The effects of the use of the computer language logo on primary children's mathematics

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THE EFFECTS OF THE USE OF THE COMPUTER LANGUAGE LOGO ON PRIMARY CHILDREN'S MATHEMATICS.

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ABSTRACT

This research aims to assess the extent to which LOGO influences the development of children's mathematical problem solving skills.

Recent literature in the area of problem solving and mathematics teaching was studied to provide background information which would form the basis for this research.

The children and teachers involved were all from schools in Cleveland where emphasis had been made of the importance of good primary practice in computing. To this end, the use of the computer language LOGO played an important role.

A programme of work to encourage the children to use LOGO at their own level was designed. Children in the ten plus age range were tested using the Bristol Achievement Test and over a twelve month period, some of the children worked with LOGO and developed their own learning pattern.

At the end of that time, all the children were tested again and their test scores were analysed. Their attitide towards mathematics was also evaluated using a Mathematics Attitude Questionnaire.

The majority of the children who had worked with LOGO became more independent learners than their peers. They also made a significant improvement to their initial test score. Children who had worked only at the existing maths scheme, not only failed to make significant progress many had actually shown a decline in the scores they obtained.

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CHAPTER 1

Within the past five years, LOGO has gradually become integrated into the curriculum of many, primary schools. In an attempt to assess the value of this programming language, this small scale research was carried out. Over a two year period the research was planned, activated and an attempt was made to analyse the results obtained.

The main body of the study took the form of observing children working on LOGO problem solving activities and assessing their progress in a variety of ways.

In preparing the format and carrying out the background research, it was necessary initially to identify skills which it was anticipated LOGO would develop.

The decision to concentrate the research around the development of children's mathematical problem solving skills was made because of the writer's interest in this area of the child's development. It was felt that the information obtained could possibly be of some value to teachers using LOGO with primary aged children.

In making a closer examination of the definition 'mathematical problem solving skills', it was first necessary to determine what was meant by problem solving and examine some recent research into the subject. To this end, the work of George W. Ernst was studied and his interpretation of the term 'problem solving' from his publication 'G.P.S. : A Case Study in Generality and Problem Solving' was quoted.

As problem solving is part of the process of thinking, the work of Jean Piaget, one of the pioneers in the area of the development of children's cognitive skills, was examined. The findings of his research have for many years dominated the approach of teachers towards directing children's learning. Although recently, conflicting arguments have developed surrounding some of these findings, it was felt that because of the influence Piaget's work had on the work of Seymour Papert, the man whose name is mostly associated with the development of LOGO, Piaget's work should be a major source of reference for this study.

A more detailed study of one specific area of the thinking process, the development of thinking as a problem solving activity has been the subject of pioneering research carried out in England by Dr Edward de Bono. He carried out several major research projects into the development of the problem solving process in children. Some of the theories advanced by him have been studied and several of his works have been used as reference material for the purposes of this research.

As the specific theme of the study was the development of mathematical problem solving skills, it was necessary to examine work which had already been carried out in this area. At the commencement of this research, Anita Straker was regarded as one of the leaders in directing teachers to use a more investigatory or problem solving approach towards the child's use of the computer in primary schools. In many of her publications and seminars, she referred to the work which had been carried out in Russia by V.A. Krutetskii. On studying some of this Russian research, it was felt that it was compatible to this study of the effect of LOGO on the development of children's mathematical problem solving skills.

So that a broader outlook could be made of recent studies in the area of problem solving, some American research was examined.

This research into problem solving had been carried out during the past few decades. The work of two of the most important men associated with this topic, Gagne and Schoenfeld was studied. Their approach to problem solving, is known as the heuristic approach. They were not alone in their theories and another name frequently associated with the heuristic approach to problem solving was that of George Polya. He carried out several research exercises and attempted to identify and simplify stages in the development of problem solving activities. The definitions which he produced are comprehensible and have therefore been referred to within the context of this study.

One of the most influential people in the area of LOGO work with children was, and still is, Seymour Papert. He carried out most of his work in America and was instrumental in encouraging teachers to use LOGO with young children. The study he has made on the subject of mathematical problem solving using LOGO provided the writer with the incentive to carry out this research.

An effort has been made to discover links between the findings of Papert, those of the other researchers previously mentioned, and those of this present research.

One of the features of the research carried out in Russia was the importance attached to the quality of mathematics teaching. Feeling that this was a relevant condition applicable to this study of LOGO activities, recent publications on mathematics teaching in England were examined in the hope that this would put in perspective the present state of mathematics teaching in primary schools.

The work for this present study was carried out within a limited area, namely four primary schools from Cleveland. It was felt that as the sample was quite small, an explanation as to how and why the schools and the children were selected should be provided.

The teachers involved in the study had all received special training from the Computing Advisory staff of the county, in the area of working with children using LOGO, and all were interested in following the agreed programme of work and in the testing and assessment of the children taking part in the study.

All the children taking part in the study were aged from ten to eleven years and it was decided to use the Bristol Achievement Maths Tests as a means of assessing the progress made by them in the area of mathematical skills development. Part A of the test was administered to all the children taking part in the research before any LOGO work began, and Part B was administered at the conclusion of the year's work with LOGO. It was also felt that it might be of benefit to teachers if an assessment could be made of the children's attitude towards mathematics and it was decided that the Assessment of Performance Unit's Mathematics Attitude Questionnaire should be administered to every child taking part in this study. It was hoped that this would determine whether the use of LOGO had influenced the child's attitude towards mathematics. A more detailed account of the selection of schools and tests appears in Chapter 4.

A record of some of the work carried out in the writer's school has been included in order to support any future development of this research.

During the writing of this research, an effort was been made to draw comparisons between the children's approach to their LOGO problem solving exercises and the approaches to problem solving which were perceived by some of the previously mentioned researchers.

CHAPTER 2

In carrying out this research in the area of problem solving, the statement made by George W. Ernst in his work 'GPS: A case study in Generality and Problem Solving' became more and more relevant:

'The term problem solving is not altogether clear. In English the term has a broad indefinite scope, as do such similar terms as 'recognition', 'understanding', 'learning', and 'searching'. Behind this vagueness of course lies the absence of a science of problem solving that would support the definition of a technical term'[1]

During this century, psychologists have made extensive studies of the development of thought in children. In particular, Piaget and the investigators who worked with him at his research institute in Switzerland spent many years in trying to trace the complex processes of thought. Although not all of Piaget's findings have been confirmed, a considerable number have been verified and a general pattern of development seems to have been established.

The following stages of growth have been distinguished although some writers number them differently:

1. The period of sensori-motor intelligence.

This lasts from birth to approximately eighteen months to two years. It is a time when sensations and actions are the most important part of a child's learning experience and the means through which he learns.

2. The period of preparation for and organization of

concrete operations.

This falls into three stages:

a) From about eighteen months or two to four years is the stage when representation becomes possible in the form of language, imaginative play and drawings

b) From about four to seven or eight years is the stage when judgements are made about size, shape, relationships and are based on the child's experiences and his interpretation of his experiences and are largely made without reasoning.

c) From the age of seven or eight to eleven or twelve years is the stage when logical operations can be carried out with concrete materials or in a particular situation.

3. The period of formal operations from eleven or twelve years when logical operations can be carried out without the aid of concrete materials.

STAGE 1 The period of sensori-motor intelligence

After a child is born, events take place in succession often with a pattern of repetition and routine. The child responds to sensations such as the sight of a bright light, the hearing of a voice, the feeling of things touching his own body. Gradually, repetition of a sensation brings recognition of the thing being repeated. During the period of motor-sensori intelligence, a child passes from experiencing actions and sensations as unrelated episodes to the coordination of the images he receives and the systemization of his actions. He discovers things exist even though they are out of his sight which means he has a mental picture and not merely the visual image of an object in front of him. This establishment of a mental picture of a thing not seen is the prerequisite of thinking. This is then extended when a child recognizes objects which have been moved nearer or farther away, or which have changed position. The systemizing of actions which takes place during this period is particularly important because the organization of simple movements is the foundation of the mental structures which will develop in later stages. A child learns to reverse his actions and to carry out a chain of actions. This precedes the ability to follow a chain of thought to reach a new understanding or to work out a plan of action.

Towards the end of the sensori-motor intelligence period, the child begins to experiment with things such as building a tower by stacking bricks one on top of the other. This action foreshadows with concrete material that of an adult who visualizes the effect which a variety of decisions could have.

'A logic of action precedes a logic of thought.'[2]

This dependence on the development of thinking on patterns of actions continues throughout the second stage in the development of thinking.

STAGE 2 The period of preparation for and organization of concrete operations

During this stage the power of representation emerges. This is probably the most powerful instrument of mathematical thinking. The child begins to use speech to provide the symbol of representation of pictures and patterns of action which have been developed in the mind. Using words greatly increases the degree of mental activity a child can carry out. This activity is demonstrated during imaginative play which the child normally uses at this time to express feelings and enables him to represent and act out experiences which have been important to him. This kind of play is usually symbolic of the child influencing things around him and reveals that he is still looking at things in reference to himself, noticing what they mean and what he can do with them.

Drawings can be a fruitful source of stimulation to the child. They represent what a child thinks he sees and they correspond to the mental picture he has formed. At this stage, they show clearly how egocentric are his impressions and how limited is his awareness of the connections between the things themselves. The child's ideas about situations are similarly unrelated. He is unable to relate two ideas together either to see that they are not contradictory or to produce from them a new idea.

This stage is a period of considerable growth towards relating mental structure to actual forms and relationships.

At the approximate age of four, lasting until the normal child is seven or eight, and covering the child's first two or three years at school, is the period of intuitive thinking.

During this period, the child's thinking is dominated by his perceptons i.e. by the interpretations he gives to his experiences of seeing, hearing, touching, moving etc. Thinking which is based on perceptions and not on reasoning is said to be intuitive. Since perceptions are mental structures produced by sensations past as well as present, imtuitive thinking about a thing or a situation takes place only when there is a direct contact with the object of thought.

Intuitive thinking, stimulated by rich experiences of manipulating things continues through the child's mental growth and applies to increasingly complex situations.

By the age of seven or eight, a child can begin to think logically and his experiences should have widened. His thinking will have a much wider range and his conclusions will be much more precise. This is the period of logical operations with concrete materials. Logical at this stage of children's thinking implies that the mental operations the child carries out have some structure of adult thinking, while an operation is defined by Piaget as

> 'An action which can return to its starting point and which can be integrated with the actions also posessing this feature of reversability.'[3]

During the period of concrete operations, children master a variety of tasks, some of them quite complex, which grow from three simple operations.

1. Classification

   The child can sort objects into class.

2. One to one correspondence

   The child relates objects to people and becomes familiar with terms such as more than, the same as etc.

3. Seriation

   The child forms sequences by using one to one correspondence. He can now put things into their sequential order.

STAGE 3 The period of formal operations.

The child from the age of eleven or twelve can begin to think without reference to actual objects. He can begin to enjoy inventing some hypothesis and work out its logical consequences.

The children who took part in this study working with

LOGO, were all in the chronological age range of the last two stages of Piaget's scheme and one would have expected their problem solving work to exhibit some compatability with the stages of development as described by Piaget.

As a human being, one is continually faced with intellectual and practical problems, as a member of a community, one is involved with practical, social and economic problems. A definition of how one person interprets the act of problem solving appeared in the publication 'Problem solving with ADA':

> 'We solve problems by thinking, but there seems to be two distinct modes of thought. When the left half of the brain is dominant, we are scientific and when the right side is dominant we are artistic. When we are thinking scientifically, we focus on language, analysis, order, law and tools; when we are thinking artistically we focus on patterns, synthesis, imagination and intuition. Both ways of thinking help us to solve problems and both should be cultivated.'[4]

The pioneering work carried out by Dr. Edward De Bono was the subject of several publications. In his work 'The Use of Lateral Thinking' he wrote:

> 'To trace fully what goes on in the mind, all its activity ultimately needs to be translated into patterns of excitation in the nerve networks of the brain. Relatively little is known at present about the detailed workings of the brain, yet it is possible to entertain a broad concept of its organization. Just as the functional organizations of the electrical circuit in a house may be appreciated without details of the layout of each wire or the design of each switch, so an understanding of thought processes may be approached by examining the outward manifestation of underlying systems.'[5]

In another of his publications, De Bono attempted to explain the term problem solving in simpler language:

'Problem solving may seem to be rather a specialized part of thinking. But if we change the name to 'dealing with a situation,' 'overcoming an obstacle,' 'bringing about a desired effect,' 'making something happen,' then it can be seen that the thinking involved is the thinking that is involved in everyday life though the actual problems may appear exotic.'[6]

The research carried out by Edward de Bono involved presenting children with a wide variety of problems. The children were expected to present their solutions to the problem in the form of a drawing. The problems were chosen because:

'...it had some special features. The cat and dog problem is a political problem involving psychology and motivation. The elephant problem involves dealing with magnitude and also dealing with maths outside personal experience.'[7]

The expectation that the child would express the solution to the problem in the form of a drawing was because:

'Young children are not always very good at expressing their ideas in words and it would be a pity if their ideas were to be restricted by insisting that they use words. Again words can sometimes be difficult to understand and interpreting the meaning behind them may become a matter of guesswork. Drawings however are clear and relatively unambiguous.'[8]

De Bono insists that by making a drawing the child has to commit himself to a definite idea and that idea because it is visible at once can be changed or modified, whereas with words the child has to either remember all that he has written or read through the description every time he wants to make an alteration.

Of the problems which were posed to the children during the course of De Bono's research, the first was 'How to stop a cat and dog from fighting.'

This is the basic political problem, how to stop people with differences of religion, race, ideologies or nationalities from fighting. As cats and dogs are as racially and culturally different as any two human beings, the starting situation is very definite.

The children involved in this research were aged from five to thirteen. Their mental growth would be expected to be within the Piagetarian stages of intuitive thinking, logical operations with concrete materials and the stage of formal operations when logical operations are carried out in the mind without the aid of concrete materials.

The responses made by the children were varied. Some suggested a ghetto solution , the separation of the fighting groups, others suggested keeping the opposing factors at arms length, and others suggested using distraction in order to make them forget their animosity. De Bono states that:

> 'Difference of approach is a very characteristic feature of children's thinking. If you put a group of adults in a room and ask them to tackle a problem, they will have relatively few approaches distributed among them. But a group of children will come up with a much greater variety of approach.'[9]

Three main psychological principles were apparent from the solutions provided by the children.

1. <u>The principle of self-interest</u>

The child made it worth while for the cat and dog to stop fighting.

2. <u>The psychological principle of distraction.</u>

This meant that the cat and dog would be too well occupied to have time to think about fighting.

3. <u>The psychological principle of getting one side</u> used to the other.

This would mean that they would lose their animosity towards each other and therefore the inclination to fight.

Sometimes the ideas of the children and the solutions they offer to problems such as those posed by De Bono seem impractical. They do however produce ideas with fluency, zest and imagination. The child's thinking ability can be used to solve problems from a very early age.

Research carried out in Russia by V.A. Krutetskii aroused much interest, not only because he appeared to be unique among Soviet psychologists in investigating individual differences, but also because the mathematical problems he used in his research were so varied and ingenious.

The aims of Krutetskii's research were threefold:

1. To investigate in close cooperation with mathematicians, the most highly developed structure of

mathematical creativity.

2. To attempt to discover in collaboration with physiologists, the physiological nature of mathematical abilities.

3. To study, together with teachers and methodologists, optimal ways of forming and developing mathematical abilities at school age, having clarified before hand to what extent the existing system of mathematics teaching actually moulds pupils' mathematical thinking, or their mathematical abilities.

Krutetskii contended that:

'Innate biological inclinations are necessary but not sufficient for the subsequent development of an ability and that abilities are created and developed only through activity.'[10]

and he then defined ability as:

'..a personal trait that enables one to perform a given task rapidly and well, in contrast to a habit or skill which is a characteristic of one's activity.'[11]

Later in his work 'The Psychology of Mathematical Abilities in Children', Krutetskii briefly stated a few assumptions upon which he had based his research:

'1. Abilities are always abilities for a definite kind of activity; they exist only in a person's specific activity.
2. Ability is a dynamic concept. It not only shows up and exists in an activity but is created and even developed in it.
3. At certain periods in a person's development, the most favourable conditions arise for forming and developing individual types of ability and these are provisional or transitory.'[12]

Various methods were used in the research and most of the data was obtained from individual interviews with approximately two hundred pupils who were given a series of problems to solve. The pupils, who varied in age from six to seventeen were asked to think aloud as they solved the problem and they were given hints if necessary. The chosen children had been classified by their mathematics teacher as being either very capable, relatively capable, average, or relatively incapable in mathematics.

Krutetskii gave questionnaires in the nature of mathematical abilities to mathematics teachers and mathematicians. He researched the mathematical background of famous mathematicians and physicists. He analysed the school's mathematics curriculum and collected data on over one thousand pupils in Moscow secondary schools to compare their progress in maths with their progress in other subjects.

Not only is the research notable for the variety of research methods employed, but also for the variety and richness of the problem tasks devised for the interviews. Twenty six series of problems were used, each series being a set of problems of the same type but differing in difficulty and designed to measure one or more of the mathematical abilities.

According to Krutetskii, there are three basic stages of a mental activity in solving a problem:

'...gathering information needed to solve the problem, processing the information so as to obtain a solution, and retaining information about the solution.'[13]

Each of these stages depends on different mathematical abilities. Capable pupils can grasp the essence of the problem quicker, can generalize the material rapidly, can skip over intermediate steps in logical argument, can switch easily from one solution to another to achieve an 'elegant' solution, and are able to reverse the train of thought where necessary.

From the work carried out, Krutetskii contends that there is such a thing as a mathematical cast of mind. A tendency to interpret the world mathematically which can clearly be seen in pupils who are especially gifted in mathematics, and he identifies :

'..three basic types of mathematical cast of mind: the analytical type (who tends to think in verbal logical terms), the geometric type (who tends to think in visual-pictorial terms) and the harmonic type (who combines characteristics of the other two.'[14]

Eminent American mathematicians such as Jeremy Kilpatrick, professor of mathematics at the University of Georgia, and Izaak Wirzup, professor of mathematics at the University of Chicago have stated that the work of Krutetskii:

'..could have the same impact on mathematical education that Piaget's work has had.'[15]

and that:

'Just as Piaget's tasks have been adapted and used by researchers alike, so Krutetskii's tasks, which are more closely related to the school mathematics curriculum could be used and adapted in the same fashion.'[16]

They went on to say:

'Just as Piaget's notions of intellectual growth have made mathematical educators aware of differences in children's thinking at various stages, so Krutetskii's notions on the structure of mathematical abilities could make them aware of different components of ability and how they might function together.'[17]

Their approval of the techniques used by Krutetskii was further exemplified in their statement that:

'Just as Piaget broadened our conception of what are appropriate research techniques, so Krutetskii may broaden this conception even further.[18]

In America, research has also been carried out into some educational and psychological aspects of problem solving. Lester has defined the terms of problem solving as :

'A problem is a situation in which an individual or group is called upon to perform a task for which there is no readily accessible algorithm which determines completely the method of solution. And problem solving typically involves performing sets of actions to arrive at a solution to some particular task.'[19]

As a result of his study of problem solving, Lester emphasizes the mental processes involved, and indicates that cognitive mathematical behaviour can be classified, as falling into three broad levels:-

1. The child memorizes facts, rules, procedures, which can be reproduced when ever necessary.

2. The child transfers learning from one context to another.

3. The child recognizes and reconstructs the variables in a problem to form new relationships which facilitate the

finding of a solution.

This can also be termed an 'open search' level of mathematical thinking, the crucial stage in problem solving processes.

Gagne, in his research carried out during the sixties, presented a model of problem solving where the production of a solution depends on the learner already knowing subordinate rules. The learner then searches his memory to find relevant rules which are combined to form 'tries' at a solution, and finally verifying or checking its possible solution. As in most of Gagne's work, a hierarchical system of applying more and more complex higher order rules is envisaged.

These 'higher order' rules are more clearly defined in the development of the area of problem solving known as heuristics. As defined by Schoenfeld, an heuristic is:

'...a general suggestion or strategy, independent of any particular topic or subject matter, which helps problem solvers to approach, understand, and efficiently marshall their resources in solving problems.'[20]

As long ago as 1944, George Polya was recognized as playing an important role in the development of mathematical problem solving. He expressed the view that the teacher of mathematics had a great opportunity and that if:

'..he challenges the curiosity of his students by setting them problems proportionate to their knowledge, and helps them to solve their problems with stimulating questions, he may give them a taste for, and some means of, independent thinking.'[21]

In his most famous work 'How to Solve It,' he outlined a four stage model for problem solving:

'1. You have to understand the problem.
2. Find the connection between the data and the unknown.
3. Carry out your plan.
4. Examine the solution obtained.'[22]

He also makes suggestions as to the kind of questions which should be answered during each stage of the problem solving process.

<u>Stage 1</u>

'What is the unknown? What are the data? What is the condition? Is it possible to satisfy the condition? Is the condition sufficient to determine the unknown? Is it insufficient? Is it redundant? Is it contradictory?'[23]

Then Polya recommends that the problem solver should draw a figure, introduce suitable notation, separate the various parts of the condition, and write them down.

<u>Stage 2</u>

During this stage, Polya suggests that the problem solver may be obliged to consider auxilliary problems if an immediate connection cannot be found and that eventually the problem solver should obtain a plan of the solution. Questions which Polya suggests should arise at this stage are such as:

'Have you seen it before? Have you seen the same problem in a slightly different form? Do you know a related problem? Look at the unknown and think if you have come across a familiar problem with the same or a similar unknown.'[24]

He then emphasizes the simplicity of this method of questioning with the questions:

'If there is a problem related to yours and solved before, could you use it? Could you use the result, or could you use its method?[25]

Stage 3

These instructions are simple enough for able eleven year olds to carry out:

'Carry out your plan of the solution, check each step. Can you see clearly that the step is correct? Can you prove that it is correct?[26]

Stage 4

Again the questions suggested are uncomplicated but may have necessitated some discussion with children:

'Can you check the result? Can you check the argument? Can you derive the result differently? Can you see it at a glance? Can you use the result or method for some other problem?'[27]

The suggestions made by George Polya were used occasionally during the course of the LOGO problem solving activities with the children and referred to later in Chapter 6.

Some of the problem solving methods described previously which were carried out during the research in England, Russia and America have been compared, at a later stage with the problem solving activities carried out for the purposes of this study.

CHAPTER 3

LOGO is one of a number of computer languages which have been developed in the field of Artificial Intelligence.

'Artificial Intelligence is the study of ideas which enables computers to do the things that make people seem intelligent.'[28]

According to Papert, the definition of Artificial Intelligence (AI) can be narrow or broad. In Mindstorms Papert states that:

'In the narrow sense, AI is concerned with extending the capacity of machines to perform functions that would be considered intelligent if performed by people.'[29]

The making of these machines could be described as a branch of advanced engineering but in order to construct these machines it was found necessary to reflect on the nature of the functions to be performed by the intelligence afforded to them. Therefore to make a machine which could be instructed in a natural language, the designers had to probe deeply into the nature of language and learning. This, according to Papert, leads to the broader definition of AI, that of:

'AI as a cognitive science. In this sense AI shares its domain with the older disciplines such as linguistics and psychology. But what is distinctive about AI is that its methodology and style of theorizing draw heavily on theories of computation.'[30]

Researchers in the field of Artificial Intelligence attempt to understand human thinking processes and behaviour patterns (such as language or vision) by trying to develop computer-based simulations of these. In pursuing this end, they have found it convenient to develop computer languages suitable to these particular activities.

One of the differences between the research carried out by Piaget and research into Artificial Intelligence was that for Piaget:-

'The study of people and the study of what they learn are inseperable'[31]

LISP (LISt Processing) was one of the programmimg languages developed in an attempt to emulate human thinking patterns. LISP is highly logical and has a powerful facility for handling and manipulating lists of items as complete units; however LISP programs have a tendency to be difficult to follow when they reach any degree of complexity.

LOGO was developed out of LISP in 1968, as part of a research project to create a language for the teaching of mathematical ideas through programming. LOGO was evolved by a team one of whom was the man nowadays mostly associated with LOGO, Seymour Papert. Its creators, mainly

Feurzeig and Papert intended that it should be easy to learn, easy to use, and easy to read.

Throughout the 1970's research was carried out on LOGO, chiefly at the Massachusetts Institute of Technology (under the direction of Seymour Papert) and at the Artificial Intelligence Unit of Edinburgh University (under the direction of Jim Howe). Some of this research was concerned with the use of LOGO in teaching mathematics, but its value in other learning areas has also been demonstrated.

Papert was deeply influenced by the theories of Piaget and his statement on the learning process that:-

'..learning consists of building up a set of materials and tools that one can handle and manipulate.'[32]

is similar in its context to Piaget's stages of thought development.

The similarity between the building up of LOGO programs and the building up of thought structures is apparent. The evolution of a LOGO program by developing and testing simple procedures and then incorporating them in more complicated ones can to some extent parallel the process of thinking. For Papert, this similarity between LOGO work and thought work is what makes LOGO not just a programming language, but a tool to think with.

'The parallelism between LOGO activity and thinking is a crucial element in the case for LOGO's relevance to education. In developing his powers of thinking, the child builds up structures of thought by exploration of the world around him.'[33]

In his own literature, Papert claims that his thinking has

'..placed a greater emphasis on two dimensions implicit but not emphasised in Piaget's own work. These are an interest in intellectual structures that could develop, as opposed to those that actually at present do develop in the child, and the design of learning environments that are resonant with them.'[34]

The learning environment in which we place children is of the utmost importance. This can be compared, according to Papert, to the famous carnival in Rio de Janeiro. There a twelve hour long procession of song, dance and theatre takes place. The groups taking part have spent the past year preparing their contribution. In their group, much of the teaching, although it takes place in a natural environment, is deliberate. As they work together, everyone is learning. At times, an expert gathers a group around and for a period of time:

'A specific learning group comes into existence. Its learning is deliberate and focused.'[35]

In using the carnival's samba schools as an example, Papert contends that:

'..it represents a set of attributes a learning environment should and could have. Learning is not separate from reality. The samba school has a purpose and learning is integrated in the school for this purpose. Novice is not separated from expert, and the experts are also learning. '[36]

This statement is important in the context of this particular research. The writer has aimed to develop such an environment in the area of the LOGO work carried out with the children involved in this study.

By using the Turtle and LOGO, Papert claims that:

> '..it can be used to illustrate both of these interests, first the identification of a powerful set of mathematical ideas that we do not presume to be represented, at least not in a developed form, in children, and second, the creation of a transitional object, the Turtle, that can exist in the child's environment and make contact with the ideas.'[37]

One example which Papert uses in his book Mindstorms is that of a sixth grader (approximately the same age as the children working in this study) called Deborah. She had problems with learning and was introduced to the world of screen turtles by being shown how to use the commands FORWARD, LEFT and RIGHT. Deborah found the use of large numbers frightening and needed constant attention and reassurance in order for her to carry out any exploratory steps using the turtle. A turning point came in Deborah's work when she imposed upon herself the restriction of only using the turning command of RIGHT 30. Instead of programming the turtle to turn RIGHT 90 in order to turn for one right angle, she would program it to turn RIGHT 30 three times. To turn LEFT 30 she would program the turtle to turn RIGHT 30 eleven times. To an onlooker this may have seemed a complicated way of achieving the end result but Deborah found this self imposed restrictive microworld exciting and she refused to use any other alternative ideas which were offered. After a space of several weeks, she emerged with a new sense of confidence which showed itself not only in the work she was continuing to do with turtles but also in the whole of her school work.

In concluding his description of Deborah's work pattern Papert states that:

'The success of a mathematical theory served more than an instrumental role. It served as an affirmation of the power of ideas and the power of the mind.'[38]

In the case of Deborah, the use of LOGO had a definite effect on her attitude towards not only mathematics but also towards all her other school subjects.

As Papert concludes:

'Children may learn to be systematic before they can learn to be quantative.'[39]

Various projects have been carried out during recent years which have attempted to evaluate the use of LOGO with children. Many have been studied by the writer of this research and those which are particularly relevant have been studied in detail.

In America, a research project was designed to answer the questions about the cognitive and social impact of

LOGO in elementary classrooms. This project, funded by the Spencer Foundation and the National Institute of Education, was carried out by Pea, Kurland and Hawkins over a two year period. One of the branches of this study was to determine whether problem solving skills were developed through LOGO programming.

The background setting to the project was a private school in New York where children in the third to sixth grade were all learning LOGO. During the school year 1981-1982, each classroom had six microcomputers.

All the teachers involved in the project had received intensive training in LOGO. During the first year of the project, the children were allowed to experiment with LOGO. The activities they undertook were child initiated and the teacher's role at this time was that of a leader more than a teacher. This changed during the second year. The teachers took a more directive role and the children were given lessons in computational techniques. At this time also:

'The older students were also given more group lessons and were required to complete more specific assignements centering on LOGO concepts and programming methods, such as preplanning.'[40]

The researchers were of the opinion that planning was a prerequisite of programming and planning required the programmer to decompose the problem, generate sub goals, modify and evaluate. They anticipated that because of the use of these problem solving skills in the planning process, these skills might be developed further.

In designing the tasks for the children, the researchers required the planning process to:

'(a) be one where a child might be expected to see planning as appropriate and valuable;
(b) be complex enough so that the means for achieving a goal are not immediately transparent and the possibility of alternative plans is recognized; and
(c) involve a domain where children have a sufficient knowledge base so that action sequences can be planned and consequences of actions can be anticipated.'[41]

During the first year of the project, the children were videotaped during their work in the planning environment. The children were asked to make a plan to do a lot of classroom chores and devise the shortest method of doing this. They were to think out loud while doing the planning and were given a pointer to show the path they had taken. They were also given paper to make notes although it was discovered that this was rarely used. This task was given to the children before they began learning LOGO and again four months later.

After the first year, the observations were:

'Route efficiency score significantly increased with age from first to last plan within sessions and across age groups. The LOGO programming group, however did not differ for controls for any plan constructed at the beginning of the school year or at the end of the school year of LOGO programmimg. Finally, each age group, regardless of programmimg experience, improved in efficiency from first to last plan.'[42]

The mean score for each of the groups improved, the children who had been using LOGO programming making no more improvement than any of the other groups.

The researchers also compared the planning processes across the various groups, in order to observe if the children using LOGO had used more advanced decision making processes than the other children. The videotape was studied and the flexibility of the child's decision making during the planning process was determined in two ways:

'(1) by looking at the number of transitions a child made between types of decision making while creating a plan and
(2) by looking at the number of transitions made between levels of decision making, irrespective of the decision type.[43]

There was found to be no difference between the indices of decision-choice flexibility of either the group using LOGO or the other groups.

Another aspect of planning which the researchers studied was that of the relationship of product to process measures; how effective was the plan as a product as compared with the decision making processes. Again there was no significant difference between any of the groups.

The first year's work was summarized by the researchers by:

'On the face of it, these results suggest that a school year of LOGO programmimg did not have a measurable influence on the planning abilities of these students.'[44]

On analysing the outcome of the first half of the project, they decided that:

'Although the planning task had features that made it formally similar to the planning in programmimg ...... students may have failed to recognize the task as an opportunity to apply the insights of programming.'[45]

It was necessary therefore to redesign the proposed second year of the study. The new task set, although it did not require any knowledge of programming, was set in an environment which was similar to the programming environments of the pupils using LOGO. These LOGO environments changed also during the second year. The teachers had expressed a certain disappointment at the quality of the children's programming work and the decision was made to provide more structure to the learning environment

for the second year.

Although at the beginning of the year there was no observable difference between any of the groups, they had all made some improvement in their planning techniques, near the end of the year there had been a change.

The new task consisted of:
'(1) a coloured diagram of a classroom
(2) a set of goal cards each depicting one of six chores.
(3) a microcomputer which would allow the students to design and check their plans with the support of the experimenter, and
(4) a graphics interface that enabled students to see their plans enacted in a realistic representation of the classroom.'[46]

The task put to the children was to devise a plan whereby a robot instructed by them would clean up the classroom in the least possible time and covering the shortest possible distance.

At the conclusion of the task, the plans were closely examined. The thinking times were compared, there was no difference between any of the groups. The method of planning did not differ from group to group.

Further findings were:

'There was no evidence that the programmers were more likely to follow a model of plan debugging by successive refinement more than nonprogrammers. Additional analysis revealed that students who modified previous plans, leaving larger portions intact, did not develop appreciably better plans than students who varied their approaches from plan to plan.'[47]

The conclusion reached by the researchers was that:

'The programming groups clearly did not use the cognitive abilities alleged to be developed through experience with LOGO in these tasks designed to tap them.[48]

In attempting to explain the apparent lack of success of their research, the writers suggested that:

'First, there are problems with the LOGO programming environment (not the instructional environment) as a vehicle for learning these generalizable cognitive skills. Second, the quality of learning about and developing such planning skills with the LOGO discovery-learning pedagogy is insufficient for the development of generalizable planning skills. Third, perhaps the amount of time students spent in the LOGO pedagogical environment was not sufficient for us to see the effects on planning of LOGO programming experience.'[49]

In the final statement on their study, Pea, Kurland

and Hawkins, the researchers were of the opinion that:-

'Learning thinking skills and how to plan well is not intrinsically guaranteed by the LOGO programming environment; it must be supported by teachers who tacitly, or explicitly know how to foster the development of such skills through a judicious use of examples, student projects and direct instructions.'[50]

The findings of W.Pea and his fellow workers have been recorded in order that comparison could be made if necessary with the findings of other, similar research projects.

In 1984, a piece of research was begun, which the researchers described as

'.. an exploratory study with the focus on describing the effects on the children studied.[51]

The first aim of the researchers was to find out whether the LOGO approach could be adapted for younger and disadvantaged children. A secondary aim was to evaluate possible effects of the LOGO experience on the children's behaviour and development. The measures which were taken were:

'(i) semi-structured interviews with the relevant school staff at the beginning and end of the study;
(ii) standard assessment of the children's LOGO competence at the end of the study;
(iii) pre- and post-testing with the British Ability Scales.'[52]

The initial sample consisted of 17 children, 11 boys and 6 girls, with a mean age of 6 years 1 month. Their knowledge of computers was almost minimal and few of them, although they could identify their own right and left hand, could identify the hands of a child sitting opposite to them. All the children were following the SPMG maths scheme and the LINK-UP reading scheme, and their teachers supplied the researchers with the details of each child's position in the scheme at the commencement of the project.

The children were withdrawn to a room which had been allocated for the work. They worked in pairs, usually of mixed sex but similar LOGO ability. The work sessions lasted between fifteen and twenty five minutes. Each session was supervised by one of the project team. The children were encouraged to set themselves goals and to discuss with each other how to achieve them. The researcher occasionally contributed to this part of the session when requested to do so.

The children, using a Concept Keyboard as an extension of the computer, worked through a variety of topics including the use of the options STARTER, PEN, SHAPES and SCREEN

At the beginning and end of the project the teaching staff involved in the work with the children were all interviewed by the researchers. They had noted their observations on the children's respones to their LOGO work. They commented that:

'(1) There was general agreement that the Turtle produced high levels of concentration from the children and that this was almost entirely self-motivated.

(2) There was also agreement that the Turtle work

helped children's mathematical understanding, particularly in the area of number and shape.

(3)The staff were also struck by the way the Turtle work had stimulated the children's language and particularly their use of mathematical terminology.

(4)There was a feeling that the children who took part in the project were more confident and mature as a result of their experience.'[53]

The second part of the assessment was to assess each child's LOGO competence. The children were shown three pictures produced by the Screen Turtle - a flag, a balloon with a star on it and a face. They were asked to produce pictures on the screen exactly like them and the resulting drawings were scored out of five for accuracy.

The results recorded were:

'Although the boys performed better than the girls on this task (mean scores out of 15: boys 9.6, girls 7.0), the difference was not statistically significant (Mann-Whitney U-test). Correlations with the initial measures described earlier showed that overall the best predictors of LOGO competence were the child's score on the Block Design of the sub-scale of the British Ability Scales.'[54]

As has been stated previously, the children were all tested before and after the LOGO project, using the British Ability Scales. This is a standardised assessment instrument which consists of a number of independent sub-scales. In addition, the scores on the sub-scales can be compiled to produce an overall IQ score. Sub-scales which were used were Matrices, Similarities, Block Design, Copying, Digit Recall, Basic Number and Naming Vocabulary.

The test was administered to the children by a post-graduate student in the Psychology Department who had trained as an educational psychologist. She was not involved in the project and did not know the individual children.

The results of these tests were:

'Statistically significant gains (t-test) were found on the following sub-scales: Block Design, Digit Recall and Basic Number. These scales were all specifically concerned with number or shape.'[55]

The researchers then carried out separate analysis for the boys and the girls. This revealed:

'Significant gains for the boys on the Basic number and Block design sub-scales. It also found for the first time, an overall, significant gain in IQ. However, there were no significant gains for the girls on any of these measures, including IQ.'[56]

The primary aim of the study was to determine whether the LOGO approach could be adapted successfully for use with infant children. Following feedback from the researchers and staff, it was decided that indeed the result was a positive one. There was also feeling that some of the skills present in older children, were also apparent in the thinking of the infants using the LOGO programme of work. These skills were mainly, concentration, the use of mathematical language, planning and problem solving.

The secondary aim of the study was to evaluate the effects which the LOGO experience might have on children's thinking and development. The results of the British Ability Scales which were applied to the children showed that there was an improvement in some area with both boys and girls. Overall, the boys scored much better than did the girls, and the researchers stated that:

'..there is at least a suggestion that the boys gained more from the experience than did the girls.'[57]

It was pointed out that these findings must be qualified by the lack of a control group but that nevertheless, they did show that there had been some measurable impact on the children's development brought about by the LOGO experience.

A report on an eighteen month study carried out as a part of the Chiltern LOGO Project, was deemed to be particularly compatible to the present work being carried out on the effect of LOGO on children's mathematical problem solving skills.

Taking part in the study were one hundred and eighteen children aged between eight and eleven, from five schools. These schools were of different types and one whole class of children was used from each school.

During the first term, the children undertook introductory work. This lasted for a period of ten weeks. Following this time, it was found that:

'A characteristic of children's early LOGO learning was the time taken for many to learn to control the turtle as a programmable object.'[58]

Another of the findings was that:

'Introductory programming was dominated by goal-directed (and largely unplanned) activity. The emergence of exploratory, less goal-directed programming activity occurred only with the acquisition of more experience and more control over the environment.'[59]

The second phase of the study which followed the inroductory phase was that of programming. Like the first phase, the teaching strategy was loosely structured. The basis of it was that the children posed their own problems. There were however certain key concepts which were identified as marking definite boundaries in the children's acquisiton of power over the computer.

It was observed that at the same time, specific types of programming activity associated themselves with particular types of mathematical behaviour.

The researchers suggested that:

'These 'learning modes' were proposed as providing some insight into the nature of children's programming activity.'[60]

The whole analysis of this particular study was structured by these two aspects, the programming concepts, and the chidren's learning modes. Programming, for the purpose of the study, was divided into the areas of procedures, iteration, sub-procedures, editing and debugging, inputs and recursion.

From the data that emerged, there were three main findings:

'1. All but nine children were able to program the computer at a functional level, and to explore or solve problems using LOGO;
2. The youngest children found most difficulty in using programming concepts flexibly within the period of the study;
3. There is some relationship between the amount of time spent programming and the range of ideas which the children were able to use.'[61]

The learning modes which were mentioned previously, were not specific stages in the children's learning pattern. At times, they overlapped one another and occasionally, the children would move from one 'level' to another in an indirect manner. The hypothesis made from the observations and analysis which was made of the three learning modes was:

'Making sense of a new idea

Children were introduced to new ideas as the need arose. They needed time to make sense of the ideas; to get a feel for the syntax and to feel in control of it.

Exploring

Exploratory activities were based on the utilisation of programming ideas as a means of extending the power of the language.....this was characterized by the children conjecturing on the effects of certain programming actions- What happens if...?

Solving problems

The problem solving mode was distinguished by its goal-directedness. Here the child was using her knowledge of programming concepts to produce a desired outcome- How do I get the computer to..?'[62]

In conclusion, the researchers suggested that:

'For young children with relatively limited computer access, learning to program in LOGO provides a means by which they can engage in mathematical activity - to do mathematics.'[63]

It was however pointed out that because the children's work had a geometric bias, it had not been enhanced by the variety of other LOGO procedures or 'microworlds' The statement which comes next is particularly important to the writer of this current research. It was that:

'If such provision were made, it would entail a more explicit relationship between conventional mathematical content and the programming work.'[64]

These three research projects, were deemed to be most relevant to the present research. It is essential at this stage to point out that no attempt was made to use any of the ideas previously mentioned during the course of this present research. These particular projects were selected as being compatable after the children had begun their programme of work designed to assess the power of LOGO to influence their mathematical problem solving skills.

CHAPTER 4

During recent years, a vast amount of research has been carried out in the area of mathematics teaching.

Following the publication of the Plowden Report 'Children and their Primary Schools' in 1967, many schools had begun to adopt a more 'child-centred' approach towards the teaching of mathematics. In-service courses were organized by the advisory service. These courses encouraged teachers to change their teaching style from the previous 'teacher centred' approach, where the children were taught to a rigid curriculum, to a more flexible curriculum which was more appropriate to the needs of the individual child.

Although the Plowden Report in general, made very little impact on the educational system, one of the proposals taken from it has recurred in other reports more recently published. This was that:

> 'Communication by the spoken word is at least as important as writing and for the majority perhaps more important.'[65]

In accordance with recommendations of the Plowden Report, the Nuffield Mathematics Project was set up. This project, which commenced in 1967 and lasted until 1973, aimed to:

'Promote understanding of the concepts and proficiency in the basic skills of mathematics in children of the age 5-11 range.'[66]

The Nuffield Primary Maths Project collaborated very closely with Piaget. Recommendations about the vital importance of practical work in primary mathematics had the implicit backing of Piaget's theory of cognitive development. The teacher's guides 'Checking Up 1,2 and 3'(Nuffield Mathematics Project 1970,1972,1973) were written by a team from Geneva, under the general guidance of Piaget. In these books many of Piaget's tests were adapted to the classroom, so as to give teachers a guide to assessing a child's stage of cognitive development.

The mathematics books which were published as a result of the Nuffield Mathematics Project, were at the time of their publication, innovative both in their content and their explicitness for the teachers and pupils for whom they were intended. From one of the stages in the scheme, stage 5, an explanation is given to the teacher:

'The materials in the Nuffield Maths 5-11 Project can be used in a variety of classroom organisations including individual work, group or class teaching. Whichever system is used, it is important for teachers to remember the following points:
a) Children learn at different rates and so will not reach the same age simultaneously;
b) Young children learn by doing and by discussion;
c) As well as finding out and 'discovering' things about mathematics, children need to be told things about

mathematics particularly if new vocabulary is involved.'[67]

In 1975, eight years after the publication of the Plowden Report, the Bullock Report 'A Language for Life' (DES 1975) was published. This report also emphasised the importance of the language of mathematics, and during the 1970's one of the major innovations was the move towards individualised learning in mathematics in the hope that children would come to understand mathematics for themselves.

The influence of the Bullock Report (DES 1975) is apparent in a later report, the Cockroft Report 'Mathematics Counts' published in 1982. In the Cockroft Report, as in the Bullock Report, great emphasis was placed on the role of language in mathematics learning, and of the importance of enabling children to see that mathematics is a means of communication which they can possess and can feel confident in using.

The Cockroft Report emphasized that:

'There is need for more talking time...ideas and findings are passed on through language and developed through discussion after the activity which finally sees the point home.'[68]

For three years, the Cockroft Committee had made a thorough survey and diagnosis of the problems of mathematics teaching and learning in England and Wales.

In addition to giving advice, the Report gave a comprehensive set of aims for school mathematics teaching. Hilary Shuard, director of the Mathematics 6-13 project, comments:

'Insomuch as these aims apply to primary children, some of them are not new; what is new is that the aims stem from, and are united by the Committee's belief that:'[69]

and Shuard quotes:

'Perceptions of the usefulness of mathematics arise from the fact that mathematics provides a means of communication which is powerful, concise, and unambiguous.'[70]

A summary of the aims expressed in the Cockroft Report was made by Hilary Shuard by assembling them under the following headings:

'1.Aims concerning language and communication.
2.Affective aims
3.Aims concerning the use of mathematics.
4.Cognitive aims.
5.General aims of primary education
Language and communication.'[71]

The Report also emphasized that:

'.. maths should enrich pupils' linguistic experience and there is a need to develop in pupils an awareness of the power of mathematics to communicate and explain. This will enable them to use it to illuminate or to make more precise an argument or to present the results of an investigation.'[72]

The affective aims of maths teaching are described as an appreciation and enjoyment of mathematics and a realisation of its role in science, technology and civilisation. The Report indicates that pupils' work in maths should enrich their aesthetic experience and that it is important for teachers to develop pupils' confidence in their mathematical powers.

The uses of mathematics, the Report points out should be mainly those of providing the children with a means of exploring their environment and by doing so they are using the processes of classifying, counting, measuring, calculating, estimating, recording in tabular or graphical form, and making hypotheses or generalisations. The pupils should also be competent in the activities which would enable them to make use of maths in everyday life in the areas of shopping, travel, model making and the daily school activities.

Among the important aims of mathematics teaching listed in the Report are those of developng the pupils' powers of logical thought and encouraging their ability to look for patterns and to explain them. In order to do this pupils need to acquire appropriate conceptual structures in mathematics and to develop general strategies for problem solving and investigation. Some of the strategies listed in the Report include:

'graphical or diagrammatic representaion
looking for patterns
making conjectures, discovering and explaining these conjectures
setting up experiments
looking at similar related problems
developing persistence in exploring problems

recording the possiblities tried
developing the ability to work with others
communicating the progress which has been made in words, diagrams and symbols.'[73]

Further recommendations of the Cockroft Report were that mathematics teaching should also enable pupils to develop the understanding and skills which they will need in adult life, employment and study both of mathematics and other subjects, and that it should equip them with the necessary numerical skills including the skills of mental calculation and enable them to acquire good habits in calculator use.

Among the more general aims of primary education, the Cockroft Report states that if mathematics is taught with the previously mentioned aims in view, it should contribute broadly to the social, personal and intellectual development of all pupils as well as providing them with a set of understanding and skills for their future and it states that:

'We do not believe that mathematics in the primary years should be seen solely as a preparation for the next stage of education. The primary years ought also to be seen as worthwhile in themselves - a time during which doors are opened onto a wide range of experience.'[74]

The view expressed in the Cockroft Report on the teaching of mathematics is largely concerned with working out these aims into practice and an exploration of the teaching styles appropriate to them. There is a constant emphasis on the need for a broad curriculum in maths and on the need for all children to experience mathematics practically:

'Practical work is essential throughout the primary years if the maths curriculum is to be developed in the way which we have advocated....For most children practical work provides the most effective means by which understanding of mathematics can develop. It enables them to think out the mathematical ideas which are contained in the various activities they undertake at the same time as they are carrying out those activities.'[75]

In 'Primary Mathematics Today and Tomorrow' Hilary Shuard is of the opinion that:

'Although the Cockroft Report was very favourably received throughout the education service, the view has gradually gained ground that the report contained nothing new.'[76]

In a further attempt to examine current thought in the area of mathematics, the work of the Mathematics 6-13 project must be taken into consideration. This project was funded by the School Curriculum Development Committee (SCDC) for the period October 1984-March 1985. The stated aim of the project was:

'..to survey the state of curriculum development in primary maths, and to make proposals for a later, substantial, curriculum, development project in primary maths.'[77]

At the start of this project, the Cockroft Report (DES 1982) had been out for about two and a half years. It was felt that this had allowed time enough for teachers and advisers to absorb its impact and to implement its recommendations.

During the six month period of the Maths 6-13 project, the project team visited local education authorities (LEAs) and schools and talked to many teachers, heads, advisers, and INSET providers. The project team also studied most of the recently published literature which had appeared since the Cockroft Report.

'A total of four seminars were held at which invited workers in mathematics education discussed some of the issues. Questionnaires about the current state of development were also sent out to all LEAs in England and Wales and to teacher education institutions'[78]

Some of the areas which were covered by the Mathematics 6-13 project were listed in the publication Primary Mathematics Today and Tomorrow. They were, Mathematics in England and Wales- the last ten years, A model for primary mathematics in the curriculum, The impact of technology, and Issues for curriculum development in primary mathematics.

The project team reviewed all the literature in the area of mathematics teaching which had been recently published, and summarized their findings:

'... practical experience and the 'joy of discovery' was stressed by such workers as Edith Biggs, the HMI Surveys from HM Inspectorate and the work of the APU in the late 1970's emphasized the great range of classroom practice and the great range of children's mathematical understanding. The Cockroft Report pulled together these ideas but with a new emphasis on the role of classroom language in the learning of mathematics.'[79]

In attempting to describe a model for the primary mathematics curriculum, it was stressed that:

'Effective mathematics teaching needs to attend to a number of different elements of mathematics:
facts;
skills;
conceptual structures;
general strategies for problem solving and investigation;
appreciation of the nature of mathematics;
attitudes towards mathematics.'[80]

With regard to the issues for curriculum development in primary mathematics, after naming them as- Education for change, Teaching styles, Processes, New technology, and Our changing society, Hilary Shuard went on to add:

'Thus there are a number of major issues that will need to be tackled in curriculum development in primary mathematics in the next ten years. These issues can only be addressed through the enthusiasm and hard work of primary teachers; it remains true that 'curriculum development' is 'teacher development'.[81]

At the conclusion of the project, one of the outcomes was the publication in 1986 of 'Primary Mathematics Today and Tomorrow', from which quotations have already been used.

Some of the issues mentioned previously, have been taken up by the PrIME Project. PrIME stands for Primary Initiatives in Mathematics Education, and the project was established following the recommendations of the previously described Mathematics 6-13 project.

The PrIME project involves groups of teachers in rethinking the primary mathematics curriculum, and the teaching of mathematics and as an outcome of their work they will prepare teacher's guides and INSET materials.

During the summer of 1986, the first newsletter of the PrIME project was published and distributed to schools. The newsletter indicated that:

'..we shall work to help teachers to make full use of the new technology of calculators and computers in primary mathematics; .. we shall work on the role of parents in their children's mathematical learning; on equal opportunities, and on mathematics in our multicultural society.'[82]

As the work of the PrIME project is ongoing and groups from over 26 LEA's have been working closely together for over a year, it is difficult to evaluate it except to add that a positive response to the needs of teachers must surely be a step in the right direction.

Several other important studies took place concurrently with the last mentioned projects. Among them were the Primary Surveys. These surveys made it clear that the Inspectorate were unimpressed by what they had observed in many schools.

In the report 'Primary Education in England', published in 1978 it was said:

'The findings of this survey do not support the view which is sometimes expressed that primary schools neglect the practice of the basic skills in arithmetic. In the classes inspected considerable attention was paid to computation, measurement and calculations involving sums of money, though these results were disappointing in some respects.'[83]

Further criticism was implied later in the statement that:

'In about a third of the classes, at all ages, the children were spending too much time undertaking somewhat repetitive practice of processes which they had already mastered.'[84]

To the dismay of teachers and advisers, the report went on to say that:

'In over half of these classes the practical activities undertaken were insufficiently demanding, for example, they were often confined to repetitive activities involving measuring and weighing and the children's attention was not drawn to the mathematical implication of what they were doing.'[85]

Later in the HMI Document 'Education 5-9', the account of practical maths in the infant age groups was even more dismal. This document was critical of:

'Those 5 year olds given access to practical activities, made tallies, demonstrated 'more than' and 'less than' and made simple pictorial and block graphs. The practical activities, where they existed, of the 6 and 7 year olds involved the use of a simple abacus and of other apparatus for work in addition and subtraction.'[86]

It had therefore been made clear that the authorities responsible for evaluating the teaching of mathematics in schools were far from impressed by what they had observed. They had observed that even in first schools:

'Teachers devote much time to work with numbers and the practice of the four rules and many children achieve a satisfactory level of competence in this narrow field, but few have sufficient opportunity for learning how to apply the new skills they acquire to the solving of problems... Too few schools make good use of the opportunities for the development and extension of mathematical understanding which arise in children's play, in their interests and in the work in other parts of the curriculum.'[87]

As a further development of the interest shown by the Inspectorate in the area of mathematics teaching, in 1979, a further document was published. This had been in the stages of preparation for several years and therefore repeated many of the suggestions which had already been made in some of the other papers already mentioned. It contained however much sound and practical advice but was published at a time when the innovation of technology into the primary schools in this country was still being planned. It did however contain some very forward looking ideas concerning the use of calculators in primary schools:

'Many children too will have access to a calculator at home if not in the classroom. It therefore seems essential to make sure that our pupils learn to use a calculator correctly and sensibly: and if they do not learn to do this at school, where else will they learn? It is not a task which can be accomplished in one quick lesson, and the foundations need to be laid in good time.'[86]

Throughout the DES document Mathematics 5 to 11, the importance of encouraging the understanding of mathematical ideas was stressed, but the document drew back from making any strong statements about traditional elements of the primary curriculum. The document failed to provide the strong lead which was at that time needed to encourage teachers who were beginning to develop their own maths teaching skills.

Another series of booklets 'Curriculum Matters' written by HM Inspectorate was published in the early 1980's. The third volume in this series, Mathematics from 5 to 16 (DES 1985) is a short book designed to be read by teachers which endorses everything which was contained in the Cockroft Report. Several statements contained in this DES publication are relevant to this study as they seem to endorse the thinking behind this research. Paragraph 4.8 states that:

'The quality of pupils' mathematical thinking as well as their ability to express themselves are considerably enhanced by discussion.'[89]

It also contains advice that:

'The mathematics syllabus should be reduced for the majority of pupils and redesigned in order that they may cover it thoroughly with useful activities at each stage. This would enable pupils to gain confidence and come to be able to tackle mathematical tasks without apprehension. Mathematics must be an experience from which pupils derive pleasure and enjoyment.'[90]

In studying these recent publications concerned with the teaching of mathematics in primary schools, it was felt that by introducing LOGO to the children, a start would be made in carrying out some of the recommendations already mentioned.

During the study of recent research into the use of LOGO with primary age children, it became apparent to the writer that there were many similarities between the claims made by the LOGO users and the recommendations made by recent mathematical reports. In a later chapter a fuller description will be given of these similarities.

CHAPTER 5

The four Cleveland primary schools which took part in this research were selected because of the following criteria:

a) They used Scottish Primary Maths as the main maths scheme.

b) They drew children from a variety of socio-economic backgrounds.

c) The class teachers of the Primary 7 age group were all teachers who used LOGO with their children.

Two of the schools were group 6 schools and the other two were group 3. Of the larger schools only the children aged ten to eleven who were actually taught by the teacher who had taken part in INSET work on LOGO, were used for the research while in the smaller schools, all the children of that age group took part. As it was felt that there should be a maths scheme which was common to all the schools which were to be involved, it was necessary that the scheme should be Scottish Primary Maths as this was the scheme being used in the writer's school.

The scheme Scottish Primary Maths - a development through activity, has its origins in a Working Party on

Mathematics in the Primary School (National Primary Maths Project), which was formed in 1971 to examine the structure and content of a maths course in Scottish Primary Schools. The working party consisted of lecturers from Colleges of Education, Primary Advisers, and H.M. Inspectors of Schools.

The recommendations of the Working Party, served as the basis for initiating a curriculum project in a number of schools and the teachers in these schools contributed to the evaluation of the material produced by the Working Party at each stage. It was decided that the most suitable age at which to begin the project was when children were about seven. There were various reasons for this decision:

1) The variety and wealth of experience normally provided for younger children gave a sound foundation for the work.

2) While many teachers recognized the value of activity in the early years of school, there was a tendency to discontinue this activity in the later years.

3) By this age it was expected that most children would be able to cope reasonably with the reading required for the presentation of mathematics in a written form.

The maths scheme which resulted from the recommendations of the Working Party and the trials which followed in Scottish Schools was published by Heinemann Educational Books Ltd in 1977 as 'Primary Maths - a development through activity'.

Stage 4 of this scheme, commonly used for children aged ten to eleven, was the stage used by the children taking part in this research. This stage consists of Workbook, Workcards, Pupil's Textbook, Teacher's Notes, Teacher's Materials Pack and Answers Book. Work content includes work on Number, Length, Weight, Area, Volume, Time and Shape.

Discussion took place among the four class teachers involved and all were to follow rigidly to the scheme with their Primary 7 children. As an alternative to spending all their maths time working at S.P.M.G., some of the children would work using LOGO. If the tests to be used were to have relevance to the research, it was necessary that the children should all spend equal amounts of time at their maths work whether it was S.P.M.G. or LOGO.

It was felt that children should be drawn from a variety of socio-economic backgrounds in order that test results could not be invalidated on the grounds of same type selection of children.

Following research into the types of tests available which would satisfy the criteria of diagnosing the child's acquisition of mathematical skills, the Bristol Achievement Maths Tests were selected as those which were most suitable.

The Bristol Achievement Maths Test 3 was that recommended for use by children aged ten to eleven. This test includes the testing of those skills which are emphasised in most modern curriculum development programmes. Part 1 of the test examines the understanding of number from the stages of conservation to the level of binary and directional number. Part 2 is concerned with sets and series and with inductive and deductive reasoning. Part 3 examines spatial discrimination and judgement and overlaps to some extent with part 4 which is primarily concerned with measurement and measurement units. Part 5 concedes the need to examine knowledge of conventions and arithmetic laws and proceses but avoids becoming tied to computational accuracy.

'For each of the separate areas of testing, the theoretical basis for the sampling of achievement was the product of an investigation of the psychological, pedagogical and curriculum literature.'[91]

The standardization of the Bristol Achievement tests was undertaken on a national basis, and schools were selected in England and Wales which in terms of their type, urban - rural, character and size, would represent a national sample of children throughout England and Wales. The primary sampling unit was therefore the school, and all the children who were in the appropriate age levels in selected schools were to be involved in the testing.

All tests were marked by teachers in the standardisation schools. Scores were reported on prepared forms and score - age distributions were prepared from these. The statistical methods used in deriving the conversion tables provided with the tests were a combination of "A Method of Calculating Age Allowance," published by Lawley (Lawley D.N.1950) and "A Method of Normalising Distributions," devised by P.L.Grundy and set out in an unpublished document for the National Foundation for Educational Research, N.F.E.R, in March 1956.

The teachers who were involved in the Cleveland study had all been selected by the adviser for computing in Cleveland schools to take part in the development of the use of LOGO within schools in the county. In 1984, these teachers attended a five day course at Cleveland Educational Computing Centre, (C.E.C.C), and then took part in six evening, workshop sessions which took place over a six week period. In 1985, the same teachers took part in follow up work on LOGO using Sprite boards again for a week's session and for six weekly workshop sessions.

All the teachers were given examples of microworlds which they would be able to use with children. These were intended to provide a basis for the teacher's and children's exploration of LOGO.

At the conclusion of the period during which the children used LOGO, all the children whether they had used

LOGO or not, would be given the Assessment of Performance Unit's Mathematics Attitude Questionnaire.

The statements presented in the questionnaire are used by the Assessment of Performance Unit (APU) as part of their assessment framework. They are designed to

'Obtain some general measures of attitude towards mathematics.'[92]

These tests, until now, have only been used on large, national samples and therefore their use in a small scale study such as this, must be cautiously regarded as an approximation of the attitudes measured. The statements contained in the questionnaire are designed to obtain information as to how the pupils appear to like mathematics, how useful they see mathematics as being, and how difficult they perceive maths to be as a subject.

Attitudes of pre-adolescent pupils towards mathematics have received less attention than that paid to the attitudes of secondary school pupils. The reasons for this are that at the present time, pupils in primary schools do not have the opportunity to withdraw from maths as do older pupils in secondary school. Whether they enjoy maths or not they are bound to participate in maths lessons. Also, it was felt for a long time that pupil's abilities are considered to be less differentiated at this age, as is the school curriculum. It may be argued however that later success and involvement in mathematics is rooted in early attitudes towards the subject. It is felt that for this one reason alone, the attitudes towards mathematics, of the the children taking part in this research should not be ignored.

The Assessment of Performance Unit (APU) was set up in 1975 within the Department of Education and Science, to provide information about the levels of performance of school pupils over a period of years. Its first report Mathematical development, Primary survey report No 1 was published in 1980. Covered in the first survey of 1978, was mathematics for 11 year old pupils in England and Wales. Its second report Mathematical development, Secondary survey report No 1 looked at the performance in mathematics of 15 year old pupils in the same year, 1978. These two surveys are the first of a series to be carried out on behalf of the APU, by the National Foundation for Educational Research. With some additions and minor changes, the second primary mathematics survey, followed the pattern established by the first. It stated that:

> 'Active cooperation from the LEAs and teachers was again forthcoming. Written tests were administered to about 14,500 pupils, the increase of 1,500 over the 1978 sample, being due to particiation for the first time of 11 year old pupils from Northern Ireland in the 1979 survey.'[93]

As in the previous survey, a sub-sample of 1,000 pupils again took an additional practical test administerd by experienced teachers. Another sub- sample of 1,200 pupils completed the attitude questionnaire administered by their own teachers about their views about mathematics as a whole and the various topics within it. Unlike the previous sample, this one was drawn from a larger number of schools than in 1978. The total number of schools involved was 100, the same as was previously and once again, their anonymity was safeguarded.

The Primary Survey Report No 3 'Mathematical Development', was published in 1982 by the Department of Education and Science. It is an account of the results of a third survey in an initial series of five concerned with assessing the mathematical performance of pupils in England and Wales and Northern Ireland. Pupils in the survey sample, reached the age of eleven during the year 1980-81. This is the age of the children being used in this research into the use of LOGO as a means of developing a child's mathematical problem solving skills.

In the second primary survey report, greater emphasis was given to a deeper analysis and comment in a selected area of mathematics than was possible within the broad sweep of the first report. The report contains some comparisons between the results for 1978 and 1979, based on the practical testing, the attitude results and the sub-category scores and background variables. It is emphasised that no valid conclusions about trends over the time can be drawn from these initial comparisons from only two surveys.

The framework on which the tests were constructed was amended slightly for the second survey. These changes did not affect the content of the tests as such.

The content of the assessment framework had three main headings, Mathematical, Everyday, and Other subject. These were further categorized as Measures, Geometry, Number, Algebra, and Probability and Statistics. Measures contained the concepts and skills associated with money, time, mass, temperaure, length, area, volume and capacity. Geometry contained the skills and concepts of shapes, angles, lines, symmetry, transformations and coordinates. Under the category of Number were the concepts of natural number which led to the skills of computation both of naturals and decimals, and the concepts of decimals and fractions which led to the assessment of the skills of fractions and application of number. Also under the number category was rate and ratio. Algebra was interpreted by the APU as containing generalized arithmetic and sets and relations, while Probability and statistics was defined as containing the concepts and skills of probability and data representation.

The practical tests for the second survey again fell under the same headings as were stated for the assessment framework. The practical topic for number was the concept of decimals and fractions, and the concept of whole numbers. This was tested by the use of string and plastic shapes which formed continuous and discrete objects. For the testing of whole numbers, number rods were used to find patterns in the partitions of whole numbers. For Geometry, the practical testing involved the child's knowledge of lines, shapes and angles. They were asked to classify shapes, estimate and measure angles, construct brick models from diagrams and recognize and construct symmetrical patterns. In order to assess the child's practical knowledge of measures, they were given tasks associated with giving change, weighing blocks and plasticine using a balance, and estimating and measuring both straight and curved lines. For the probability test, they were given the task of predicting and recording the outcomes of chance events.

Overall in 1979, the tests involved the understanding of measuring instruments such as the ruler and the protractor, and the use of apparatus such as a balance, and everyday materials such as scissors, string, paper and pegs to carry out tasks which involved mathematical concepts and activities.

The attitude questionnaire of 1979 was identical with that used in 1978, but the sample although of the same size was spread more thinly over more schools in order to reproduce a more representative picture.

The aim of the APU was to produce an overall national picture of certain aspects of actual pupil performance. It was not concerned with the assessment of the child as an individual.

In referring to the work of the APU, the writer of this study intended that comparison could be made between the findings of the APU Surveys and those from the work carried out for this particular research.

The programme of LOGO work which was carried out is described in Chapter 6.

CHAPTER 6

In preparing to introduce LOGO work to groups of ten and eleven year olds, it was essential that a uniform plan of work should be used.

Projects which had recently been carried out in Britain were studied. During recent years several of these projects had been carried out using the floor and screen turtles. In Lancashire, a 'Primary School Experiment' was set up in a junior school. This was:

> 'A controlled experiment involving the use of floor and screen turtles with two groups of fourth year primary children.'[94]

From the diary which was kept on this project, valuable information was gained as to which problems to avoid. Several organizational problems which had arisen during the Lancashire project, and tactics which could have been used to avoid them were discussed by the teachers taking part in this research.

As all the teachers in the Cleveland project were using a Logotron LOGO chip and disc drive on which to save the children's work, problems such as the tape not loading the program would not arise.

Another Lancashire problem was that the teacher had borrowed a BBC computer to use with the children and had numerous problems in making it work. Such problems as:

'The message was BAD COMMAND AT 100 so I LISTed 100 and found FX2.2. I did not have a Beeb manual with me so I borrowed the schools: the particular command referred to was not listed.'[95]

Following discussion on this problem, it was decided that a computer in each of the four participating schools should be set aside for the use of LOGO. Hopefully there would be no problems then with erratic machines.

As the Lancashire teacher was working with children with whom she was unfamiliar, it was felt that there would be a certain advantage in the fact that the children taking part in the Cleveland project were working in their own classroom situation.

After two weeks of the Lancashire project the teacher wrote:

'The previous fortnight had been so bedevilled with problems concerned with this endeavour that it seemed hardly possible that any turtle sessions would take place at all...'[96]

By learning from the mistakes made during the Lancashire project, it was expected that some problems could be eliminated from the present research.

Another project which was referred to in the preparation of the Cleveland project was that carried out in an infant school in Devon. This study was aimed at:

> '..observing the reactions made by a selected group of 7- year olds, to a version of the programming language LOGO and to the turtle. It aimed to give the reader an insight into the thinking behind the actions made and the decisions taken by the children, in order that the value of the turtle as a teaching aid may be judged.'[97]

The children who had been selected for the purpose of the Devon study were all of average or above average ability. After following the programme of work prepared for them, it was observed that:

> 'Although the groups were small and a lot of attention was given to the children, it was evident that they were developing a degree of independence .....the children were coming into contact with concepts and skills which in conventional classrooms would be difficult to teach: as such I believe that the turtle earns its place in the classroom.'[98]

The children taking part in the Cleveland project were not all of average or above average ability, some were of below average ability. They had all chosen to 'learn' LOGO and it was decided that they should be given the opportunity to do so regardless of ability.

The teachers, who were taking part in the Cleveland study, discussed among themselves the skills each of them hoped would be developed in their children as a result of their participation in this small project.

Their list of skills was similar to the list of basic skills which had already been summarized by Christopher Schenk in his article 'LOGO philosophy and the progressive tradition in primary education'. These were:

'To encourage independent learning,
To develop mathematical concepts through activity and investigation,
To gain insight through programming.'[99]

Some of the ideas used by Beryl Maxwell during the Walsall LOGO Project were identifed as being particularly relevant to the Cleveland teachers. Among them were:

'Separate folders were kept for the fourth year children for the 'turtle work'. I kept a diary to record each individual group's work. This indicated the date of the work and the picture drawn. This I found necessary with every child 'turtling', so that I could monitor the stage they reached and see if progress was being made.'[100]

The teachers' group then set about designing a basic plan of LOGO work which would be followed by all the participating children.

Using some of the ideas to which the teachers themselves had been introduced during their own training sessions, and some used in the course of the Walsall Project, they drew up a skeleton plan of work. This was:

a) the children would use screen turtle graphics,

b) use of the screen turtle with procedures,

c) floor turtle with graphics using direct drive,

d) floor turtle with graphics using procedures,

e) branching story microworld,

f) mazes microworld.

Initially, it was decided, the children should be given the basic commands needed in order that they could begin to use screen turtle graphics.

The basic commands, which it was felt, the children should be introduced to were FORWARD, BACKWARD, RIGHT, and LEFT. These were presented to the children in the form of a workcard (Appendix 1) The next stage, was to use the command PENUP, PENDOWN and REPEAT (Appendix 2). How to set up a procedure, was the next step in their LOGO work. (Appendix 3)

The workcard was given to each group of children to enable them to begin to use LOGO immediately.

The work they did during these stages was discovery work. They set their own tasks for their group to work on and directed their own learning. (Appendix 4-9)

Once the children were confident in the use of these commands and the setting up of procedures, they were introduced to the intricacies of the floor turtle.

They were shown how to set the turtle in action, how to avoid tangling the cord from the turtle to the computer, and then they were left to explore its possibilities.

The children were still instructed to use the commands which had been listed previously, the idea being that they would explore and adapt them, in order to extend their usage.

In order to carry out this work successfully, the children were given workcards to enable them to explore the difference between the size of the screen turtle moves and that of the floor turtle. (Appendix 10)

For the branching story microworld, it was decided that preparatory work should be done away from the computer.

This microworld:

'..allows the children and teachers to develop and use branching storylines, which can be used as the basis for further language based computing work for yet other children. The Microworld tools required are minimal and the majority of LOGO work done by the children uses the primitive commands.'[101]

The children were introduced to the branching story microworld by means of a skeleton plan of a short branching story. (Appendix 11)

Next the children had to create their own story which had a maximum of two minor branches from each main branch. The idea of this restriction was that they would be able to concenrate on the plot of their story without too many diversions.

Once they had grasped the idea of what was meant by a branching story, the children were given basic instructions, again in the form of a workcard, which would enable them to begin to program their own branching story. Five simple routines were initially described, these were new to the children. The routines were TO PRINTERON, TO PRINTEROFF, and PRINT OPPS. (Appendix 12)

To facilitate their introduction to the branching story, the children were next shown how TO START and how to ensure that the credits were given to them as authors by using the procedure TO WHO. (Appendix 13)

Once a group of children had completed a branching story, it was intended that:

> 'Once the microworld has been created,, it can be used by typing START. From the text presented, make a decision and type in one of the words in capital letters. Continue reading the story presented and continue making decisions until the end of the story.'[102]

The maze microworld which was selected for use during the period of the Cleveland project was one of the microworlds used by the teachers during their in-service training in the use of LOGO. This microworld:

> '..allows children and teachers to design and negotiate a maze which may be as complex as is desired.'[103]

Prior to their actual introduction to the maze microworld, the children were given practice in playing a 'battleship' type game. Instead of having to find hidden ships, they had to discover where their partners had hidden the walls of their maze. (Appendix 14)

The maze they would build in their microworld would:

> '.. be based on interconnecting boxes. They consist of cells or rooms with names, which are either joined together or separated by walls. Each cell is defined by the children and this cell definition must carry with it all the legal approaches to that cell.[104]

A map of a maze can be found in Appendix 15. A maze microworld prepared by the class teacher was given to the children so that they would have a clearer idea of what the microworld contained.

Workcards which stated the tools or procedures they would need to use were given to the children and an explanation of these tools was to be discussed before the children began to design their own maze microworld. (Appendix 16)

It was the opinion of the original designer of the maze microworld that:

'Each maze exists only in the child's mind, as this LOGO microworld does not initially draw the maze.'[105]

The intention of the maze designer was that:

'This activity should enable another child, or preferably a group, to build up a map of the maze by systematically exploring it, filling in walls wherever they are met.'[106]

Some of the work carried out by the children in the area of maze microworlds can be seen in Chapter 7.

This plan of work was therefore common to all the teachers who were involved in the Cleveland project. The amount which was covered by each child was expected to vary with the individual child but it was felt that the children would be motivated to develop their ideas to the full.

CHAPTER 7

In attempting to describe some of the conversation which took place during the LOGO sessions, it was necessary to concentrate on the work of two groups. This enabled the writer to carry out a fuller study than would have been possible if this particular aspect had been extended to include all the children taking part in the research. In addition to these two groups of children being closely listened to during their work, a cassette recorder was placed near enough to them to record their conversation. This ensured that a finer analysis could be made at a later date than was possible during the LOGO sessions.

The two groups were chosen not because of any particular ability associated with the LOGO work but because of their ability to work and carry on without inhibitions during the recording.

Group A was a group of four girls and group B was a group of three boys. The children selected their own groups and no attempt was made to pressurize them into varying their choice. It was felt that if they were comfortable working in single sex groups, then this would add to the benefit they could gain from their LOGO sessions. The only stipulation made by the teacher was that once these groups had been selected, they would not be changed for any reason whatsoever.

From the first workcard (Appendix 1) Group A investigated the ability of the screen turtle to first of all draw lines of differing lengths on the screen. Then they spent time working out the number of turns the turtle had to make to make a right angle on the screen.

It was then suggested to them that they should find out how far the turtle would travel in different directions. Some of the conversation was:

Suzanne- You see how far it'll go along that way.

Tanya - You'll have to turn it round so's it's pointing the right way.

Kelsey - Turn it round for 90 like we did to get a right angle and see what happens.

Lisa - It hasn't moved.

Tanya - I bet that's cos we didn't tell it to go forward.

Lisa - If we draw that line we could double it cos the turtle is starting in the middle of the screen, and then we'll know how far it's along that way.

Tanya - Hurry up Suzanne it's my turn next.

Teacher - How far do you think you will have to tell the turtle to move to do what you want it to do?

Lisa - About 400 I think.

Tanya - I think it's more than that, I'll say 520.

Kelsey - I don't think it's that much, about 500 I think.

Suzanne - I'm going to say 450 because I don't think 400's enough but you two have guessed too big.

Suzanne typed in FORWARD 450

Lisa - That's not far enough, I was miles out wasn't I?

Tanya - It's nearly to the side of the screen. I said 520 that would have made it get nearer to the side so I was the nearest.

Teacher - How much further do you think you should have made the turtle go?

Lisa - About 150.

Kelsey - No that's too much about 100 I think.

Tanya - I'll say 125 then.

Suzanne - I'm guessing 175 then.

At this stage in their work, the children did not appear to be thinking logically. They appeared to be merely manipulating numbers. They were either adding to or subtracting from numbers previously mentioned by other members of the group. They were not using concrete examples by referring to the actual length of the line drawn on the screen, they were merely juggling with ideas expressed by other members.

The children were fitting into the pattern of the theory of Edward De Bono in Chapter 2 that young children are not very good at expressing their ideas in words. (page 14)

Suzanne typed in Forward 175 and the turtle disappeared from the right side of the screen and appeared again on the left. This discovery led them to further discussion.

Lisa - That was really good Suzanne, but it's gone too far. How can we get it to go back so we can start again?

Teacher - Before I tell you that, let's look at what has happened and what you've done so far.

Tanya - We made the turtle go forward for 450 but that wasn't enough, so we made it go for another 175 but that made it go off the screen and come up on the other side.

Teacher - So can anyone tell me another way you could have used to find out how wide the screen is?

Kelsey - Yes we could've told the turtle to go forward for about 1000 and it would have come back to where it started. It would be a good idea if we had wrote the numbers down and then we could have remembered them better.

At this stage the teacher provided the children with an exercise book which consisted of pages made up of half a drawing page and half a lined page. They then attempted to remember what each of them had suggested for the distance the turtle would travel. They argued about their numbers and could not accurately remember. The teacher then suggested that they should have another try and use their notebooks if they wished. In order to do this they had first to be told how to get the turtle back to where it had started. The teacher told them that the HOME command would do this and Kelsey suggested that they should write this in their books.

On the second attempt Lisa insisted on following up the suggestion which she had made previously, that was to draw the line to the side of the screen and then double the number to find out how far the turtle would need to go forward to cover the width of the screen. She typed in Forward 600 and the turtle moved to a fraction away from the edge of the screen. The children said that was near enough and told her to get the turtle back and see what happened if she told it to go forward for double that amount. Suzanne reminded Lisa that she needed to type in HOME to start again.

The children became very excited when Lisa typed in HOME and then FORWARD 1200, and the turtle appeared to travel for the width of the screen and come back to where it had started. The teacher then pointed out that because of the actual size of the screen turtle, they could not really see if they were accurate. She suggested that thay should try to make the turtle disappear. After typing in a variety of words, such as GO AWAY, GET OFF, DISAPPEAR and SCRAM, none of which had any effect on the turtle, the teacher asked them what exactly they wanted the turtle to do and got the immediate response from Lisa "Hide itself." They were then congratulated on their efforts and given the new command HT which would hide the turtle. After typing in HT the children discovered that in fact the line drawn by the turtle did not quite come back to where it had started. After further investigation, the children found that the screen was approximately 1274 wide and following further experimentation they found out that the screen was approximately 764 from top to bottom.

It was felt that the investigation of the screen size would possibly provide the children with something concrete which they would be able to apply to future screen turtle work.

The words of Edward De Bono (page 14) seem to adequately describe the children's development at this stage in their problem solving work. He stated that although problem solving seemed to be a rather specialized part of thinking, the name could possibly be changed to dealing with a situation, or overcoming an obstacle. This description could be applied accurately to the previously mentioned work pattern of the group of children.

At their own suggestion, the children then wrote a short account of what they had done. Lisa's account was:

'We tried a lot of different numbers to see if the turtle would go from the middle of the screen to the right hand side. Some of us tried numbers which were too big and the one I said at first was too small. Then the teacher showed us how to get the turtle back where it had started and we tried again and again. In the end we managed to do what we wanted. It helped us when we wrote down hints from our tries before. I think my idea was a good one to double the number it took to get the turtle from the middle to the side. We got the number it took to take the turtle right round and back where it had started. It was 1274. Then we tried to find out how far it was from the bottom of the screen to the top and it was 764'

It was obvious that the children were using some of the thinking processes stated by Piaget. They were using concrete operations to build up their ability to solve the particular problem. They were also using a method prescribed by Kruteskii, that of verbalising their thoughts. The interaction between members of the group was enabling them to work as one and each member was aiding the others.

Group A went on to draw recognised shapes on the screen, e.g. a house, a tree, and a dog.

They were quite happy exploring this activity. The pictures they drew were their own idea. At first they had a problem with the turns the turle made. Lisa became quite excited when she continually turned the turtle the wrong way. The discussion which took place briefly was:

Lisa – I'm going to do a house.

Tanya – That'll be hard cos there's corners on it.

Lisa drew a line by typing FORWARD 100 and then tried to turn the turtle right for 90 but typed in LEFT 90. She was convinced that there was something wrong with the turtle as it had not done what she wanted.

The other members of the group saw what she was doing wrong but were told not to tell her. The teacher felt that she should be allowed to work at this problem by herself. Once she had discovered her mistake, there were no more problems of that type from that group.

During this conversation, elements of the problem solving process as described by Gagne (page 21) were apparent. The learner (Lisa) knew the subordinate rules and was searching her memory to provide the information she needed at that time.

Working concurrently, the second group had been progressing along similar lines. The boys had discovered how far the turtle would travel across the screen and from top to bottom without any problems. They were not very interested in using paper and pencil to record their thinking out process, but after seeing that the girls could describe their activity away from the computer by referring to their notes, Group B also decided to make an attempt at recording their thoughts and ideas.

Once the children had reached the stage where they were confident using the commands they had been introduced to, they were given their second workcard with the commands PENDOWN, PENUP and REPEAT. They were left to explore these commands. Group B discovered that they could now draw a house and put a door where they wanted by using the command PENUP. Until then they had been drawing a door by moving along a previously drawn line and then instructing the turtle to draw.

Before the children began working on the REPEAT command there was some group discussion about how a square would be drawn:

Teacher - Some of you have already drawn a square, can you remember what you told the turtle to do?

Kelsey - I've got some notes on what our group did.

Suzanne - I didn't write anything down, can I share with you?

Teacher - Don't you think it would be a good idea if you kept a note of your own ideas instead of relying on other peoples?

Kelsey - We typed FD 200 RT 90 FD 200 RT 90 FD 200 RT 90 FD 200 and that drew a square.

Teacher - Did you notice anything about your instructions to the turtle?

Tanya - I did we kept on having to tell it to do the same thing over and over.

Lisa - There might be a quicker way of doing that.

Teacher - I'll show you an easier way if you want.

Kelsey - Can I write it down?

Teacher - Not yet, let's talk about it first. Has anyone any ideas of how we could save space in our program?

Lisa - Yes, we could have told it to do the forward and right turn twice and that would have saved typing in two of the instructions.

Suzanne - Why couldn't we have told it to do the same thing four times and that would have saved a lot more space?

Teacher - That sounds like a good idea Suzanne, but what would you need to instruct the turtle to do?

Suzanne - Well it would go forward four times and turn right four times.

Teacher - You try that then. Type REPEAT 4 if you want the turtle to do the same thing four times. Then you need this type of brackets. Inside the brackets you put all that you want the turtle to do. Now think carefully before you go any further.

Tanya - I think I know what to tell it. FD 200. Then it'll draw the four sides of the square.

Teacher - Are you sure?

Suzanne - Well we want four sides that are 200 long so we'll have to tell it that.

Teacher - Try that then.

After typing the instructions REPEAT 4[FD 200] and pressing the RETURN key, the turtle proceeded to draw a line 800 long which wrapped around the screen and appeared again on the left side. The children were immediately aware of what they had forgotten. They all said at once "We didn't tell it to turn for 90." For their second attempt, they typed in REPEAT 4[FD 200 RT 90] and the turtle drew a square as they had wished. All the groups of children working at LOGO, were encouraged to discover for themselves how to use the REPEAT command as it was felt that by doing their own thinking they would be more likely to remember the process, rather than if they had merely been presented with the command and told what to do.

The approach of the children at this stage in their work would fall into the pattern that Krutetskii described.(page 19) This was of the child who thinks in verbal, logical terms, or the child who thinks in visual-pictorial terms, or the child who combines both these characteristics.

They were also coming close to the heuristic definition (page 21). This was the development of a general strategy which would help them to approach, understand and efficiently use their resources in solving problems.

Group B, the boy's group did not have the same problem as Group A, the girl's group. They saw at once that they must tell the turtle to go forward and then right, and they drew a square at the first attempt.

At this stage in the development of their problem solving skills, the children were displaying some of the traits described in Chapter 2 as being defined by Lester viz. the 'open search' level of mathematical thinking. They were memorizing facts, rules and procedures which they were able to reproduce when necessary. They could also transfer learning from one context to another.

The children worked for some time using the commands to which they had been introduced. They drew pictures of yachts by using the REPEAT to draw triangles for the sails. They drew their initials and wrote down their program in their note books. Then they read through their program to see if they could have used REPEAT to make their program more compact.

The work on this section took the children two weeks. Each group had one hour's computer time every alternate day. This meant that a total of five hours exploration had been given to each of the groups at the end of a fortnight. At the end of this time some of the children were not confident enough to wish to go further, but some of the children proceeded to the next stage.

The next stage was the conversion of known facts to drive the floor turtle. At first, Group B attempted to find out how many the turtle needed to travel to go along the side of a large piece of paper. They were astonished to discover thet if they told the turtle to go forward for 200, it travelled many times further than the screen turtle did.

Some of their conversation went:

Chris - Type in FD 200 Ben.

Ben - O.K. It'll be an easy one this.

Teacher - Now watch carefully to see what happens, even though you think it's so easy.

Ben - It's going miles. Stop it or it'll draw on the tiles.

Teacher - Press escape.

Ben - It says STOPPED on the screen.

Teacher - Well that's what you've just done, you've stopped it moving haven't you? Now let's see what you've done wrong.

Chris - The floor turtle must go much farther for 200 than the screen one does. I think it's about four times as far.

Teacher - What do you think Matthew, you've been very quiet?

Matthew - I think it must be more than that I think it'll be about ten times farther.

Ben - No, not as much as that, about seven times I think.

Teacher - Well who wants to see who was the nearest?

Ben - I will.

Ben decided to type in the amount of moves which corresponded to his guess, and he said that 200 divided by seven was about 30. He typed FORWARD 30. The turtle drew a line which was still too long. After much discussion, the group agreed that after seeing how far the turtle moved when moving a distance seven times less, that perhaps ten times less would have been a more appropriate number to choose. On typing in FORWARD 20, the turtle moved along the paper for the expected distance. Group B then wrote in their books that to change a screen turtle program to a floor turtle one, they had to divide the amounts they had used by ten. They then went on to investigate what happened to the amount of turn the floor turtle made when making right angles and discovered that this was still the same as it had been using the screen turtle.

As the little programs which the children were designing became longer it was not practical for them to keep on using direct drive where the turtle responds immediately to instructions. As each group became profficient in using both the screen and floor turtle, they were encouraged to begin to write their programs using procedures. To enable them to do this, they were given the third workcard. This gave them examples of procedures and the card was explained to them by the teacher. (Appendix 3)

At first, the children found that waiting until they had typed in a whole procedure before the turtle responded to their instructions, rather frustrating. One example of this was the discussion which took place in Group A, the girls' group.

Lisa - I'm going to try to draw a square on the right of the screen, one on the left and one in the middle. The square's the easiest to do.

Tanya - I fancied doing that because it's dead simple, now I'll have to do something else.

Lisa - I'll do a procedure for it.

Suzanne - You'll have to do PENUP for it or you'll get a line drawn between the squares.

Lisa - I know that, but that's not hard.

She typed in

```
TO PATTERN

REPEAT 4[FD 150 RT 90]

PENUP

FD
```

and then she became unsure of her next move. She asked:

Lisa - How far shall I move along before I draw the next square?

Tanya - Well, it's about 1270 along so if you're going to draw a square that's 150 along the side, you'll have to half 1270 and then take off 150 because that's how long the side is.

Suzanne - And then you'll have to move the turtle so that it's 150 away from the edge of the screen, so you'll have to take off another 150.

Lisa - That's what I was going to do, but will the turtle be pointing the right way?

Suzanne - Of course it will.

Lisa finished off her procedure

FD 335

REPEAT 4[FD 150 RT 90]

END

She decided to see how that procedure would work before trying to draw the third square. It was obvious that by now she was beginning to have second thoughts about the difficulty of her chosen design. On typing in PATTERN, the screen turtle drew a square from the centre point of the screen and then moved around an invisible square.

Lisa - What's gone wrong. Miss, the turtle's broken it's not drawing anymore.

Teacher - Let's have a look and see what's wrong, then.

Lisa - But we can't see what we typed in anymore.

Teacher - Yes you can, Type EDIT "PATTERN and you'll be able to see your procedure again.

One of the group did this and the procedure appeared on the screen again. Lisa suggested that they should make a note of how to get the procedure back again. They all wrote down the instructions in their note books. At this stage the teacher felt that it would be more beneficial for the children to make their own notes rather than have any more facts presented to them in the form of a workcard.

On reading through their procedure on the screen, Lisa spotted her own mistake.

Lisa - I've told the turtle to PENUP but I haven't told it to PENDOWN, That's why it's drawn an invisible square.

They were shown how to EDIT their procedure, make the correction they thought necessary and come out from the EDIT mode. Again they chose to make their own notes of the instructions. They were very pleased with themselves and Lisa typed in again PATTERN. This time the turtle drew a square from the centre of the screen, moved up the screen for 150 and proceeded to draw another square above the first square. Panic set in, and they began to argue that the turtle was not working correctly. They looked at what the turtle had done and discussed what could have gone wrong. Tanya decided that the turtle was not pointing the right way when it had started to draw the second square, and after further discussion, they came to the conclusion that they would have to turn the turtle right for 90 before they told it to go forward to where they wanted the second square to begin.

Again, the children were using one of the methods described by Gagne on page 20. They were able to transfer learning from one context to another.

They EDITed their procedure again, and added the correct instruction, so that their procedure read:

TO PATTERN

```
REPEAT 4[FD 150 RT 90]
PENUP
RT 90
FD 335
PENDOWN
REPEAT 4[FD 150 RT 90]
END
```

On typing in PATTERN, the turtle drew one square from the centre of the screen and another on the right hand side of the screen. The teacher then discussed with them how they would get the turtle to complete the third square. As they had used up all their time for that day on the computer, the group moved away and began to discuss their problem theoretically.

They realized that they would have to turn the turtle round again and went to great lengths to calculate the distance the turtle would move before beginning to draw again. What they had not taken into account was the fact that the first square which was drawn was not central. It began in the centre of the screen and the square was off centre by half of its side length.

During their next session on the computer the group tried out their ideas. After three attempts and a great deal of further discussion, they succeeded in writing the procedure they had initially described as easy.

The problems which had occurred had been seen as a challenge by the children. Although they grumbled and groaned when their procedure did not work the way they had envisaged, they were eager to continue with their work and protested when their time using the computer was up.

The definition of Lester (Chapter 1 page 20), that the learner knows subordinate rules and searches the memory to find and implement them appears to describe the way that the children were working at that time.

Next, the group attempted to use procedures to drive the floor turtle. As they were involved in a class project around Beamish Museum, they decided to attempt to draw some of the things they had seen during their visit there. Group B drew a coal truck using several smaller procedures built into a much larger one. They spent a great deal of time discussing their design and several of their computer sessions were spent in perfecting their work. In all, the design took them three hour sessions to complete. At the end of that time they had produced a detailed picture of a coal truck.

During their planning, they had to use knowledge they had already gathered, adapt some of it, and add to it by experimentation. They displayed traits which could be likened to Piaget's theory on the development of thinking. They were using experiences they had already had and building on them to achieve a deeper level of understanding of the problem in hand. They were also still following the recommendations of Kruteskii and verbalising their problem solving activities.

After each session using LOGO, each group spent time discussing their work. From this feedback, they often obtained ideas which helped them in future exploration with LOGO. It seemed that they were in fact practising some of the theories put forward by Seymour Papert in his book Mindstorms and which were quoted previously in Chapter 3.

As a further step towards LOGO familiarisation, the children were introduced to branching stories. This happened when it was felt that they were competent in the use of procedures. The teacher discovered that words like procedures, editing, discussing, adapting, debugging, and simplifying now fell easily off their tongues. They argued their point with confidence and could apply observations from their previous work to new problems.

Branching stories were introduced to them as has previously been described in Chapter 6. (Appendix 11 and 12)

It was essential that they spent time in planning this work away from the computer and that they should fully understand the aim of this part of LOGO work before they attempted to carry it out.

After examining the description of a branching story and discussing it among themselves, they set about planning their own story. At the time, the class theme for the term was based on the computer program Adventure Island, so they decided to write a branching story using a similar idea.

The work and discussion carried out by Group B was closely followed.

The first procedure TO WHO was a procedure which prints the credits for the story. They referred to their workcard to ensure that they had correctly formed the procedure. One of the boys, the most nimble fingered of the group, was elected as typist. He typed in their prepared procedure but when it was carried out, they were dismayed to find some faults. There followed a rather heated discussion as to where the fault lay:

Ben - That's not what we told you to put, we wanted the writing to come halfway down the screen, it looks daft up there.

Christopher - I've just typed what we all agreed on. I'll edit it.

Matthew - It looks allright. Maybe if we started the procedure further down the screen, it'd print further down.

Christopher - Right I'll try that but it doesn't sound a very good idea, I can't see how it will have any effect on where the writing comes.

Ben - You're right, it hasn't made a scrap of difference. Edit it again and let's have a look.

Christopher - What we want is a space before we begin to write. That means we'll have to have a space for our first line.

Matthew - Yes but we want more than one space we don't want our writing to begin only one line away from the top of the screen.

Christopher - O.K. then, I'll type in space for the first few lines of printing and that should work.

After typing in several lines of procedure which contained no words to be printed out, they ran their procedure using Ben's name as the first line of writing following six lines of spacing. The name was printed halfway down the screen just where they had wanted it to be. They were very pleased with their success and went on:

Ben - We're brilliant aren't we, that was a great idea. Now we can get going with the rest.

Matthew - Yes, Chris get on with the typing.

Christopher - It's going to take ages to type cos we'll want all the story to be printed out down the screen and every procedure'll have to begin with lines of spacing.

Ben - Unless we can make a procedure that'll give us a space every time.

Christopher - That should be the best way, if we can manage it. We'll call it TO SPACE eh?

Matthew - Yes and then every time we tell it to space, it'll leave a space before it begins to write.

Ben - It mightn't work but it's worth trying.

Christopher - Of course it'll work, you've just been saying how brilliant we were.

This conversation of the group was evidence of Piaget's theory (page 12) that from the age of eleven the child can begin to think without reference to actual objects and can hypothesise and work out logical consequences.

They proceeded to type in the rest of their procedure TO WHO and then ran it. To their dismay, the words were not complete on some of the lines. Unlike Wordwise which they were accustomed to using, LOGO does not automatically place words on new lines if they have too many characters for the previous line. This meant that they had to edit the procedure several times until they were satisfied with their screen presentation. Finally after four corrections, their procedure worked the way they wanted it to. Their time had not been wasted. They had learnt many facts which they would find useful with the rest of their branching story work and their knowledge would make each further stage so much more comprehensible.

At one stage in their story they became rather confused because they had not typed in their procedures in the order in which they would appear if they were called up. This led to them trying out parts of their branching story and being met with the message 'I DON'T KNOW HOW TO .' from the computer. Again they had to edit the contents of their procedures to find out where they had gone wrong and as time went on they were more careful to enter the procedures in the order required.

Krutetskii, the Russian researcher, would have seen in the chidren's work at this stage, elements of his own findings. As had been described in Chapter 2 (page 18), the children were gathering information, processing that information and retaining information about the solution. They were also confirming the statement made by De Bono (page 15) that difference of approach was a characteristic of their thinking. Once the story was completed to their satisfaction, they took great pride in encouraging their classmates to work through it to try to find the treasure at the end of the story. Later in this chapter, it is described how this group developed their work further using an idea of their own.

From branching stories, the children progressed to using and building a maze microworld. As has been described in the previous chapter, the children worked through a maze microworld which had been programmed by the class teacher and then played maze battleships, (Appendix 14). This gave them a fuller idea of what the microworld involved rather than just working through sets of instructions.

When it was felt that they understood the possibilities which the microworld offered, they were encouraged to plan their own. This was done away from the computer. The groups worked together and talked through what they wanted to achieve from this part of their LOGO work. Group B, decided that if possible, they wanted to incorporate their maze microworld into their branching story microworld at some later stage. Group A was not as ambitious as this, they merely sought to plan, program and execute a maze microworld which was more complicated than that designed by the class teacher.

Both groups were working simultaneously on their microworlds, but neither group offered information to the other as to how they were progressing. At this stage they seemed to be competing against each other in an attempt to be the first to succeed in this new branch of LOGO work.

They first planned out their maze on paper by drawing it and colouring in where they wanted their walls to be. Then, working from the workcard of procedures which had been prepared for them (Appendix 16), they began to type in their procedures. At this stage they felt confident enough to type them directly into the computer without writing them down beforehand. As this was being done, the children were discussing thoroughly what they were doing and the quality of their discussion was interesting.

Ben - We've written the first procedures for the microworld because all we need to do is to put our own words instead of the ones on the workcard.

Christopher - Yes, but we'll have to keep the procedure for TO CHECK the same, we can't alter that because the computer has to come back to that one every time to check if there's a wall there.

Matthew - We know that, we'll have to keep TO ROOM the same as on the workcard as well because that has to keep the same for the program to work properly.

Christopher - Right we'll get those two typed in first and we'll save them because we've only got ten minutes computer time left.

Ben - That's a good idea, because remember the other day, we forgot to save our work because the girls were hassling us to get their turn on the computer, so if we save theprogram in parts that'll make sure we don't lose our work again.

Matthew - Right, let's see if we can get some of the rooms typed in before we have to stop. We haven't written them down but they should be able to go straight into our program if we watch what we're doing.

Christopher - I've got room A1 in my mind, I'll type it in and see what you think.

He typed in the first procedure for room A1 and the boys all looked carefully at it.

Ben - That looks O.K. You've got the room number first and then it's also the last number inside the brackets the way it's supposed to be. Check and see if the rooms we want room A1 to be joined to are in the brackets as well.

Matthew - That looks as if it'll work, we'd better work through the rooms in order then we'll be able to keep checking what we've done.

Christopher - That's a good idea, then we can change things as we go along instead of finding out mistakes when we think we've finished.

Ben - That procedure for room A3 isn't right, cos you've put A5 into the brackets and you couldn't go from A3 to A5 cos that's more than one move.

Christopher - Yes, that's a mistake, it should be A4 shouldn't it? I know, why don't we to go to A4 and B3 from A3 but block the route from A3 back to A2 by leaving A2 out of the procedure.

Ben - That's a great idea, that's going to make our maze much harder for the others to work through because walls will be appearing and disappearing depending on whether you're going forwards or backwards through the maze.

The boys' thinking had reached a new level. They were now carrying out investigations which were far superior to anything previously expected of them by the class teacher. They were anticipating results and eager to develop their microworld to as great a depth as possible.

They were displaying elements of the ideas expressed by Polya (page 22) that they should ask themselves the questions had they seen the problem before in a different form, could they use information they had gained from previous work?

The programming sessions for the maze microworld took nearly four weeks. During that time the children were continually trying out their procedures and changing them as they went along in order to ensure that on completion, they would be able to execute their microworld without any problems occuring.

When they had completed it to their own satisfaction, they encouraged one of the other groups who had just reached the stage of working with mazes to use their microworld instead of the one prepared by the class teacher. The teacher having checked through their work on the computer was sure that there were no faults in the programming and allowed them to do this.

The atmosphere created by this experiment was one of extreme excitement, much more than had been created by any other of the LOGO work.

At various times throughout the past months, their excitement had been almost uncontainable when they had had particular success with their work, yet nothing could compare with the sense of achievement displayed by the children on the completion of this branching, maze work.

Carried along by their success, Group B decided to take their microworld further by extending their maze to a six by six maze. This meant adapting their microworld and adding to it the procedures for the new rooms which needed to be created. Rather than totally incorporate their first maze, the group decided to leave Maze 1 as they had originally designed it but to use the whole of Maze 1 as the basis for Maze 2. Because of their forward thinking they were left with two separate mazes at the end of their work. In order to carry out the plan they had at the beginning of their Maze microworld work, that of incorporating their maze into their branching story, a great deal of discussion was necessary. On checking the printout of their branching story, the boys realized that they would have to rewrite some of it in order that the maze could be integrated completely into their story. This rewriting was carried out by each member of the group, and then they each read out their version, and a vote was taken among themselves to decide which version to use. They had reached the stage quite a long while ago where they had ceased to be sensitive about criticism, and were positive in their handling of the situation.

Ben - I've written, As the men walked into the forest, the trees became bigger and bigger, and they could not see through the maze.

Christopher - That's quite a good idea of the trees getting bigger, I like it. This is what I've put down. The quicksand was beginning to suck the men down and there was a gurgling noise from Joe as he began to sink. He said "We've got to get out of the maze."

Matthew - That's good I like the way you've put about the noises, listen to mine. As the men forced their way through the forest, the sun beat down on them. The creepers were getting thicker and thicker, and some of them wrapped themselves around them like the tentacles of an octopus. All they could see was a maze formed by the lifelike creepers. Should they try to proceed through the maze or should they turn back?

Christopher - That's the best because you've got plenty of description to make it more interesting, I think we should use yours Matthew.

As they all agreed that Matthew's description should be the one to be used, the procedures in their original branching story were edited to incorporate the new words.

Once this had been done, the boys had to edit the start of their maze microworld so that the instructions given fitted into the story plan of their branching story. They found this work laborious and unchallenging. They viewed it merely as a means to an end, and worked through it as quickly as they could.

The resulting microworld was exciting to all who used it. It was much more ambitious than the class teacher had anticipated and the group were exhilarated by their success.

Throughout the programme of LOGO work, the children were continually talking about their work and sharing ideas with other group members. Some of the groups did not reach the branching story stage in the programme, yet they were still able to share their ideas with their peers. Although Group B seemed to make the most progress as far as the actual quantity and quality of the work they covered, an equivalent result from the tests which were administered to them could hardly be taken for granted.

From the recorded discussions which took place during the children's LOGO sessions, several aspects of problem solving techniques became apparent.

Krutetskii in his research had found that:

> 'Average pupils did not always subsume the problems under a general type of their own; they did not always perceive the common type in externally different problems by themselves, but generally coped with each task successfully with the experimenter's assistance.'[107]

This could be a description of the majority of the discussions which had taken place in the girls' group. They were not as able as the boys at expressing themselves and needed more direction from the teacher.

The boys in Group B on the other hand were more compatible with the statement of Krutetskii that:

> 'Even before solving problems, at the stage of preliminary analysis, able pupils rapidly perceive the similarity in type between one problem and another. After solving the first problem, they easily carried over the solution of one problem to that of another.'[108]

Although the research which had been carried out into the nature of thinking and the problem solving process had been varied (Chapter 2), it appeared to be relevant to the accounts of the children's conversations which took place during their LOGO work.

Because of the wide variety of the work covered by the different groups using LOGO, it was decided that a closer look should be taken at the results obtained in a wider range of skills than had been originally planned. This would enable the writer to focus attention on as many advantages, or disadvantages as the case might be, of primary seven children using a planned programme of work using LOGO.

CHAPTER 8

As described in Chapter 5, the Bristol Tests, were administered in September 1985, at the start of the research period, and again in July 1986 at the end. The following table is a list of the results obtained by the girls who used LOGO. The first figure is the pre - test score and the figure in brackets is the post - test score. The results are tabulated according to decile results of skills specified by the Bristol Tests. These are Number, Reasoning, Spatial, Measurement, Arithmetic Laws, Standardized Score and Percentile.

NUMBER	REASON	SPACE	MEAS.	LAWS	S.S	%
4(8)	3(5)	3(4)	2(5)	0(3)	99(106)	48(66)
4(8)	7(8)	5(8)	3(4)	6(4)	104(107)	61(68)
7(8)	3(6)	7(8)	2(8)	0(6)	106(114)	66(82)
0(8)	8(7)	7(7)	3(7)	4(8)	106(117)	66(87)
4(5)	9(6)	5(8)	3(8)	0(4)	113(111)	81(76)
8(8)	7(7)	3(5)	6(7)	4(8)	117(116)	87(86)
8(8)	7(9)	9(9)	9(8)	5(5)	124(122)	95(82)
6(5)	1(6)	7(8)	2(7)	0(7)	101(109)	52(73)
3(3)	6(3)	2(5)	6(5)	5(7)	103(104)	58(61)
8(8)	6(7)	2(7)	3(2)	7(5)	109(106)	73(66)
3(6)	3(6)	4(8)	5(9)	5(6)	103(111)	58(76)
0(6)	9(8)	9(9)	3(8)	4(7)	105(113)	63(81)
8(8)	8(8)	8(8)	6(9)	0(7)	120(123)	91(94)
7(8)	9(9)	9(9)	6(8)	7(8)	125(131)	95(98)
3(8)	9(8)	2(8)	6(8)	4(7)	107(118)	68(88)
5(8)	2(4)	7(8)	5(9)	6(6)	108(113)	70(81)
3(8)	8(9)	7(8)	6(8)	0(3)	108(115)	70(84)
7(8)	3(9)	7(8)	6(7)	0(6)	108(113)	70(81)
5(7)	7(8)	6(6)	2(4)	4(0)	110(109)	75(73)
5(5)	7(6)	3(5)	7(9)	5(5)	114(114)	82(82)

7(8)	5(8)	7(8)	7(9)	4(5)	114(117)	82(87)
5(8)	9(8)	9(9)	6(9)	5(4)	118(121)	88(92)
7(7)	9(9)	9(6)	5(9)	6(6)	119(119)	90(90)
8(8)	9(8)	5(9)	7(8)	5(8)	120(125)	91(95)
8(8)	9(9)	9(9)	7(9)	7(9)	128(132)	97(98)

An initial examination of these scores reveals that the majority of the girls who used LOGO did make some improvement to their initial standardized score.

The following is a table of the scores obtained by the boys who worked at LOGO.

<u>LOGO BOYS</u>

NUMBER	REASON	SPACE	MEAS.	LAWS	S.S	%
0(6)	2(2)	0(6)	3(5)	5(5)	88(100)	21(50)
1(4)	0(5)	7(8)	5(7)	6(5)	100(107)	50(68)
5(5)	3(4)	8(9)	6(7)	4(8)	108(108)	70(70)
7(8)	2(8)	8(8)	5(8)	0(8)	112(122)	79(93)
4(8)	7(8)	5(5)	7(8)	0(3)	113(116)	81(86)
5(8)	6(7)	7(8)	7(8)	5(7)	116(118)	86(88)
6(6)	8(8)	6(7)	7(7)	7(6)	117(113)	87(81)
4(8)	8(8)	5(8)	7(8)	0(4)	113(121)	81(92)
4(4)	7(8)	7(7)	7(7)	8(8)	114(110)	82(75)
4(5)	5(6)	7(8)	6(8)	5(8)	106(111)	66(76)
2(2)	7(8)	4(5)	3(5)	4(5)	102(102)	55(55)
2(5)	3(2)	6(7)	6(7)	6(6)	102(104)	55(61)
3(5)	3(7)	4(6)	2(1)	7(6)	102(102)	55(55)
3(8)	6(8)	9(9)	6(8)	6(8)	112(121)	79(92)
2(5)	6(8)	9(8)	7(9)	5(7)	114(120)	82(91)
8(8)	9(9)	9(9)	9(9)	8(9)	131(130)	98(98)
8(8)	9(9)	9(9)	9(9)	7(8)	132(132)	98(98)
2(8)	5(8)	9(9)	7(9)	5(8)	113(124)	81(95)
7(80)	7(8)	9(9)	9(9)	9(9)	128(130)	97(98)

As can be seen, a similar pattern was apparent from the scores obtained by the boys who used LOGO.

A disturbing pattern was observed from the results of the children who had not used LOGO.

In their case, the majority of the children's scores had decreased. This was an unexpected result and could possibly form the basis for future research in the area of the development of children's mathematical problem solving skills.

The tables which follow are first the girls's results and secondly, the boys.

NON-LOGO GIRLS

NUMBER	REASON	SPACE	MEAS.	LAWS	S.S	%
0(1)	0(0)	1(0)	1(0)	3(0)	89(78)	24(7)
1(1)	3(3)	3(2)	2(2)	4(3)	100(94)	50(34)
1(2)	3(3)	6(6)	0(1)	5(4)	100(100)	50(50)
8(8)	9(8)	5(6)	5(2)	5(5)	118(109)	88(73)
4(1)	3(1)	0(1)	2(1)	4(0)	96(83)	39(13)
4(8)	9(9)	9(8)	7(7)	9(8)	119(113)	90(81)
4(6)	8(7)	9(7)	7(8)	6(5)	121(108)	92(70)
3(0)	0(1)	3(0)	2(0)	0(0)	94(73)	34(4)
8(7)	9(8)	8(5)	7(6)	6(4)	124(111)	95(76)

The decline in some of these scores can only be described as dramatic. A similar pattern emerged from the boys' results.

NON-LOGO BOYS

NUMBER	REASON	SPACE	MEAS.	LAWS	S.S	%
6(6)	8(6)	8(8)	4(6)	3(7)	112(107)	79(68)
3(7)	1(4)	4(8)	2(0)	6(3)	92(96)	30(39)
4(2)	0(0)	0(3)	0(2)	0(4)	91(91)	27(27)
0(0)	0(0)	0(3)	0(3)	0(0)	86(77)	18(6)
8(4)	3(6)	2(7)	5(5)	0(6)	109(107)	73(68)
0(1)	5(6)	7(6)	6(6)	4(6)	103(100)	58(50)
3(4)	5(5)	7(7)	3(0)	8(3)	104(92)	61(30)
6(5)	9(8)	7(8)	3(5)	0(4)	112(107)	79(68)
5(5)	7(7)	7(6)	5(3)	5(7)	114(106)	82(66)
5(5)	6(6)	8(7)	7(7)	7(5)	115(106)	84(66)
6(6)	9(8)	7(7)	6(7)	6(5)	116(105)	86(63)
8(8)	6(8)	5(6)	6(5)	4(4)	116(113)	86(81)
0(2)	2(1)	8(4)	3(2)	0(3)	102(88)	55(21)
4(1)	5(1)	7(6)	2(2)	0(3)	108(96)	70(39)
4(5)	2(4)	6(5)	6(1)	0(4)	105(96)	63(39)
7(5)	5(8)	5(6)	6(6)	6(6)	114(109)	82(73)
5(2)	5(5)	9(4)	7(6)	6(4)	118(99)	88(48)

Without referring to any specific statistical measures, it can be observed from the tables that a wide difference in scores was apparent. In attempting to carry out a detailed analysis of the scores obtained, various aspects were considered, and all the relevant findings are described at some length later in this chapter.

In searching for a test which would comply with the conditions set up around this particular piece of research, the test which was thought to be most suitable was a matched pairs test.

This test is used when testing two samples which are related. An example of related samples are when the same subject is tested under two different conditions. The conditions for this particular piece of research are in accordance with those described above viz. the same children were tested under the condition of pre LOGO and post LOGO work.

In The Statistical Tests Handbook, published by the Open University for Course 261, it is stated that a 't' test can only be assumed to be of value if the following conditions are met:

'The subjects have been randomly selected from the defined population.
The standard deviation for the two scores for the two samples should be approximately equal.
The population from which the samples have been drawn are normally distributed.'

A check was made on these assumptions with reference to this particular research. The children had been selected at random, no attempt had been made to interfere with the groups by rearranging them according to ability or sex. The standard deviation for the two scores was approximately equal, and the population from which the samples had been selected was normally distributed.

It was decided that the matched pairs test could be used to evaluate the results which had been obtained from the administration of the Bristol Achievement Tests to the children involved in this study.

In assessing the 't' test further it was felt that as the probability of getting a particular difference between means in either direction is double the probability of getting the same difference in one direction alone, the 'one tailed'test of significance should be used.

The fact that statistical tests operate on the assumption that the differences being assessed are indeed due to the manipulation of the independent variable, and not due to systematic bias, must be kept in mind.

An analysis of the scores achieved by the 44 children who had taken part in the programme of LOGO work was made using the one tailed 't' test. This analysis revealed that the t-Value was 5.647

Using Tables For Statistics, the significance level of this t-Value for 44 children was less than 0.0005 which showed that there was a significant improvement between pre and post standardized scores of the group of children who had used LOGO. The null hypothesis could certainly be rejected

From the quality of the discussion which had taken place during the LOGO work, it appeared that the boys had reached a higher level of ability in orally working out the problems associated with their LOGO activities. In order to assess whether this had been carried over to the results obtained from their tests, it was decided to analyse the results of the boys and girls separately.

The t-Value of the girls' scores was 4.736, and that of the boys was 3.189. Although both these results are significant at the 0.0025 level, only the t-Value result of the girls is significant at the 0.0005 level. Both results were however significant at the usually accepted level of 0.05. It can be stated therefore that the progress achieved by the girls was in fact superior to that achieved by the boys. This was in spite of the fact that from the quality of their language during problem solving work using LOGO, it appeared that this could be otherwise.

A further investigation was carried out using the decile scores which were obtained by the children in the area of Reasoning.

The results from the 't' test indicated a reversal of previously stated findings. The t-Value of the girls' scores was 1.644 while that of the boys was 3.496. From the statistical tables applied to the 't' test, it was found that the t-Value of the girls' score was 0.075 which would not be regarded as significant, while that of the boys was almost significant at the 0.001 level. This would seem to be a more accurate description of the progress the boys appeared to be making.

In testing the all round improvement made by the children who had used LOGO, it became evident that there was an obvious discrepancy between the 't' test results for the whole standardized score and those for the Reasoning part of the Bristol Tests. It was decided therefore to take a closer look at the various skill's areas of the Bristol Tests in order to ascertain where the source of this discrepancy lay.

The results of the decile score for Number skills for both the boys and girls were tabulated. The t-Value was found to be 4.028 for the girls and 4.594 for the boys. In this area of mathematical skills, the boys had again achieved a more significant result than had the girls. The third area of skills which were assessed as part of the Bristol Achievement Tests was that of Spatial Awareness. The t-Value of the scores was more significant for the girls than the boys. The girls' had a value of 3.674 while the boys had a value of 2.559. The girls result was significant at the 0.0005 level while the boys was only significant at the 0.01 level, although both were within the usually accepted levels.

As the scores had so far been more or less balanced, it was decided to look further and attempt to assess in which area of mathematical skills, the girls had made the most progress compared with the boys. Measurement skills were the next to be evaluated. The t-Value for the girls in this area was substantially higher than the boys being 6.365 while that of the boys was 4.135. Both of these values were however highly significant both being less than 0.0005 on the t-tables.

The final area for assessment was that of Arithmetic Laws and Processes. The t-Value for the girls in this area was again higher and more significant than the boys. The girls achieved 3.578 and a significance level of 0.0005 while the boys achieved 3.177 with a significance level of 0.0025.

From these findings it can be seen that in the areas of Spatial Awareness, Measurement and Arithmetic Laws, the girls had made a more significant improvement than had the boys. In the area of Number Skills and Reasoning, the boys' improvement was more significant than was the girls.

The results indicated that LOGO had caused a greater improvement across the whole area of mathemetical problem solving skills with the girls than had been the case for the boys. In the specific area which of all the areas could probably be most closely associated with problem solving, the area of Reasoning, the boys' improvement had been more significant.

In an attempt to evaluate whether LOGO had actually effected the children's attitude towards mathematics, the APU Mathematics Attitude Questionnaire was administered to the children. (Appendix 17 -19) The responses given by the 44 children who had worked with LOGO were considered. As had been recommended by the APU, no attempt was made to total the scores for the children, the questions and their responses were looked at from the point of view of their actual wording and the childrens' choice of response to that wording.

One aim of all the teachers of young children must surely be to create an enjoyment of mathematics. The aims and recommendations of Cockroft, Plowden HMI documents etc. mentioned in previous chapters, can be interpreted also as bringing about a change in the attitude of a child's enjoyment of mathematics. If a teacher is carrying out the recommendations and making mathematics teaching more exciting, practical, relevant, and less dependent on teacher directedness, one would expect, the attitude of the child towards mathematics must change.

The first statement in the Attitude Questionnaire was 'I enjoy most things I do in maths'. The highest grade of score which could be given was 5 for 'Strongly Agree' with this statement. All the children scored either 4 or 5 against this statement. The next statement which indicated whether a child enjoyed mathematics was that of 'I'm always glad of a break from maths'. The lowest score which could be achieved for a response to this statement was 1 for Strongly Disagree. Of the forty four children who had used LOGO, thirty five made this response, while the majority of the remaining children stated that they agreed with the statement.

Negative statements on attitude towards mathematics were such as 'Maths is not one of my favourite subjects', 'I wish I didn't have to do maths', 'Even when I can do maths I don't enjoy it' and 'I don't enjoy maths lessons'. The responses made by the children to these negative questions scored at a low level, indicating that the children were in fact enjoying their maths.

The responses of six of the children who completed the Maths Attitude Questionnaire, were not consistent. These six children responded positively to the questions on the enjoyment of maths but had also responded positively to five or less questions on the negative aspects of maths.

Later questioning by the researcher revealed that in all but two cases, the children had misinterpreted the question. The other two children were adamant that their responses were the ones they had intended. An example of this was the response that they strongly agreed to the statement that 'I look forward to the maths lesson' but had also strongly agreed to the statement that 'I don't think that maths is very interesting'. Both children insisted that although they looked forward to the challenge which maths work afforded, they could not agree that maths was interesting because of this.

Making a general observation on the results obtained from the use of the Maths Attitude Questionnaire, the majority of the children who had worked with LOGO as part of their allotted maths time, appeared to have a more positive attitude towards maths. The responses of the children who had only use SPMG maths varied and was not consistent enough to prove that they had either a positive or negative attitude.

The teachers who had been involved in working with LOGO with their children all came to similar conclusions regarding the high motivation level of using LOGO with primary children.

They all commented on the eagerness with which the children carried out tasks which were self directed and the perserverance with which they carried out these tasks.

It was also observed that these children made a significant improvement in their social development in as much as they gained in confidence and were eager to discuss with visitors the advantages they saw as being derived from their use of LOGO, the programming language.

CHAPTER 9

During the course of this research, every effort was made to make using the programming language LOGO as simple as possible. The children were encouraged to work at their own pace and develop their own ideas. It was however occasionally found necessary to direct their ideas as they sometimes sought advice as to where they would go next.

The literature which formed the background to this research became more relevant as the project progressed. The writer became more aware of the significance of some of the previous research findings as the children became more involved in LOGO.

As the children developed more confidence with their use of LOGO, they were continually planning, discussing, adapting and redrafting their programs until they were as streamlined as they could possibly be. The deeper they became involved in LOGO programming, the more adept they became at this streamlining exercise and as this happened, the more logical were their plans.

The use of LOGO as a means of encouraging the children to become more aware of the need to think logically and plan their procedures and programs was an obvious success. The children apparently enjoyed their work using LOGO and their enthusiasm was carried over into their other activities.

The purpose of the research was to attempt to discover if the use of LOGO actually caused any improvement in the children's mathematical skills. As can be seen in Chapter 8, there was a significant improvement in several areas of the children's mathematical problem solving skills, although there was a variation according to the sex of the child.

It was found that although the boys made significant improvement in the area of Reasoning and Number skills, the girls had made a more significant improvement in the area of Spatial Awareness, Measurement and Arithmetic Laws.

As regards to the results of the Maths Attitude Questionnaire, it was seen that the attitude of the children who had used the programming language LOGO was much more positive than was the attitude of the children who had not used LOGO.

The plans which were used with these children were discussed with teachers preparing to use LOGO. Many of them used the workcards as a basis for introducing younger children to the challenge of developing their own short LOGO programs.

All the teachers involved in this particular research were convinced of the suitability of using LOGO with primary aged children. They were impressed with the children's determination to accept the challenge which LOGO offered to them and every teacher discovered more than one child who had not previously appeared to be a methodical problem solver yet who would persist in tackling the redesigning of a LOGO procedure until satisfied by its clearness of definition.

Although the final analysis did indicate that the use of LOGO was beneficial to the development of the children's mathematical problem solving skills, this was in fact thought to be less important than the fact that the exercise had convinced many teachers that the way ahead in the development of good practice in primary schools must include the use of LOGO as a programming language.

APPENDIX 1

See What Happens

FORWARD 100	Makes the turtle move forward for 100
BACKWARD 100	Makes the turtle go backwards for 100
RIGHT 30	Makes the turtle turn right for 30 degrees
LEFT 30	Makes the turtle turn left for 30 degrees

It is quicker to type

FD 100

BK 100

RT 30

LT 30

Can you draw something on the screen using these commands?

APPENDIX 2

Some new commands to try.

PENUP This lifts the pen up so that the turtle can move without drawing a line.

PENDOWN This puts the pen down so that the turtle can draw a line when it moves.

Draw a picture on the screen and use these two commands.

Can you draw a line which is 100 long and then has a gap of 100 and then is 100 long after the gap?

Did you remember to put the pen down?

Try to draw a square.

When you have drawn a square show your teacher.

How did you draw a square?

REPEAT is a command which repeats what you tell the turtle to do.

You must remember to use square brackets like this.

REPEAT 2[FD 100 RT 90]

This will make the turtle move forward for 100 and turn right for 90 twice. You have told it to REPEAT 2.

Use this command in your next pictures on the screen.

APPENDIX 3

If you want the turtle to draw many lines you can make the instructions into what is called a PROCEDURE.

This is how you do it.

Give your procedure a name e.g. PATTERN

You begin your PROCEDURE with TO PATTERN

The next line could be FD 100 RT 30

The next could be FD 100 LT 30

You always finish off your PROCEDURE with the word END

This is what this PROCEDURE would look like.

```
TO PATTERN
FD 100 RT 30
FD 100 LT 30
END
```

Type this in and see what happens.

Did it say PATTERN defined?

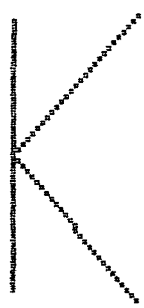
This means that the computer now knows what you have called a PATTERN.

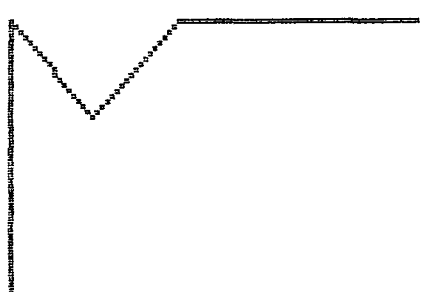
Type in PATTERN.

What happened?

APPENDIX 4

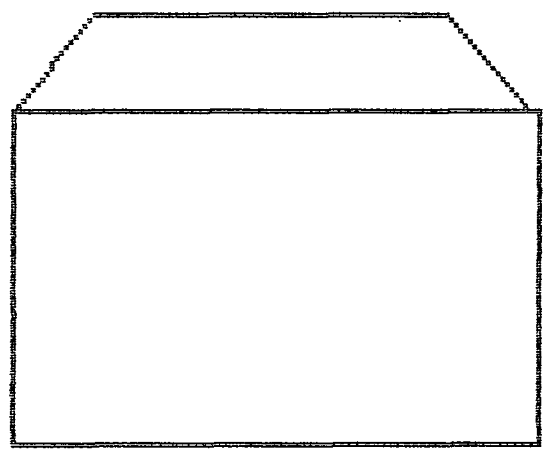
One group of children drew their initials on the screen.





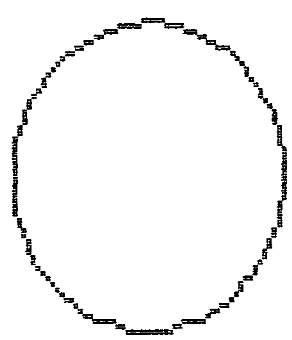
APPENDIX 5

Another group tried to draw a house.



APPENDIX 6

After drawing their initials the group tried to draw a circle. This took some time, a great deal of discussion and several attempts before they produced.



APPENDIX 7

Using the REPEAT command the same group tried to draw a circle. They discovered that they had not put in enough REPEATs. The circle was not complete. After much discussion they realised that the turtle would have to turn through 4 right angles in total and that the number of REPEATs must be compatible with the turn which the turtle made.

```
TO CIRCLE
REPEAT 40[FD 10 RT 5]
END
```

This produced:

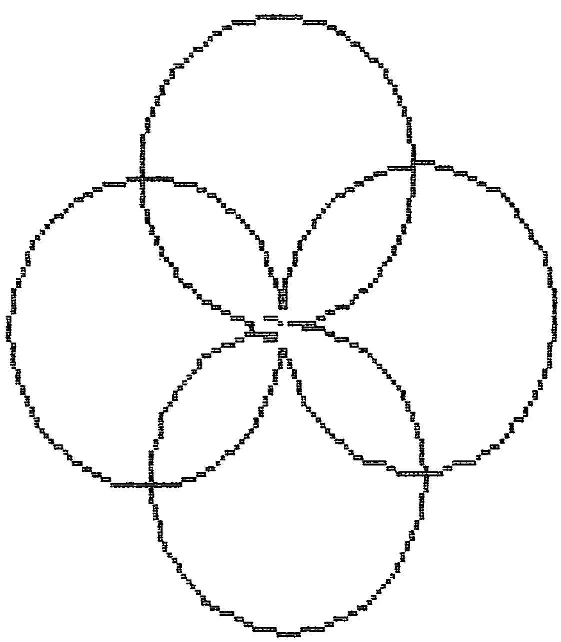
This was corrected to

```
TO CIRCLE
REPEAT 72[FD 10 RT 5]
END
```

and produced a circle.

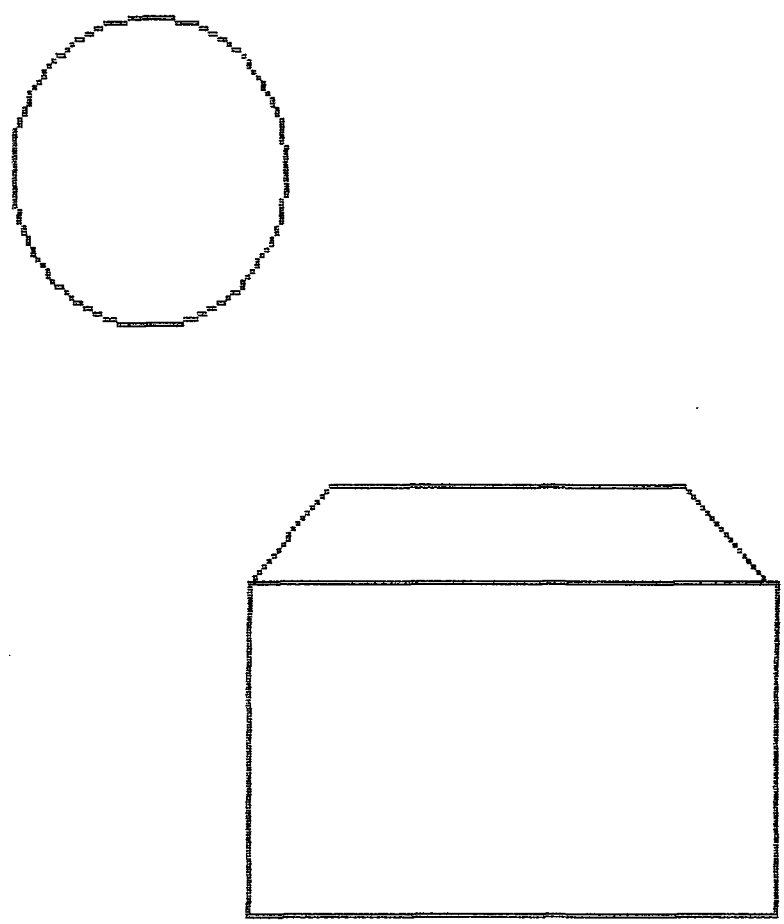
APPENDIX 8

The group then used the PENUP command and drew a series of circles around the screen using the CIRCLE procedure which they had previously defined.



APPENDIX 9

A house was drawn using procedures. A sun was drawn above the roof of the house.



APPENDIX 10

WARNING!!

IF THE TURTLE IS GOING OFF THE PAPER PRESS ESCAPE

Do you remember how far the screen turtle went for 100?

Program the floor turtle to move for 100.

Does it go further than the screen turtle did?

Did you have to press ESCAPE?

Draw a line 30cm long on your paper.

Try to program the turtle to draw a line which is exactly the same length.

Does the floor turtle turn as exactly as the screen turtle did?

EXPLORE! EXPLORE! EXPLORE!

Share your findings.

APPENDIX 11

BRANCHING STORY

What is a branching story?

It is a story which can have more than one ending. This depends on which way you travel through the story.

Here is a short branching story. Read down all the branches.

PARK

One day some children were walking in the park. They came to a place where the path divided into two. One path was YELLOW and one path was RED. Which path should they take?

YELLOW	RED
Going along the yellow path they arrived at the pond.Do you think they would CLIMB in a boat or FEED the ducks?	They went down the red path and came to a hut. The door was open. Would they CREEP inside or SHUT the door and walk away?

Can you see how the story has begun to branch?

This is how it would look if you spot the keywords.

PARK

YELLOW		RED	
CLIMB	FEED	CREEP	SHUT

Can you write endings for each of the branches?

APPENDIX 12

Here are some commands you will need when you are writing LOGO branching stories.

If you want to print out your procedures you need to define:

TO PRINTERON

VDU [2]

END

Every time you type PRINTERON you will be able to print out what is on the screen.

If you want to stop printing out you need the procedure:

TO PRINTEROFF

VDU [3]

END

Then when you type PRINTEROFF you will no longer be able to print what is on the screen.

If you want to print out procedures which you have already defined you need to use the command

PRINT OPPS

If your procedures are called PATTERN and SQUARE you need to type

PRINT OPPS

PATTERN SQUARE

Try to print out some commands.

LOGO branching stories.

When you write a LOGO branching story you will want to tell the reader who has written it. In order to do this you need the procedure TO WHO

Here is an example

```
TO WHO
PRINT [Adventure in the park]
PRINT [by]
PRINT [Names of Author]
END
```

Try this procedure. Try to print the credits so that they appear where you want them to on the screen.

Another procedure you need is START

This is the first part of your story. If you call it START it will make it easier for you to begin with. Here it is:

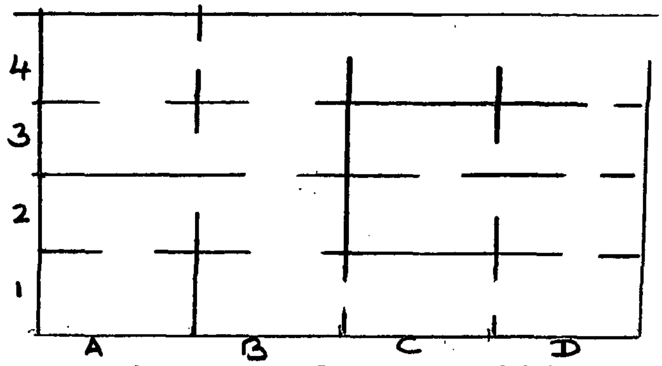
```
TO START
PRINT [One day, some children were walking in the park]
PRINT [They came to a place where the path divided into
two.]
PRINT [One path was YELLOW and one path was RED]
PRINT [Which path should you take?]
END
```

Try this procedure and try some similar ones of your own.

APPENDIX 14

Here is a maze.

The maze is made up of rooms. You can get through the maze in some directions but not in others.



Can you make a maze of your own which is made up of rooms? Choose a different start and exit from the one you have seen.

The idea is that your partner will try to find a way through your maze. Tell your partner how many rooms you have in your maze and where your starting room is.

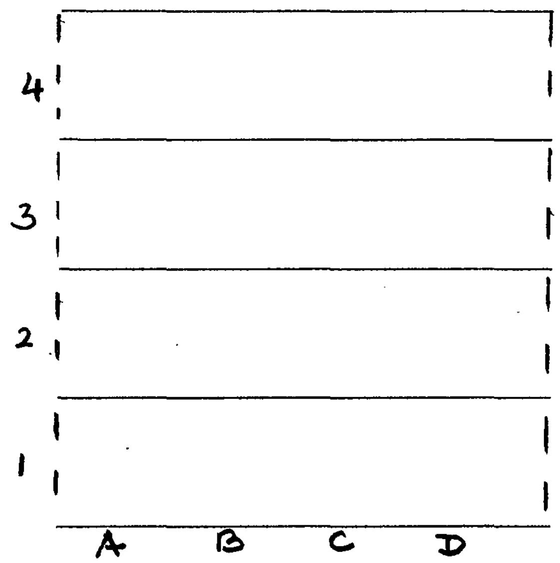
You can only move from a room into the room to the side of it NOT in a diagonal direction.

Your partner can now move through your maze. If you have put a wall between two rooms you must tell your partner there is a wall. As your partner guesses he will draw in the walls on the maze he has made.

See if your partner can find the way through your maze in twenty guesses or less.

APPENDIX 15

Here is a maze microworld.



START

Get the disc entitled MAZES and load MAZE1

You can see you are starting at B1. Try to move to either C1 or A1 or B2 and see if you are told OK! or Wall.

If you are told Wall draw in the wall on your map of the maze.

If you are told OK! you will have moved to the new room you typed in and your next move will be from there.

Try to find your way around my maze and find the exit.

When you think you have found it type EXIT and if you get the answer OK! you know you have found it.

Good Luck!

APPENDIX 16

Some procedures you will need to use.

```
TO START
PRINT [You are at the entrance to a maze]
PRINT [You can move one space at a time by typing]
PRINT [in the coordinates of the room you wish to go to.]
PRINT [You cannot go diagonally.]
PRINT [If you are in A1 and you want to go to A2 type A2]
PRINT [If there is a wall you will be told Wall.]
PRINT [The entrance is at B2. Type B2 to begin.]
MAKE "room [START]
END
```

```
TO CHECK :rooms :newroom
IF :rooms = [ ] [PR [Wall] STOP]
IF :room = (SE FIRST :rooms [ ] ) [PR [OK!] MAKE "room
:newroom STOP]
CHECK BF :rooms :newroom
END
```

```
TO EXIT
CHECK [EXIT D1] [EXIT]
END
```

```
TO A1
CHECK [A1 A2 ] [A1]
END
```

Bring out this card and we will go over it.

STATEMENT	Strongly Agree	Agree	Disagree	Strongly Disagree	Unsure	
I enjoy most things I do in maths.						10
I often get into difficulties with my maths.						11
Maths is a very useful subject.						12
I'm always glad of a break from maths.						13
I'm surprised if I get a lot of maths right.						14
I never feel like doing maths.						15
Maths is only important in a few jobs.						16
Maths never gets boring.						17
I think that girls and boys are equally good at maths.						18
Maths is not one of my favourite subjects.						19
I use maths to help me in lots of ways in school.						20
I usually understand a new idea in maths quickly.						21
Maths books are interesting.						22
I think it's difficult to get on in life if you haven't done much maths.						23
Maths is one of my better subjects.						24
At the end of a maths lesson I feel more clever.						25
I can usually understand my maths textbook.						26
I wish I didn't have to do maths.						27

APPENDIX 18

STATEMENT	Strongly Agree	Agree	Disagree	Strongly Disagree	Unsure	
I can use maths to solve some everyday problems.						28
Even when I can do maths I don't like it.						29
I get lost if I miss any work in maths.						30
I like it when there is something new to learn in maths.						31
I enjoy everything I do in maths.						32
I think that without maths our lives would be much harder.						33
I don't like maths lessons.						34
Maths often gets too complicated for me.						35
Maths will help me to get a job one day.						36
I'm disappointed when I miss a maths lesson.						37
There are far too many things to remember in maths.						38
I sigh with relief when maths is over for the day.						39
I don't need maths much out of school.						40
I'd rather do other subjects than maths.						41
A lot of the maths we do is a waste of time.						42
Maths books are hard to follow.						43
I think that girls are normally better than boys at maths.						44
I'm always keen to start my maths lessons.						45

5.

STATEMENT	Strongly Agree	Agree	Disagree	Strongly Disagree	Unsure	
Ordinary people don't use maths very much.						46
I look forward to my maths lessons.						47
I usually get most of my maths right.						48
I don't think maths is very interesting.						49
I shall be able to get on without knowing much maths.						50
I find maths an easy subject.						51
Maths won't be very important to me when I leave school.						52
I don't think maths is difficult.						53
Boys are normally better than girls at maths.						54

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