of Abilities. London. Univ. of London Press.

" (1965b) Environmental handicaps and Intellectual development, Part I. Brit. J. Educ. Psychol. 35, 9-20

Vinackre W.E. (1952) The Psychology of Thinking. N.Y., McGraw-Hill.

Wallace H.R. (1961) Creative Thinking: A factor in sales production. Voc. Guidance Quarterly 9,223-226.

Wallach M.A. and Kogan N. (1966) Modes of Thinking in Young children. N.Y., Holt, Rinehart and Winston.

Wallas G. (1926) The Art of Thought. N.Y. Harcourt Brace.

Wallen N.E. and Travers R.M.W. (1963) Analysis and investigation of teaching methods. In N.F. Gage (Ed) Handbook of Research on Teaching, Skopie, Illinois, Rand-McNally.

Ward J. (1918) Psychological Principles. Cambridge. C.U.P.

Ward, James (1967) An oblique factorisation of Wallach and Kogan's 'creativity' correlations. Brit. J. Educ.Psychol. 37, 380-382.

Wertheimer M. (1961) 1st Edn.(1945) Productive Thinking. London, Tavistock Publications.

White J.P. (1968) Creativity and Education: A Philosophical Analysis. Brit. J. Educ.Studies 16, 2, 123-137.

White R.W. (1961) Motivation Reconsidered: the Concept of Competence. Psychol. Rev. 66, 297-333.

Williams J.D. (1966) Effecting educational change - some notes on the reform of Primary School mathematics teaching. N.F.E.R., Educ. Res. 8, 3, 191-195.

Wilson R.C. (1958) Creativity. In N.B. Henry (Ed.) Education for the Gifted. 57th Yearbook. Nat. Soc. for Study of Educ. 57, II, 108-126.

Wiseman S. (Ed.) (1967) Intelligence and Ability: Selected Readings. England, Penguin Books.

Wooton W. (1965) S.M.S.G. The Making of a Curriculum. New Haven.- Yale Univ. Press.

Yamamoto K. (1964) The role of creative thinking and intelligence in high school achievement.- Psychol. Rep. 14, 783-789.

" (1965a) Creativity: A blind man's report on the elephant. J. Counselling. Psychol. 12(4) pg.428.

" (1965b) Effects of restriction of range and test unreliability on correlation between measures of intelligence and creative thinking. Brit.J. Educ. Psychol. 35, 300-305.

APPENDIX

Areas covered in questions to Headmasters on School organisation, Teaching Method etc.

1. Number of pupils.

2. Number of full-time and part-time teaching staff.

3. Details of teaching staff:

   (a) Special qualifications in Mathematics.

   (b) Mathematics courses attended.

   (c) Involvement in A.T.O. Mathematics courses.

   (d) Length of experience.

   (e) Classes taught.

4. Streaming?

5. Type and extent of methods of teaching in Mathematics.

   (a) Headmaster's own description.

   (b) Discovery approach?

   (c) Formal methods?

   (d) Amount of work on the four 'rules' of Arithmetic.

   (e) Project work?

   (f) Use of publications of the Nuffield Mathematics Project?

   (g) Use of text books.

   (h) Use of assignment cards.

   (i) Presentation of work: (i) In exercise books, rough books, folders on charts etc?

   (ii) Use of ink, pencil, etc.

   (iii) Degree of emphasis on neatness.

(j) Time spent in whole-class teaching.

(k) Extent to which initiative from the children affects the content and method.

(l) Time spent in mathematics classes.

(m) Methods of assessment.

6. Mathematics equipment.

(a) Types and amount of apparatus.

(b) Extent used.

(c) Expenditure in recent years.

7. Description of Catchment Area.

(a) Type of housing and population.

(b) Urban/Rural. Proximity to fields, parks etc.

8. Description of the School.

Date built, sufficiency and use of classroom space, playing fields, dining room, main hall, mathematics room, etc.

9. Infants schools.

(a) Number contributing to the Junior School intake.

(b) Methods used in the Infants department.

(c) Any special emphasis on mathematics?

FREQUENCY ANALYSIS OF REPLIES TO THE CIRCLES TEST

Examples of response categories and items, with the corresponding frequency.

(Total population, N = 265)

$f > 18$ Common (No originality marks)

Faces	Sun/moon/planets	Watch/clock	Flowers	Head of pin/screw
Coins	Buttons	Eggs	Pots and Pans	Balls
Fruits	Symbols (letters	Cakes	cups, plates	Bicycle
Porthole	Satellite or numbers)	End of a pencil	wheels	lollipop

$11 \leq f \leq 18$ (1 originality mark)

magnifying glass	gun sights	open mouth	T.V. set	chair
fish bowl	ice cream cornet	bird's nest	table	picture
Dumb-bells	keyhole	basket	tree	polo mint
Barometer	meteor	shield	snail	Pie chart

$6 \leq f \leq 10$ (2 originality marks)

Bell	Cobweb	Flying saucer	Front of a train	telescope eyepiece
Bomb	Doorbell	cave	propeller spinning	piece of coal
Badge	Door Knob	Venn diagram	traffic lights	lampshade
Headlamp	torch	A (2 oz.) weight	scale-pans	record

$2 \leq f \leq 5$ (3 originality marks)

Buffer of a train	Bath plug	Someone bending down	Radio	Telephone
volcano	Bow	Crystal ball	Paw mark	Umbrella (dial
Binoculars	press stud	A cheese	frogs spawn	finger print
Bubble	Coil of rope	Cigarette end	pill	Circus hoop on fire

$f = 1$ unique

Olympic sign	Circle on football field	Electric saw	fishing float	typewriter key
Orb	Camp fire	Drain cover	A note in music	loo roll
Branding Iron	Ripples of water	discus	Pig's nose	pendulum
Car licence	Dog's name disc	golf green	T.V.Channel selector	germs on a microscope slide

FREQUENCY ANALYSIS OF REPLIES BY A SAMPLE OF 100 PUPILS TO THE USES TEST

Examples of items and categories with the corresponding frequency:-

$f > 20$ (no originality marks)

Newspaper	Spoon	String
To read	Eat with	To tie parcels
Light fire	Stir	To tie up people
Make papier-maché	Mix things	Hanging pictures
Wrap up Fish and Chips	Measure out teaspoonfuls	hair band
Make paper models	Dig with	
Making a scrap-book		

$10 \leq f \leq 20$ (1 originality mark)

Newspaper	Spoon	String
Keep floor clean	drumstick	Measure with (instead of a ruler)
for doing puzzles (crosswords etc.)	for bending to show strength	Clothes line
Make a dress pattern	Flick things with	Belt
for T.V/Cinema programmes	Egg and spoon race	Dog's lead
Put under messy things		shoelace
		skipping rope.

$4 \leq f \leq 9$ (2 originality marks)

Newspaper	Spoon	String
To advertise in	Melt down and use the metal	Bow and arrow
Bedding for animals	open a tin	Dishcloth
Blanket for tramps	scrape things up	Conkers
Crumple to make a ball	to throw at someone	Hair for rag doll
To cover windows when decorating/moving	Clappers	to fly a kite
Wipe things clean	To take wheel off bicycle	pull a tooth out.
Put over face to sleep in sun		Tie round finger as a reminder
Making a kite		Tripline
Megaphone, trumpet		

$2 \leq f \leq 3$ (3 originality marks)

Newspaper

To blaze the fire
Carpet underlay
For conjuring tricks
Keep out draughts
To stuff a guy
Wallpaper
For pressing trousers

Spoon

Cut with its edge
Mirror
For doctor to look down your throat
To kill insects
Put down back for hiccups or nosebleed
Shoehorn

String

Keep cowboy's hat on
To draw circles
Plumb-line
String telephone
make a string bag
to raise a flag
Tie round pencil to show it is yours
Finishing tape for a race

$f = 1$ (5 originality marks)

Newspaper

To cut out letters and numbers and make new words
To make confetti
Keeping birds off plants
To find lighting-up time
To slide on
To stuff in shoes to make taller
For cutting out Prime minister's picture to throw darts at
Wrap up ice cream
For grocer to wrap soap in so as not to make the other food smell

Spoon

Clearing cobwebs
Carrying beetles you don't want to touch.
Door knocker
Eyeshade
Feed sick animal
Heat wax in it
Letter opener
screwdriver
Write about in a nursery rhyme
To poke eyes out
A slide for ants

String

Wrap up an Egyptian mummy
To cut and "declare open"
Soak in paraffin and use as a fuse
Guide line for gardeners
Start up a model boat engine
Keep meat together in the oven
Wick for a candle

FREQUENCY ANALYSIS OF REPLIES BY A SAMPLE OF 40 PUPILS TO THE CONSEQUENCES TEST

Examples of responses with the corresponding frequency:-

$f > 8$ Common (no originality marks)

If suddenly we had no hair on our heads

No need to go to the hairdresser
Barbers would be out of business
Brushes and combs wouldn't be needed
Out heads would get cold
There would be no need for hairribbons/hair bands/shampoo
We would not have to wash our hair

If we did not need to eat or drink

Food shops would close
Food and drink factories would not be needed
Knives and forks would not be needed
There would be no steak pies, sweets, etc.
We would die) Very common
" " get very thin) but dis-allowed as not proper consequences

$2 \leq f \leq 8$ Uncommon (one originality mark)

People would buy wigs
People would not need to buy wigs
There would be no wigs of real hair
Hair could not get in our eyes
We would need warm hats
Pop singers would not have long hair
Men and women would look the same
No one could pull our hair
Ears would be cold
We wouldn't get dandruff

Cookers wouldn't be needed
No dinner hour
Life would be dull
There would be more time to play
No need to go shopping
Reservoirs would not be needed
We would save a lot of money
Our stomachs would rumble
We wouldn't get stomach-ache
No need to clean teeth
Lavatories not needed

$f = 1$ Unique in sample (Two originality marks)

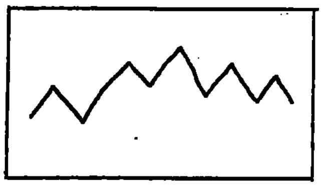
We would dream of having nice long hair
Our hair couldn't turn white with fright
There could not be hair raising stories
Could not grab hair to save someone by
You could not suffer from falling hair
We could paint on our heads
We would look like men from space

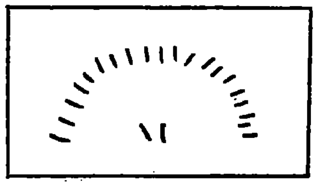
No need to do hair before going out

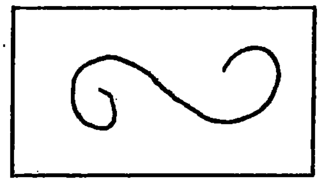
Couldn't get food poisoning
No need to keep cows for milk
No need to kill animals for food
Would not get food stains
Could live in the desert
We would not be hungry or thirsty
Christmas and Easter wouldn't be much fun
No washing up
We could wash in milk
No T.V. adverts on food

FREQUENCY ANALYSIS OF REPLIES BY A SAMPLE OF 40 PUPILS TO THE PATTERN MEANINGS TEST

Examples of responses with the corresponding frequency:-







$f > 8$ Common (no originality marks)

Mountains
Zig-Zag pattern
Teeth

Clock/watch
A light shining
Sun
Sunrise/sunset

Letter 'S'
Snake/worm
Squiggley line
Piece of string

$2 \leq f \leq 8$ Uncommon (one originality mark)

Spearheads/arrowheads
Icebergs
Crown
Big dipper
Top of fence
Egg after hatching
Graph/Temperature chart
Rockets taking off
Rough Sea
Pointed hats
Lightning
Rocks
tops of trees
Saw

Archway
Caterpiller
Dial on scales
Eyebrows
Flames from fire
Half a flower-head
Grassy mound
Hedgehog
Golliwog's head
Matchsticks in a half circle
Protractor
Peacock
Rainbow
Entrance to a tunnel
Moustache
Radar screen

Hook
Handle(jug, box etc.)
A sign in music
Coil of wire
Cloud
A scroll of paper
Sea horse
Animal's tail
violin
Waves
A whale
Figure 2
Road on a map

f = 1 Unique in sample (Two originality marks)

End of wallpaper cut with pinking shears
Frayed end of cloth
Stones on edge of garden path
Folding ruler
Glass on wall
Interference on T.V.
Heartbeat on a machine
Snail's trace
Bottom of a dress

An Army surrounding two men
Bird flying
Bristly chin from upside down
Crater
Balloon bursting
Circular saw
Golden egg
Iron filings near a magnet
Dandelion clock
Two flies with silver paint on, making them shine
Waterwheel
Fan
People marching with banners

Arm of a chair
Path of a rocket
Sky writing
A bed mattress rolled up
Decoration on clown's hat
Top of a Roman Helmet
Cream on top of a cake
Smoke rising
Inside a rabbit's burrow

TEST PROCEDURES

(One copy for each teacher).

• Sequence and duration of the tests

ay 1

(i) Attitude questionnaire — Time:

"Things you do at School" — Approx. 3 minutes

(ii) Creativity Booklet — Total Time: 62 minutes (excluding the reading of instructions).

(a)	Circles Game	15 mins
(b)	Uses for Things	15 mins
(c)	Consequences	10 mins
(d)	Pattern Meanings	12 mins
(e)	Make-up Problems	10 mins

ay 2

(i) Arithmetic booklet — Total Time: 29 minutes (excluding the reading of instructions)

(a)	PART 1	12 mins
(b)	PART 2 (Filling Spaces)..	7 mins
(c)	PART 3 (Easy Ways of Solving Problems)	10 mins

(ii) N.F.E.R. Arithmetic Progress Test C_1 — Time: 30 minutes

ay 3

N.F.E.R. Intermediate Mathematics Test 1 — No time limit (50-60 mins approx.)

General Notes

(a) Please keep to the order of testing days as given above, and to the order of tests within each day.

(b) Provided the order on any day is adhered to, separate tests (or separate sections of the 'Creativity' or 'Arithmetic' booklets) need not be done in one continuous session, but to prevent "leakages" they are best held simultaneously in all the classes in a particular school.

(c) Please read the instructions and the examples for each test aloud to the class asking the children to follow on their own papers.

(d) Timing starts when the teacher says 'begin' and does not include the preliminary reading of instructions.

(e) Timing should be adhered to EXACTLY. It is best to write down each starting and finishing time. Note that the tests usually have several sections each separately timed.

(f) The supervisor should try to ensure, especially if it is impracticable for the children to sit at separate desks, that there is no copying.

(g) The supervisor should walk around quietly and, if any child is obviously not carrying out the instructions correctly, he should point out the instructions and whisper a few words of explanation. No actual help should be given.

(h) In particular the supervisor should watch that children do not turn over prematurely, and, equally important, do not stop if the instructions at the end of the page tell them to turn over and carry on without waiting.

(i) Please return the completed tests to the box in the Headmaster's study as soon as possible after the completion of each test.

cont./

Preparation.

(a) Desks should be clear except for two sharpened pencils. All rulers, rubbers, spare paper etc., should be put away. (The teacher should have some spare pencils available).

(b) The children should, if possible, be seated separately. If this is impossible the teacher must endeavour to see that they do not copy.

(c) The supervisor should have a reliable stop watch, or a clock or watch with a second hand.

Administration.

(a) DAY 1.

(i) Do not tell the children that there will be more tests later in the week but read the following on the first morning before any of the testing begins:-

"Three schools in Northumberland have been asked to take part in a survey of children's attitu des, work and imagination. This school is one of them and it is hoped that you will enjoy answering the questions, which have nothing to do with the 11+"

(ii) Give out the Attitudes Questionnaire: "Things you do at School"

Tell the children to fill in their names then ask them to follow while you slowly and deliberately read the whole sheet prior to letting them write in the numbers.

Allow about three minutes and collect in the sheets when each child has filled in all the boxes. Please check this afterwards.

(iii) Give out the Creativity booklet

Tell the children to fill in their names, school etc. It is helpful if the teacher completes a fictitious example on the blackboard.

Read, slowly and deliberately, the instructions to the booklet and to the first section (the Circles Game).
Remind the class NOT TO TURN OVER ANY PAGE UNTIL TOLD.
Tell them that if they fill up a page before the end of the time they should continue their answers opposite on the back of the previous page.

Finally ask "Are there any questions?" If so, answer them briefly. Time the test from when you say "Begin".

Each of the five parts of the booklet are separately timed.
Repeat the above procedure for each set of instructions and examples.

TES:

1. If a child fills up all the circles he can draw extra rough circles, freehand, on the page opposite.

2. Please read the whole of the 'story' in the test of 'Make-up Problems'.

cont./

DAY 2

(i) Arithmetic Booklet.

Ask the children to fill in their names, school etc.

Then say:-

"There will be no need to do any rough work in this sort of Arithmetic test, but if you wish to do some, you may use any space available including the back of the previous sheet which is opposite"

NO SEPARATE ROUGH PAPER IS TO BE ISSUED.

Remind them that they are not to turn over when it says 'STOP HERE' but THEY ARE to turn over when they come to the end of page 1 as the twelve minutes allowed for PART 1 includes pages 1 and 2.

Ask: "Are there any questions?" Then begin.

NOTE

The instructions and examples for PART 3 take up the whole of the page entitled "Easy ways of Solving Problems". Please read slowly through the whole page asking the children to follow on their own papers. Time 10 minutes from when you read 'START NOW'.

(ii) N.F.E.R. Arithmetic Progress Test C_1 Time : 30 minutes

The N.F.E.R. 'Manual of Instructions for Arithmetic Progress Test C_1' is provided for this test. There is a copy for each teacher. Please read the section headed 'Instructions for Adminstration' and proceed as stated.

DAY 3

N.F.E.R. Intermediate Mathematics Test 1 NO TIME LIMIT (approx. 50-60 mins.)

The appropriate N.F.E.R. 'Manual of Instructions' is again provided for this test with a copy for each teacher. Please read the section 'Instructions for Administration' and proceed as stated.

Name ....

Things you do at School

Some children were talking about the things which they did in school. Here are some of the things they said. Read carefully what they said and see if you feel the same. You might like some things a lot, others you might not like at all. Different children like different things.

Each thing the children said has a number by it.

1. I hate it.
2. It is the worst thing we do in school.
3. I can't stand it.
4. It is alright sometimes.
5. I think it is good.
6. It is most enjoyable.
7. It is good fun and I like it very much.
8. I love it.

Now, write down the number of the sentence which says how you feel about these things you do in school. Write the number in the box after the name of the thing you do in school.

READING	☐
MATHEMATICS	☐
WRITING STORIES	☐
ART	☐
P.E.	☐

Name ______________________ School ______________________________

Sex ________ Class ________________

I want to find out how good you are at thinking up new and interesting ideas, and I have asked your teacher to give you these papers to complete. There are no right or wrong answers so write down as many ideas as you can think of.

Remember to work quickly, each part will be timed by your teacher.

1. ____________

2. ____________

3. ____________

4. ____________

5. ____________

Circles Game

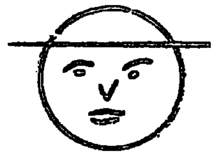
I want to see how many objects you can make from the circles in fifteen minutes. With a pencil add lines to the circles to complete your picture. Your lines can be inside the circle, outside the circle, or both inside and outside.

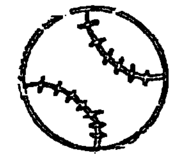
Make as many DIFFERENT things as you can.

Do not spend much time on any one drawing - you may add titles under your drawings if you do not think they are clear enough.

Look at the two examples on the next page and make as many of your own as you can.

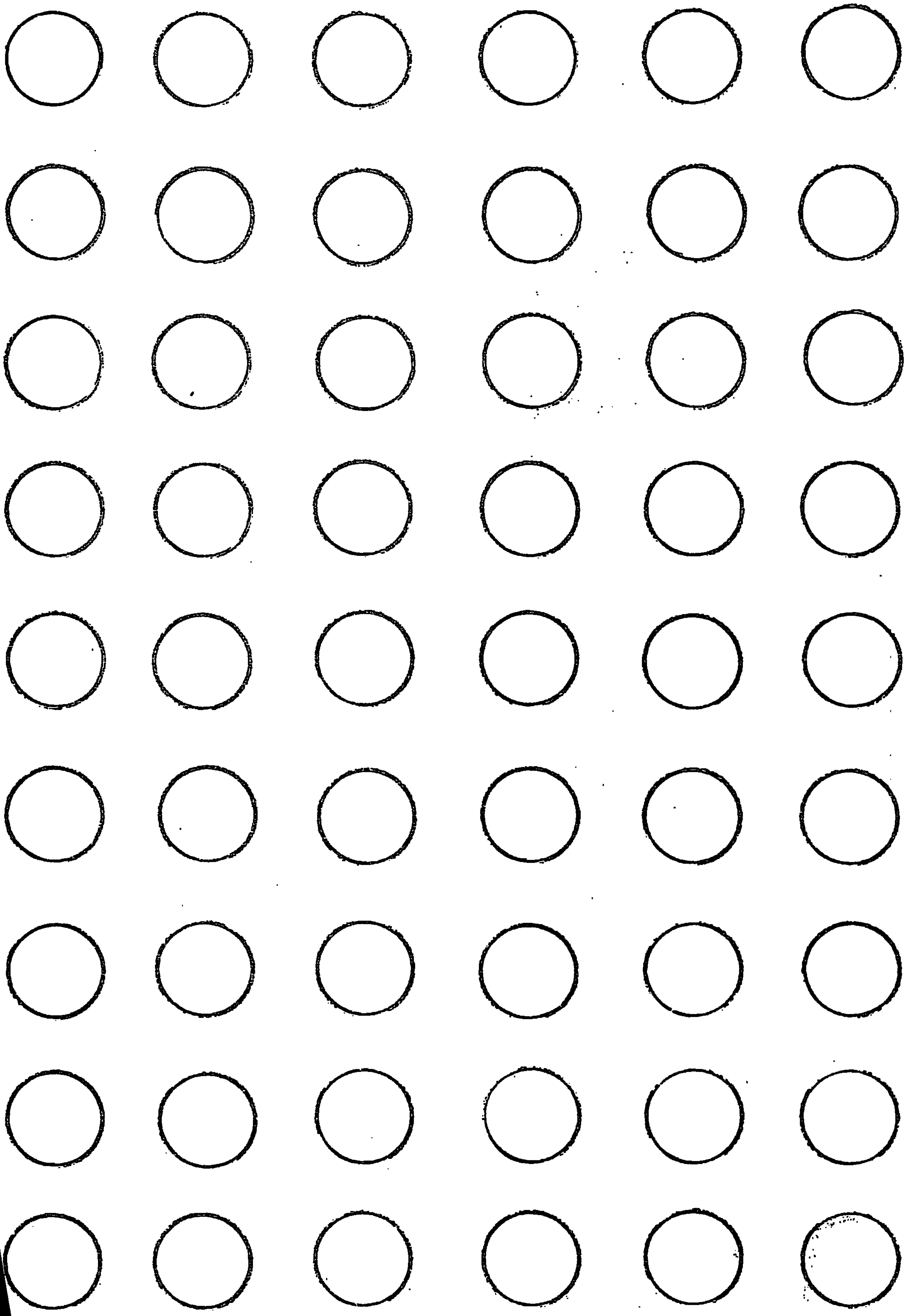
Here are the two examples





tennis ball

You have 15 minutes to make as many of your own as you can.



Uses for Things

The names of THREE objects are written below. I want you to write down as many DIFFERENT uses as you can for each object. Write down anything that comes into your mind, no matter how strange it may seem.

Here is an example:-

A BUCKET: Hold water, sit on, make a helmet with.

You have 15 minutes.

1. A NEWSPAPER

2. A SPOON

3. A PIECE OF STRING

Consequences

Here is an example of some things that would be different if everyone had only one hand:-

(a) We could not use a bow and arrow

(b) We might count in fives instead of tens

(c) We would not need a pair of gloves

(d) Could not thread a needle

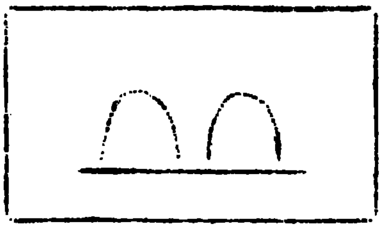
I want you to pretend that the two changes given below suddenly happened. Write down as many different results of the changes as you can think of IN TEN MINUTES.

1. If we had no hair on our heads ______________________________

2. If we did not need to eat or drink ______________________________

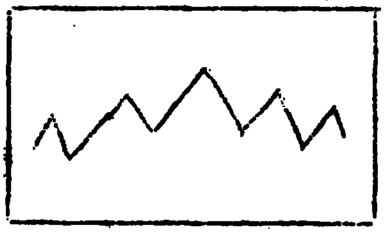
Pattern Meanings

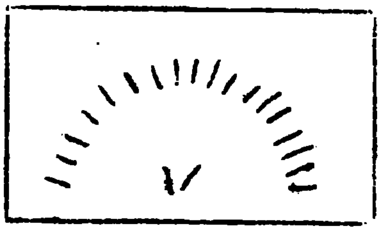
Example

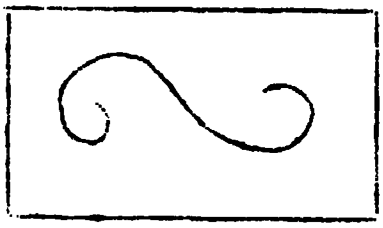


This drawing might be two igloos, or two mountains, or two mouseholes.

Write down all the things you think that the following drawings could possibly be. YOU HAVE 12 MINUTES.

1. 

2. 

3. 

Make-up Problems

After reading the following short story I want you to make up as many problems from the story as you can for me to solve. YOU ARE NOT TO WORK THEM OUT YOURSELF. You can ask anything you like provided that the answer can be found from this story.

Mr. Smith is the Head Teacher of a Junior School which has 300 pupils. He is taking the 10 year old pupils for a days outing by bus. There will be 100 pupils, 60 of them girls. 3 other teachers will go with them. The bus fare will be 5/- each.

Lunch in a cafe will cost 2/6d. each. There will be packed sandwiches for tea, paid for by the school at a total cost of £5. The Head and the Teachers will pay 3/- each for their sandwiches.

It will cost 9d. each to go in a Museum, 3d. each to go into a ruined castle, and 6d. each to go for a sail in a boat. The children have been asked to bring 10/- each, and after all expenses have been paid the money left will be pocket money.

Mr. Smith wanted to be back at school at 5.0 p.m. because he did not want to be away for more than eight hours. However, they were 30 minutes late returning.

Here is one example: How many boys went?

Now write as many other problems as you can in the space below and on the next page.
YOU HAVE TEN MINUTES.

Name................................ School...........................

Sex ....   Class ....

ARITHMETIC

There are three parts in this booklet, each is separately timed and your teacher will tell you when to begin and when to stop.

Read the instructions carefully and if it says STOP at the end of a page do not turn over until you are told.

Part 1	
Part 2	
Part 3	

PART 1

1. Tick the number below which is equal to 100+100+100+10+10+1+1+1+1+1

300205 30010 3011 3025 325

2. Tick the number that is nearest to 101.

1001 99 104 89 110

3. Tick the biggest number that can be made by using the figures 2537 once each.

5372 7532 2357 3275 7325

4. Put a ring round the SMALLEST fraction.

$\frac{1}{3}$ $\frac{1}{2}$ $\frac{1}{6}$ $\frac{1}{10}$ $\frac{1}{4}$

5. Tick the number which is one more than 999.

100 10100 9991 1000 9910

6. Looking under a fence I counted 56 legs belong to sheep. Tick what I have to do to find out how many sheep there were.

MULTIPLY ADD SUBTRACT DIVIDE NONE OF THESE

7. 42 children in a class give 6d. each to buy a present for their teacher. Tick about how much they can spend on the present.

2/- £2 £1 10/- 4/2d.

8. How many tens are there in 800?

....

9. 246 people paid 2/9d. each to see a football match. Tick what you do to find out how much they paid altogether.

ADD SUBTRACT MULTIPLY DIVIDE NONE OF THESE

10. In the number 55 how many times is the first 5 bigger than the second 5?

the same 5 times 10 times 20 times 100 times

11. Tick the number that is about three times as big as 65.

21 125 365 200 2000

12. Write down the number with four tens and eleven ones.

....

13. Tick the biggest number that can be made by using all the figures 24195 once each.

94512 19542 95421 19425 59241

14. Write down the number with fourteen hundreds and six ones.

....

15. Tick the number which has sixteen tens and thirteen ones.

29 1613 163 173 1703

O STRAIGHT ON TO THE NEXT PAGE WITHOUT WAITING TO BE TOLD.

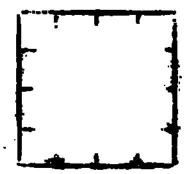
In RURITANIA they use the following measures: fips, yogs and nams.

There are 4 fips in 1 yog and 6 yogs in 1 nam.

fip yog nam

1 square fip

1 square yog



....

Part 1

1. How many fips are there in ONE NAM? ....

2. How many fips are there in TWO NAMS? ....

3. How many YOGS are there in THREE NAMS? ....

4. 3 yogs and 1 fip plus 1 yog and 3 fips make... ....yogs ....fips

Do not forget that 4 fips make 1 yog.

Part 2

At the top of the page you will see pictures of a square fip and of a square yog. A square **fip** is one **fip** along each of its sides. A square yog is one yog along each of its sides.

5. How many square fips do you need to cover the whole of ONE SQUARE YOG? ....

6. How many square fips do you need to cover the whole of TWO SQUARE YOGS? ....

7. How many square YOGS do you need to cover the whole of ONE SQUARE NAM? ....

PART 2

Filling Spaces.

You have 7 minutes to finish this page.

Complete the following rows of numbers where there is a blank space ____.

1. 3, 6, 9, 12 ____
2. 21, 16, 11, 6 ____
3. 15, 14, 12, 9, ____
4. 2, 3, 5, ____, 12
5. 3, 6, 12, ____, 48
6. 80, 40, 20, 10, ____
7. 1, 3, 7, 15, ____
8. $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, ____
9. 1, 11, 20, 28 ____
10. 81, 27, 9, ____ 1

Fill in the blank spaces to complete the following sums:-

Here is an Example

```
   3  7
- [2][4]
  ------
   1  3
```

11.

```
  □ 6
-   □
  ---
    7
```

12.

```
   3 □
+  □ 2
  -----
 □ 1 9
```

13.

```
    □ 9
+ □ 0 □
  -------
  1 0 0 0
```

14.

```
  □ □ 3 □
-   9 □ 1
  --------
      9 5
```

15. (Long Division no remainder)

```
          1 0 □
      -----------
 □ 3 ) 2 □ 3 □
       □ □
       ---
         □ □ □
         □ □ □
         -----
         . . .
```

STOP HERE

PART 3

EASY WAYS OF SOLVING PROBLEMS

Example 1. Find 36 + 107 - 36

Answer = 107.

Do not add all the numbers but notice that adding 36 and then subtracting 36 leaves 107 the same. We have paired the numbers, as shown by the arrow:-

36 + 107 - 36

Example 2.

Add: 96 + 97 + 98 + 99 = 101 + 102 + 103 + 104.

Can you see an easy way to do it? Pair the numbers again, as shown by the arrows

96 + 97 + 98 + 99 + 101 + 102 + 103 + 104

we get 96 + 104 = 200

97 + 103 = 200

98 + 102 = 200

99 + 101 = 200

TOTAL = 800

Now work out the following problems, in a similar way if you can. You can draw arrows on the paper if you like.

REMEMBER TO USE A QUICK METHOD OR YOU WILL NOT HAVE ENOUGH TIME.

Do not spend much time on any one question.

Have a good look at each problem AND THINK.

TURN OVER AND START NOW.

YOU HAVE 10 MINUTES ONLY

1. $35 + 14 - 35 =$ ....

2. $21 + 16 - 16 + 83 - 83 =$ ....

3. $196 + 77 - 77 + 134 - 134 =$ ....

4. $196 + 77 - 134 - 77 + 134 =$ ....

5. $87 + 69 - 60 - 9 =$ ....

6. $99 + 87 + 1 + 13 =$ ....

7. $301 + 296 + 199 + 204 =$ ....

8. $1799 - 68 + 101 - 32 =$ ....

9. $\frac{1}{4} + \frac{1}{3} + \frac{1}{2} + 1 - \frac{1}{2} - \frac{1}{3} - \frac{1}{4} =$ ....

10. $\frac{1}{3} + \frac{2}{3} + 1 + 1\frac{1}{3} + 1\frac{2}{3} =$ ....

11. $2\frac{1}{4} + 2\frac{3}{4} + 3 + 3\frac{1}{4} + 3\frac{3}{4} =$ ....

12. $\frac{272 + 272 + 272}{3} =$ ....

13. $83\frac{1}{3} + 83\frac{2}{3} + 84 + 84\frac{1}{3} + 84\frac{2}{3} =$ ....

14. $\frac{178 + 179 + 181 + 182}{4} =$ ....

15. $\frac{133 + 134 + 135 + 136 + 137}{5} =$ ....

16. $\frac{1}{8} \times \frac{1}{4} \times \frac{1}{2} \times 1 \times 2 \times 4 \times 8 =$ ....

17. $1 + 3 + 5 + 7 + 9 + 11 + 13 + 15 + 17 + 19 =$ ....

18. $1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 + 11 + 12 + 13 + 14 =$ ....

19. $17 + 18 + 19 + 20 + 21 + 22 + 23 =$ ....

20. $11 + 12 + 13 + 14 + 16 + 17 + 18 + 19 =$ ....

21. $1 + 5 + 9 + 13 + 17 + 21 + 25 + 27 =$ ....

22. $1 + 2 + 3 + 4 + 16 + 17 + 18 + 19 =$ ....

23. $40 + 42 + 44 + 46 + 54 + 56 + 58 + 60 =$ ....

24. $1 \times 2 \times 3 \times 10 \times 15 \times 30 =$ ....

25. $1 + 2 + 3 + 4 + 5 + 6 +$ ... and so on adding all the numbers up to 100

Answer ....