The use of dart in the development of mathematical language and problem solving skills

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THE USE OF DART IN THE DEVELOPMENT OF MATHEMATICAL LANGUAGE AND PROBLEM SOLVING SKILLS

BY

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Abstract

The research was designed fundamentally to answer questions about the role of computer proramming experience for children and the level of importance attached to it in the primary school curriculum.

In relation to this role areas targetted for investigation were the development of language competencies, improved attitude towards mathematics and the growth of transferable problem solving skills.

During the course of the research the issue of gender presented itself. It could not be overlooked and was discussed at some length. The strong cultural association of males with computers and related gender issues in mathematics is an area which warrants greater research.

Despite changes in personnel during the research period every effort was made to maintain continuity and progression. Unexpected difficulties caused by the change were dealt with as quickly and efficiently as possible. It must be acknowledged that the change could have marginally influenced the outcome of the study.

As the research progressed significant similarities could be noted with that of Pea, Kurland and Hawkins, "Logo and the Development of Thinking Skills 1984". However on completion of this project it was found that no solid conclusion could be drawn from the results as some of the evidence appeared to be somewhat contradictory.

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Chapter 1

The Nature of the Concern

The writer started her teaching career in a small village primary school in September, 1973. At that time the school had a staff of five full time teachers and a head teacher. The school was in a social priority area. Many of the parents were unemployed, others were in low income jobs and there was a significant number of one parent families. The first year intake of pupils came from the Infant School which was situated on the same school site. The teaching staff of this school consisted of four full time teachers, a head teacher and also had the support of a full time auxiliary. Owing to educational cutbacks and falling rolls, by September, 1982 the infant staff had been reduced to a total of two teachers, the junior staff remained virtually the same. The two schools were amalgamated in September, 1982, the infant head teacher retired and the junior head teacher became head of the amalgamated school.

Prior to the amalgamation there had been very little contact between the two schools, each school functioned separately. Both schools had independent schemes of work which had not been amended for approximately twenty years.

"Schools need sensitive antennae to detect change and sensitivity in adapting and up-dating their aims in response to them. In these fast moving times the need is for constant review. At the very least perhaps schools should agree to let no set of aims run for more than five years without review." (1)

The need for change was apparent. Both the junior and infant schemes of work needed to be analysed and revised with the prime objective being continuity and progression throughout the school.

Two quotations are appropriate. The first from D.E.S.Circular 6/81 and the second from R.G.Mager 1982. These are:

"Schools should set out in writing the aims which they pursue" (2)

and

"If your not sure where you're going, you're liable to end up some place else and not even know it." (3)

This then was the situation in September, 1982. Over the next two years the writer prepared a scheme of work for language development for use throughout the school. The headteacher, who was fast approaching the age of retirement and seeing the obvious need for curriculum change in the school took responsibility for mathematics education.

The Scottish Primary Mathematics Group Scheme (S.P.M.G.) was hastily bought and implemented. The mathematics scheme was amended, that is, £.s.d. was crossed out and £.p. was substituted. Although the school now had a valued and useful practical mathematics scheme the process of promoting change in the school was not well designed and clear cut.

Neal Gross suggests Educational Administrators conceive the process of promoting change in schools as including three requirements:-

1. Locating or developing a promising new idea.
2. Obtaining funds to carry it out.
3. Convincing staff that the innovation has educational value.

Gross believed that if the "initiation" phase was well handled then innovations would be readily implemented. Although the above conditions may constitute necessary pre-requisites for successful initiation of educational change, they do not represent sufficient requirements for successful implementaton of innovations.

The writer felt that only one of the criteria had been partially fulfilled, that is, locating a promising idea. Unfortunately, development of the idea had not been successful. Criteria 2 and 3, were both very important and both had been sadly neglected.

Other procedures necessary for successful curriculum change had not been carried out.

a) There had been no review of the school's mathematics scheme of work in order to ascertain where and how modifications, when made, would benefit the children in the school.

b) There had been no review of the school's current practices in order to identify the level of match between practices and objectives.

c) There had been no prioritisation of needs.

d) There had been no identification of resource implications and training needs.

e) There was no planned programme of in-service training to implement and support identified change nor were there any plans for the monitoring and evaluation of the proposed curriculum innovation, that is, the new mathematics scheme.

On retirement of the head teacher in the Summer of 1984, a female head teacher was appointed. During her first year she made an appraisal of the school curriculum in order to identify its strengths and weaknesses with a view to re-writing the schemes of work. This would also clarify her thinking and lead to the formulation of the aims and objectives needed by the school for submission to the Director of Education in the Summer of 1985.

She soon realised that the second and third criteria had not been met and took steps to correct the situation. Funds were made available to purchase mathematics equipment necessary for the implementation of the scheme. Staff meetings with the mathematics adviser were organised in an effort to meet the requirements of Criteria 3. A further change occurred in 1985. The writer was given curriculum responsibility for mathematics and R.E. throughout the school. Hitherto her interest in mathematics centred solely on the development of the children she was teaching and mathematics had not been one of her special curricular interests or strengths.

In order to avoid falling into the trap, identified by R.G.Mager, "not knowing where you're going", her personal knowledge of current mathematics research and its influence on educational practice had to be evaluated and up-dated.

She began by attending a two day mathematics course organised by the L.E.A. Mathematics Adviser. It was based on aspects of the Cockcroft Report and held at a local college.

Points put forward for discussion and consideration were:-

a) The child needs to be encouraged to be the tool in his own learning.

b) That the teacher should provide a mathematically stimulating environment.

c) Relevant problems should be posed for the child to solve both by himself and in groups.

d) The teacher must act more as a facilitator or enabler rather than an instructor and must not be tempted to provide a quick and easy solution to the child's problems.

e) The teacher should create an environment where children could be scientifically observed during problem solving activities in an effort to find out what skills have NOT been learned. The theory being that once identified, steps could then be taken to improve teaching techniques.

The above points formed the basis of an approach to teaching mathematics which was completely new and exciting to the writer. Problem solving of this nature was an area of the school's curriculum that had hitherto been unheard of. Previously problem solving had been interpreted as giving conventional text books to the children which provided them with the exact amount of information with which to solve the set problems and this was coupled with the view that a particular method should be used to solve these problems.

The writer having considered the above in conjunction with her knowledge of the inadequacies of the mathematics scheme and the inefficient teaching methods employed in the school, realised that before the formulation of a new mathematics policy, a great deal of "homework" on a long term basis, must first be completed. If the policy was to incorporate the belief in the value of problem solving in developing young children's mathematical thinking, then a careful analysis of the word "problem solving" and proof of its validity in the mathematics curriculum must first be undertaken.

Chapter 2

Why Solve Problems?

The organiser of the L.E.A. two day mathematics course held the view that problem solving is an essential, if not a major, component of a primary mathematics scheme. This prompted a study of recent governmental and other publications relating to the teaching of mathematics in primary schools to see which articles, if any, supported the view.

Brief reference had already been made to the Cockcroft report and this was turned to for further study.

The report suggests that mathematics is taught for the following reasons:-

1. To promote arithmetical skills
2. As a basis for scientific discovery and the development of technology
3. To develop mathematical techniques to be used as a management tool in commerce and industry.
4. As a means of communications to represent, explain and predict.
5. To present information.

6. To show that mathematical statements can relate to more than one situation.

"Results which have been obtained in solving a problem arising from one situation can often be seen to apply to a different situation." (4)

7. Mathematics encourages the development of:-

   a) logical thinking

   b) accuracy

   c) spatial awareness

It must be noted here that other subjects can also help encourage the development of these skills.

If one assumes that teaching practitioners have accepted the above as being a reasonable criteria on which to base their mathematics teaching, so enabling them to equip children to deal with mathematics in society, then one would also assume that much of the teaching in Britain's schools has been geared to meeting those requirements. The list is varied and comprehensive. If considered, understood and assimilated it could over the years have provided teachers with very exciting mathematical avenues to explore with their children.

If this were indeed the case then one would hope that after having passed through at least eleven years of compulsory schooling many adults would feel quite confident in dealing with mathematics in everyday life and have quite positive views towards the subject as a whole.

This is not the case. Research by the Advisory Council for Adult and Continuing Education (A.C.A.C.E.) in a study entitled "Use mathematics in daily life" found that there was a huge percentage of negative opinions towards mathematics in all aspects of society. Feelings of guilt and inadequacy were high amongst the group of people whom others considered to be educated. Many people commented of feelings of inadequacy because they did not use a "proper method" to arrive at the correct answer.

The survey showed that many people saw mathematics in vocational utilitarian terms, few saw it as serving any wider purpose.

Research by the A.P.U. states:-

"It is not easy to pick out points which summarise all the research on attitude to mathematics. Strangely polarised attitudes can be established even amongst primary school children and 11 seems to be a crucial age for the establishment." (5)

A strong tendency amongst pupils of all ages was the belief that mathematics was useful but not necessarily interesting or enjoyable. The research also appeared to show that the set of people who liked mathematics had only a relatively small overlap with the set of those who were good at it.

From this it can be deduced that a large percentage of the now adult population have found their mathematics education to be unsatisfactory, leaving them with negative attitudes towards the subject and often ill equipped to deal with the mathematical needs of adult life.

Cockcroft sums up these needs as being, in very broad terms, " a feeling for number and a feeling of measurement."

Perhaps then, mathematics has been taught too strictly, from the textbook and out of context, forgetting that to children it should show itself to be a live and interesting subject.

Cockcroft upholds this view:-

"However. we do not believe that mathematical activity in schools is to be judged worthwhile only in so far as it has clear practical usefulness. The widespread appeal of mathematical puzzles and problems to which we have already referred shows that the capacity for appreciating mathematics for its own sake is present in many people. It follows that mathematics should be presented as a subject both to use and enjoy." (6)

How then should mathematics be presented and how important is the role of "problem solving" in this presentation?

The report states that the study of shape and space, graphical methods of presenting information, studying number properties all help develop the powers of "abstraction" and "generalisation" both of which are necessary for the understanding of higher level mathematics.

Pupils should be encouraged to look for "pattern" in results of number work and linguistically explain their results.

The use of mathematical games and puzzles can often clarify mathematical concepts and promote the development of logical thinking. Confidence and understanding will increase if children are given activities which allow them to think about the process of mathematics in ways which are different from those encountered in the usual channels. If children have had a wide variety of mathematical experience then problem solving activities may be easier to understand. Cockcroft is firm in his belief in the importance of problem solving.

"The ability to solve problems is at the heart of mathematics. Mathematics is only " useful " to the extent to which it can be applied to a particular situation and it is the ability to apply mathematics to a variety of situations to which we give the name "problem solving". However, the solution of a mathematical problem cannot begin until the problem has been translated into the appropriate mathematical terms. This first and essential step presents very great difficulties to many pupils, a fact which is often too little appreciated. At each stage of the mathematics course the teacher needs to help pupils to understand how to apply the concepts and skills which are being learned and how to make use to them to solve problems. These problems should relate both to the application of mathematics to everyday situations within the pupil's experience and also to situations which are unfamiliar. For many pupils this will require a great deal of discussion and oral work before even very simple problems can be tackled in writtem form." (7)

The development of mathematical language is of fundamental importance if children's problem solving capabilities are to be increased. Language should be developed through discussion and explanation and by encouraging the children to suggest their own problems and express them in their own words.

"All children need experience of applying the mathematics they are learning both to familiar everyday situations and also to the solution of problems which are not exact repititions of exercises which have already been practised." (8)

It must be stressed that children should not give way to a method of learning which is based wholly on the assimilation of received mathematics knowledge and whose test of truth is "this is the way I was told to do it."

A booklet published by the N.A.H.T. "Mathematics in Primary Schools" supports this view. It believes that problem solving encourages pupils to think clearly and independently, to use the mathematics they already know intelligently and to apply it to unfamiliar and challenging situations.

They will learn by "doing" - consequently the "mathematics" learnt will make more sense. It advocates that the chosen tasks should have the purpose of encouraging children to find their own methods.

The H.M.I. document "Mathematics 5-16 "is also fully supportive of a problem solving approach.

"Problems should be chosen with a range of possible outcomes. Some problems have a unique solution, some have no solution, others would have a solution if more information were available, many will have several solutions and the merit of each may need to be assessed." (9)

One of the aims expressed in the curriculum document issued to all County Durham Schools, entitled "Curriculum in the Primary School" is:-

"For children to develop an awareness of the uses of mathematics in the world, its application to problem solving and its power to provide ways of representing and explaining events." (10)

Recent significant reports and documents support the view that "problem solving" is an important element in the development of children's mathematical understanding and use of mathematical language. That problems should be interesting, enjoyable, placed in context, give opportunities for discussion and argument on strategies to be followed and should encourage the use of equipment such as calculators and computers.

The emphasis placed on the use of computers in education has gained momentum in recent years. This has been necessary because of the growth of technology which has resulted in changes in the pattern of skills and knowledge which are needed by adults to equip them to find a worthwhile and happy place in society. In schools there has been a shift from a knowledge based curriculum to a skills based curriculum. The computer lends itself well to the development of skills necessary in a technological society. It can easily simulate learning situations which might otherwise be difficult to create in the classroom. It can also, with apparent ease, create opportunities for problem solving in its widest sense, examining such questions as:-

> "What happens if............."
>
> and
>
> "What is the effect of......."

It would appear that the writer's preliminary reading supports the view of the importance of a "problem solving" approach within the primary school curriculum.

The next objective must be to examine the philsophical framework of "problem solving" and the accompanying psychology and if this proves sound then to investigate the possibility of initiating a computer based programme in school to develop children's problem solving skills.

Chapter 3

Approaches to Problem Solving

According to the A.P.U. Mathematical Development Primary Survey Report No.3, the importance placed in the development of thinking skills and problem solving has gained momentum since 1979. Yet as early as 1901 John Perry, talking to the British Association, recommended an approach through experiment in the teaching of mathematics. A few years later in 1914, Percy Nunn advocated that pure and applied mathematics should not be separated, his view seems to have been neglected, for in 1982 the main concern of the Cockcroft Report was about the teaching and learning of mathematics in schools at all levels and the need for more emphasis to be placed on problem solving skills in mathematics.

But what is problem solving and what are problem solving skills? Many teachers interpet problem solving as being strictly structured word sums taught in a particular way. Children then try to do what the teacher wants them to do, often becoming frustrated in their efforts. In a rigidly formal and strictly supervised day the child may often come to the conclusion that doing things neatly in a particular way is the object of the exercise. Bruner calls this extrinsic problem solving; it has nothing to do with the learning tasks associated with the subject matter.

Much of mathematics teaching in the past has been based on the principle that before solving certain types of problems all the techniques which might be needed must first be carefully taught. The philosophy behind this idea was that if the child could still remember the various techniques in relation to the problem, he would then be able to solve it. This approach is more logical than psychological. It is worth trying to present the problem first, then helping the child to discover what they need to know on the way. By doing this the child may be able to generalize the problem and look at the rest of the theory later.

At this point it is beneficial to review some of the theoretical frameworks relating to problem solving that currently grace our library shelves.

Historically Rene Descartes (1596-1650) is regarded by some as the founder of modern philosophy. Many people believe that his work changed the face of mathematics.

During his lifetime Descartes planned to present a universal method for solution of problems. He expected the following to be applicable to all types of problems:-

First - reduce any kind of problem to a mathematical problem.

Second - reduce any kind of mathematical problem to a problem of algebra.

Third – reduce any problem of algebra to the solution of a single equation.

One can see that Descartes rules are not practical in the majority of cases. However they may prove useful for an older child when working with a complicated word sum. Although this is a very brief synopsis of his work, it is sufficient to indicate that whilst his views may have had great influence in scientific fields, they have very little relevance in the teaching of problem solving in primary schools.

Investigating the nature of "problem solving" led next to Polya's book "Mathematical Discovery on Understanding, Learning and Teaching Problem Solving".

In it Pólya states:

"Solving a problem means finding an obstacle, attaining an aim which was not immediately attainable. Solving problems is the specific gift of mankind: solving problems can be regarded as the most characteristically human activity." (11)

The aim of this section of the work is to better understand Polya's view of the nature of the activity and to examine his proposals for teaching it.

He believes that solving problems is a practical art and that it can only be learned by imitation and practice. An analagy here could be the art of learning to swim. Children do not learn to swim by reading books and studying diagrams. They may, if they are keen, look at diagrams and sports books in an effort to improve a particular stroke, but essentially swimming is learned through practical activity on a regular basis. In learning to swim children must be given many opportunities for imitation and practice. So too with problem solving.

Polya suggests that children must start by solving simple problems through their own effort, these may then become a model for solving other similar problems. Imitation becomes more difficult when similarities are not obvious.

Although Polya acknowledges that there is not a perfect method for solving problems he does offer a method called heuristics. This term is applied to the study of means and methods of problem solving.

The A.P.U. Mathematical Development Primary Survey Report No.3, distinguishes four phases in Polya's heuristics, also called discovery procedures. They briefly are:-

6.61 1. Understanding the problem

What is the data?

What are the conditions?

What are the unknowns?

2. Devising a plan

Connecting the data to the unknowns.

Think how to use a related problem.

3. Carrying out the plan

   Check each step.

   Can each step be proved?

4. Reviewing the solution

   Can the result be derived differently?

   Can the result be used for some other problem?

The suggested procedure of "think of a related problem" is important in that it could lead to the discovery of a new line of attack by the child.

Polya also advocates that the problems should be challenging, interesting and that they should allow the use of initiative by the child. His belief in the involvement of the child in the formulation of his own problems is particularly strong.

He does not suggest that the teacher's role in the classroom is unimportant, what is important is that the teacher recognises that s/he acts as a facilitator for the children to discover by themselves as much as is feasible under the given circumstances. He advocates that children should be encouraged to contribute to the design of the problem that they have to solve afterwards. He suggests that sharing in the construction of the problem encourages students to work harder and desirable attitudes of mind are cultivated.

"If students have had a share in proposing the problem, they will work at it more actively afterwards. In fact in the work of the scientist formulating the problems may be the better part of discovery, the solution often needs less insight and originality than the formulation." (12)

The writer firmly believes this to be true and sees tremendous opportunities for cross-curricular links in primary schools. During the month of October in the research year it was decided as a school to work on the theme of "Foods" for Harvest celebrations. The research class decided to make broth for the whole school. It evolved into an exciting week of problem solving activities, each problem developing from the one before and each eventually being solved by children working co-operatively together in groups. The task involved many concepts both scientific and mathematical - estimating, volume, measuring, costing, predicting outcomes, weight, temperature, time, expansion and contraction. It raised issues relating to health and hygiene, moral and social.

The children did indeed work hard and improvement in attitude was noticed by all members of staff. It proved to be an extremely successful week culminating in some very interesting language work. One piece entitled "A problem to be solved - making broth for the school" was subsequently published by D.C.C. Education Department in a book entitled "The Mind's Eye" which is a collection of children's Art and Writing. (Fig.1)

Whilst Polya is strong in his view that the child should be instrumental in his own learning, he is not suggesting that the teacher's role is being made redundant, rather a modification of the traditional role.

Polya expands further by suggesting that knowledge about any subject consists of information and of know how and that in mathematics teaching the know-how is more important than mere possession of information. This view is currently much in vogue in educational curriculum documents issued by Durham County in all subject areas.

Polya defines know-how as being the ability to solve problems which require some degree of independence, judgement, originality and creativity. An assumption can be made that Polya's idea of an able teacher would be one who would emphasise methodical working habits, develop know-how, reasoning ability and have the skill of being able to recognise and encourage creative thinking. He stresses that the teacher should know what he is supposed to teach and relate it to the ability of the individual child. He acknowledges the fact that the teacher's own mathematical education may not have been developed in this way. It would seem that a programme of re-training for many teachers is necessary if pupils are not be handicapped in acquiring the problem solving skills which are so much in demand in a modern technological society.

"If the teacher has had no experience of creative work of some sort, how will he be able to inspire, to lead, to help or even to recognise the creative ability of his students. A teacher who acquired whatever he knows in mathematics purely receptively can hardly promote the active learning of his students. A teacher who never had a bright idea in his life will probably reprimand a student who has one instead of encouraging him." (13)

The Cockcroft Report very much reflects Polya's view of the role of the teacher. It suggests that teachers should develop in children a feeling for number and measurement and the ability to think clearly, confidently and logically through an understanding from the earliest stages. Teachers should not give way to a method of learning which is based wholly on the assimilation of received mathematical knowledge and whose test of truths is "This is the way the teacher told me to do it".

Mathematics 5-11 is also supportive of this view of mathematical education and like Polya, acknowledges the difficulties faced by teachers in fulfilling their role.

"The primary teacher today is faced with a considerable task, brought by the changes which have taken place in the teaching of mathematics..........

Today, the child is encouraged to make enquiries, investigate, discover and record; learning is not looked upon as something imposed from without. It is recognised that it is through his own activity that the child is able to form new concepts which will in turn be the basis of further mathematical ideas and thinking." (14)

Having examined Polya's framework for problem solving and noted the position of the teacher's role in that framework, further clarification of the definition of problem solving is required.

The word "problem" can have a very comprehensive meaning. Polya defines problem solving as the need:

"to search consciously for some action appropriate to attain clearly conceived, but not immediately attainable aim." (15)

To solve a problem means to find such action. By its very nature a problem must have a certain level of difficulty. Solving problems is the specific achievement of intelligence. The ability to solve problems successfully has raised man above the most clever animals. Much of man's conscious thinking is concerned with solving day to day problems, of varying degrees of difficulty and importance.

Irrespective of the size or scope of the problem Polya suggests that they generally fall into two groups, those "to find" that is, ones in which the aim is to construct, obtain or identify a certain object, or the unknown of the problem and those "to prove" that is to decide whether a certain ascertation is true or false, to prove it or disprove it.

Polya's heuristics, his suggested groupings for problems and his belief in the importance of the formulation by the child of his own problems, becoming therefore a significant tool in his own learning has influenced the thinking behind the A.P.U. Mathematical Survery Report No.3. The A.P.U., initiated a conference entitled "Problems, applications and investigations". From this conference a number of assessment categories for problem solving were formulated. They bear the mark of Polya's philosophy. They are:-

6.1 – 6.7

1. Processing information

   Paying attention to relevant details, ignoring irrelevant details. Understanding sentences, tables, diagrams,etc.

   Translating from one medium of communication to another, for example:-

   from discourse to diagram, table or graph, using notation.

2. Formulating problems

   Given some information, focus on some aspect and devise a problem or ask a question.

3. Strategies and methods of solution

   Representing the problem using notation, graphs, diagrams etc.

   Reasoning: use of mathematical (or other knowledge) and deduction in order to arrive at a result.

4. Generalising solutions

   Recognising patterns and relationships; continuing patterns.

   Hypothesising generalisations.

5. Proving

   Explaining and justifying results.

   Comprehending a logical argument.

   Constructing a logical argument.

   Detecting logical errors..

6. Evaluating results.

   Relating results to the original problem.

   Devising possibilities for the development of an investigation.

Problems often require a high level of concentration and judgement. Certain advantages arise from working in groups. Children can discuss their work and clarify their thinking, both of which promote the development of use and understanding of mathematical language.

Polya gives guidelines for group work in mathematics. They are as follows:-

1. Each pupil receives a different problem which s/he is supposed to solve in that session; s/he is not supposed to communicate with his/her peers but may receive help from his/her teacher.

2. Before the next lesson each pupil should review his work, if possible simplifying his solution and looking for other methods of arriving at the same answer. By these means

she/he masters the problem as fully as s/he can, s/he should then begin planning in an effort to best present the solution to the class. The child is given the opportunity to consult the teacher about any of the above points.

3. The pupils should then form free choice discussion groups of four. One member of the group acts as "teacher" and presents his/her problem to the class. His/her aim should be to guide them to the solution. Once the solution has been reached friendly criticism should take place. Each member has a turn as teacher with his/her own problem. Particularly good problems should be given a more polished finish; they can then be presented for discussion by the whole class.

Whilst the writer sees the value of Polya's guidelines, she thinks their use would need considerable modification for primary school children. The number and variety of problems needed by one class would be too great to cope with satisfactorily. Difficulties would also arise in a class of children with a wide range of mathematical ability. Stimulating problems for brighter children would prove too complicated for less able children to understand during discussion time. Conversely it would also be a fruitless task for a brighter child to listen to a presentation of a problem which he could probably solve mentally. Upon modification, certain elements of the guide lines could prove to be most useful during problem solving activities. The writer believes the value of group work during problem solving activities lies in the interaction between children, their ideas and in the development of their abilities to hypothesise and experiment. By stressing the active involvement of the learner children can exercise their natural skills of thinking, of dealing with the world, of creating and manipulating in their minds models which can guide their activity and illuminate their experience. Problem solving involves a lot of wondering, "What if......?" and working out the consequences of hypotheses, checking inconsistencies and above all trying to convince others. Working in groups can be seen here as a distinct advantage. Group work also promotes the idea of the importance and necessity of using symbols and diagrams to communicate with themselves as much as others, as an aid to the convenient handling of complex ideas.

Whilst agreeing in part to much of Polya's philosophy and seeing educational value and significance in his work, search continued for a suitable philosphical framework which could be justified in the writer's school situation.

Stephen Lerman's work,"Problem solving or knowledge - centred: the influence of philosophy on mathmatics teaching" (p.198) gave further ideas.

He believed that teachers of mathematics could be divided into two clear groups. Those who believe in:-

a) The Euclidean programme, which is an attempt to base mathematics on knowledge based foundations,

and those who believe in

b) the quasi-empirical programme - that is the recognition that mathematics progresses heuristically.

In his book Lerman argues for the latter i.e. Polya's heuristics which have already been discussed. What then is the Euclidean programme? According to Lerman it implies the tendency to see the teaching of mathematics as being deductive in nature, that is, if correct methods of deduction are applied to a perfectly set question then a satisfactory answer will be achieved. However for the child there is no real sense of purpose in the task and satisfaction in a job well done is often limited to the receiving of a "red tick" on a page in the child's work book. The Euclidean method implies that one must learn methods first and understand uses, applications and relevance afterwards. This could well be the reason why many children and adults dislike the subject and fail to see its value and are unable to apply whatever mathematical knowledge they possess to real situations or other problems which vary slightly in presentation. The Cockcroft report noted that most people, when interviewed, saw mathematics in vocational utilitarian terms. Very few saw it as serving any wider purpose, particularly the type which could be termed of a cultural or general educational kind. This research was also supported by the A.P.U. which was set up by the Department of Education and Science. The Assessment of Performance Unit (A.P.U.) came into being in 1975. Its brief was to supply the D.E.S. with information about the performance levels of the nation's school children. As a result Mathematical Development Primary Survey Report No.1 was published in 1980. The second report was published in 1981. The National Foundation for Educational Research carried out the surveys on behalf of the A.P.U.

Both surveys involved large scale reseach. Primary Survey No.1 acknowledges that the thoughts and feelings of pupils toward the activities they engage in at school are an important feature of their learning, if these thoughts and feelings are of a positive nature then pupils will have a greater security in their learning and more enjoyment in their work. The A.P.U. felt it was important to gauge pupils' attitudes though it was recognized that there would be difficulties involved in attempting to do so.

As a result of their work a questionnaire relating to attitude was evolved as part of their assessment framework. This questionnaire is referred to in greater detail later in the study.

Their large scale research showed that there is a strong tendency among pupils of all ages to believe that mathematics is useful but not necessarily interesting or enjoyable. This attitude is encouraged by teachers, who, when asked about the reason for studying a particular topic answer, "Because it's on the syllabus." or, "You'll understand when you grow up."

The quasi-empirical, Polya's view, leads to a completely different approach to mathematics teaching.

To argue for the latter Lerman turns to Piaget and his views on develomental psychology. It is the work of Piaget which suggests that there is a strong analogy between the growth of new knowledge and conceptual development in an individual. If one accepts this view then it seems logical to consider that mathematics teaching should be based on the idea of children being encouraged to search out solutions to problems at all levels from pre-school to research fellow. Pupils would then be encouraged to propose ideas, suggest methods, test hypotheses and search out other problems of a similar nature, all relevant to their stage of development. This should lead to a much greater degree of participation and involvement by the child in his activity, consequently greater pleasure and satisfaction of a problem solved will be derived. Perhaps this may encourage a change in attitude towards mathematics and promote a healthier view about its value and use in the real world.

The consequences for choice of content are well expressed by Jere Confrey in "Conceptual Change and Analysis: Implications for Mathematics and Curriculum Inquiry." He suggests that if the curriculum theorist accepts a conceptual change theory of knowledge in mathematics then questions are raised relating to the determination of content. He believes that this can be answered at two levels.

1. That what one teaches ought to reflect the theory of knowledge which one thinks is most appropriate and adequate for that discipline, that is, content should be selected which accurately portrays the particular discipline involved. In mathematics it ought to be portrayed evolving, growing and changing.

2. There should be an analysis of particular concepts and of the variety of ways in which they develop. The curriculum theorist must also consider alternative conceptions of particular concepts in an effort to assess their appropriateness for inclusion as content.

Ruth Rees and George Barr in "Diagnosis and Prescription" believe that although the ability to solve problems is important, the placing of mathematics in a relevant context is not necessarily a general panacea.

Rees states that problem solving should be interpreted as being mathematics in an appropriate context. For many this may mean an appeal to imagination, discovery, or artistry. For others it may imply familiar everyday contexts or the application of other subjects studied.

In whatever context problem solving is placed, the child's knowledge of mathematics must be sound. Therefore it is crucial that the teacher be aware of the:-

1. Level of difficulty at which the mathematics is pitched.

2. Level of familiarity and relevance that the context presents.

Rees suggests that successful problem solving may represent the ultimate in understanding. The aim of the educator must be for the child to acquire the ability to apply learned concepts and skills to many and varied contexts.

Two components of problem solving are identified as:-

a) mechanical

and

b) inferential.

Rees goes further and gives four categories into which she believes problems fall.

1. Mechanical mathematics embedded in a clearly defined mechanical context.

2. Mechanical mathematics embedded in a more inferential context, that is, the learner has to infer not only what to do but why and when.

3. Inferential mathematics in a mechanical context.

4. Inferential mathematics in an inferential context, this appears to be the most demanding and difficult category.

In her summing up Rees states that in designing problems for our children, the teacher should ask herself the following questions:-

1. Is the mathematics involved mechanical or inferential?

2. Is the context appropriate, is it straightforward or inferential in its demands?

As long as the teacher is aware of what she is requiring from her children then she can mix and match between the categories of problems always being aware, explicit and flexible.

Polya states:-

"It is foolish to answer a question that you do not understand. It is sad to work for an end that you do not desire" (16)

The above statement could apply to many children when tackling problems. Although understanding and motivation in pupils are desirable objectives, mathematical knowledge is also an important requirement for successful problem solving.

Lerman claims that the problem solving approach reflects the conceptual growth view of mathematical knowledge and also the nature of the learning process. However care must be taken to ensure topics come within the conceptual ability of the child and also that teachers do not expect a piece of knowledge to be tagged on to the existing conceptual framework of the child. Lerman is clear in his view that knowledge must be assimilated by a growth of the existing concepts of the child. His solution for the correct choice of problems is for the teacher to stimulate the child in an effort to examine his knowledge. If found inadequate to solve the problem, then they should be guided to extend their knowledge by hypothesis, or by taking a solution from another problem and then testing the hypothesis, that is, by the use of Polya's heuristics.

In conclusion it can be said of the two schools of mathematical thought Lerman refers to, that is, the Euclidean programme and the quasi-emperical programme, that the latter seems better suited to the situation in mathematics today, as outlined in the Cockcroft report. However although the approach appears to be dynamic and exciting it demands a complete re-appraisal of all aspects of a teachers work.

Having found similar philosophies firm in the belief in the value of problem solving, which supported initial interest, evidence of a more concrete nature was needed to give credance to the research plans.

Leone Burton ended the search. She reported in an article entitled,"The Teaching of Mathematics to Young Children using a Problem Solving Approach - Volume 11,1980", her aims for the project were:-

a) to construct an inventory of mathematical skills and procedures available to mathematical problem solvers.

b) to design and test a structured teaching programme through which appropriate problem solving skills and procedures could be taught and learned by pupils aged 9-13 years

Burton, like Lerman, used Piaget's developmental phychology as theoretical boundaries to her work. Burton reinforces Lerman's view on the nature of learning, believing that for a child dependency upon concrete experience constrains the type and variety of experience through which learning takes place. Lerman states clearly that not only does the informational content have to be contextually available but abstraction and generalisation must take place before the mathematical content can be said to be "learnt". Burton, like Lerman, rejects the Euclidean programme on the grounds that arithmetical concepts taught in isolation from meaningful, interesting and enjoyable applications will be learned, if at all, at the instrumental level only. She opts for the quasi-empirical view and states clearly that a child is motivated to learn by seeing relevance and use for the new learning when the concept or skill is placed alongside the structure he already has.

Burton's opinion of the importance of the development of mathematical language falls in line with the recommendations of the Cockcroft report and also of the view held by Polya. She states that mathematical language walks hand in hand with mathematical understanding. That it is linguistically dominated and embedded in the language development of children. She expands further by stating that it is a language in itself with its own symbols and rules for correct usage. She believes that as the child acquires the terminology and structures more complex activities can then take place.

Burton acknowledges also that mathematics is both a content and skill based activity. An infant child spends much of his time learning to count, to add, to measure etc. These are skills which are teachable components. They are dependent upon mathematical content for their data since a skill can only be exercised on some data. She also agrees with Piaget on the nature of children, that during their early years they are driven by curiosity, physical and mental control to experiment, connect and relate and comprehend their environment. She suggests that mathematics is a useful vehicle in the satisfaction of this drive. Through mathematics a child is able to describe and manipulate simple ideas of shape, structure, pattern, number and measurement all of which help the child to comprehend and understand the environment about him. That of making sense of the world is one of the major aims of the Cockcroft report.

Burton states:-

> "That the nature of mathematical activity in young children is three fold:-
>
> It is linguistic in that the growth of understanding is interdependent with the development of the means to verbalise or symbolise that understanding;
>
> It is environmentally based in that the mathematics of the world about us is, for the child, part of his understanding of that world;
>
> It is process dominated in that through the process of doing mathematics they can have experiences which not only illuminate mathematics itself, but also increase their mathematical creativity and effectiveness."(17)

Leone Burton's analysis of mathematics is complimentary and similar in many ways to the view of mathematics as expressed both by Polya and Lerman. It leads also to the same belief that there should be a change of emphasis from the isolated content and skills based view of mathematics (the Euclidean programme) towards a process-based view which is the same as Lerman's quasi-empirical view or Polya's view and his belief in heuristics.

She suggests that what is required in mathematics teaching today is a:-

> "shift in perspective both in terms of mathematical activity and in terms of the nature of learning mathematics. The wide range of individual differences to be found in a class of children, together with an understanding of what mathematics is and how it is produced and used leads inevitably to a method of teaching which is both active, exploratory and experience-based and which allows the individual a range of choice and discretion over his mathematical experiences. This method of teaching is being called problem solving." (18)

Similarities with Polya's work on problem solving appear again when she discusses the implications for teachers in introducing a problem solving approach to the classroom. She suggests that often their own mathematics is too fragmented to cope with relating one topic to another and of extending problem solving activities. Also that the heuristics of problem solving have not been incorporated into the teacher's own scheme of understanding. Teachers therefore have little background on which to draw for the children. These problems must be overcome. The rapid growth of technology has led many employers and decision makers to emphasise the need for increased problem solving ability in young people as they enter the world of work. Unfortunately the task is made more difficult by parents who put pressure on schools to conform to curricula and methods with which they identify.

The implementation of a problem solving approach in mathematics depends upon the ability, experience and attitude of the teacher, school and parents. It would seem that some sort of in-service re-training for teachers is necessary if mathematics through problem solving in schools is to gain momentum.

Teachers prepared to use problem solving techniques in their classrooms should note that it can be justified as the process aspect of mathematics and that it has a repertoire of mathematical skills which are appropriate to it.

Burton suggests that the skills of comprehension, transformation and communication can be taught and stored for future use. Here again are similarities to Polya's heuristics. She further divides skills into two categories:-

Representational skills, those which facilitate the construction and/or the use of different modes of presentation. They appear as:-

1. Linguistic
2. Pictorial
3. Concrete
4. Symbolic
5. Translation
6. Modelling

Information analysis skills are those of collecting, organising, analysis and presenting information. They appear as:-

1. Using representational skills to identify data and information.

2. Making known and unknowns explicit.

3. Using systematic arrangement of information.

4. Presenting data.

Leone Burton suggests that the above skills can only be applied when the problem has been heuristically approached, that is, when certain procedures have been applied.

She contends that problem solving draws upon a combination of these skills and procedures, and that they span all likely problem solving techniques. If the skills and procedures are involving and engaging enough then mathematics may be seen as an enjoyable and useful activity and this may well help change the negative attitude towards mathematics experienced by many children.

In summing up Burton claims that problem solving is a valuable method of teaching mathematics because it encompasses individual differences, engenders positive effect and provides opportunities for teaching the skills associated with it. She does not believe that it should occupy every minute of school mathematics time rather that it should be incorporated as a necessary and vital part of the time-table. By doing so it could help erradicate negative opinions and attitude towards the subject and increase interest in the growth and development of mathematical skills in children which will assist them in the assimilation and understanding of facets of the world about him.

Chapter 4

Mathematical Language

The short quotation, used previously, from the Cockcroft report "Mathematics Counts - 1982",

"The ability to solve problems is at the heart of mathematics" (19)

has been used frequently in education circles and has often been used in advertising I.N.S.E.T. mathematics courses. This over exposed quotation should not be considered in isolation but rather in conjunction with paragraph 250 which states that:-

"The idea of investigations is fundamental both to the study of mathematics itself and also to an understanding of the ways in which mathematics can be used to extend knowledge and to solve problems in very many fields." (20)

The report expands further:-

"Mathematical exploration and investigations are of value even when they are not directed specifically to the learning of new concepts." (21)

The quotations from the report focus on active investigation and exploration. Whether at the service of another discipline or in its own right, mathematics is a "doing subject". As outlined earlier it is used to solve useful problems, it can also be played with in a creative way to see what can be discovered, it has power to inform and it is the basis on which intriguing puzzles can be invented. All good reasons to validate a problem solving approach in understanding and developing mathematics.

The success of investigation and exploration incorporated in a problem solving approach depends greatly upon children's language competencies. As in the Bullock Report "A Language for Life" (D.E.S.1975) the Cockcroft Report placed tremendous weight on the role of language in mathematics learning. Cockcroft states:-

> "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." (22)

Mathematics can and should enrich pupils' linguistic experiences. Teachers need to develop and encourage in their pupils an awareness of the power of mathematics to communicate and explain. The development of this skill in children should enable them to make more precise an argument or to better present the results of an investigation. The introduction and use of new vocabulary in mathematics should be carefully planned and monitored from the children's first entry into nursery school. The gradual assimilation of technical language into everyday speech patterns should greatly facilitate the child's development in all aspects of the curriculum, particularly mathematics, science and technology.

Mathematics can be used as a powerful tool for clarity of communication. It is concise and unambiguous.

Recently the Kingman Committee underlined the kinds of talk teachers need to encourage:-

"In addition to encouraging the development of speech for communication, teachers need to encourage talk which can be exploratory, tentative, used for thinking through problems, for discussing assigned tasks and for clarifying thought: talk is not merely social and communicative, it is also a tool for learning." (23)

Children who have acquired a broad understanding and use of mathematical language will have an advantage over their peers in problem solving activities. For many children mathematics consists of a collection of facts which must be be remembered and skills to be practised. If a wide mathematical vocabulary were added to the two lone components and opportunities for active problem solving given, then hesitancy may be replaced by confidence and dependence by autonomy. Apathy towards mathematics by many children may then be replaced by enthusiasm.

Leone Burton in "Thinking Things Through" 1984, believes that the overwhelming importance of problem solving is in the opportunities it provides for pupils and teachers alike to, through their own enquiry, establish different styles of teaching and learning. She believes that problem solving cannot be taught, rather it develops in an environment where skills which have already been acquired are given opportunities for exercise.

The use of a problem solving approach in mathematics, gives even the least capable child the opportunity to start from where they are and use whatever they can to make progress, hence the motivating power of problems. If children's curiosity can be nurtured and developed and their spirit of enquiry refined then sound skills will be established for their learning both in the present and in the future.

To help develop a spirit of enquiry an atmosphere in the classroom of questionning and challenge must prevail. Questions by children should be respected for their existence. They can prove to be starting points for important mathematical investigations and in tackling the problems which have evolved from the questions, the teacher can make use of a variety of mathematical concepts. From their earliest attempts at problem solving children should be encouraged to challenge the mathematical arguments relating to the solution. This would enable very young pupils to begin to distinguish between an argument which is itself satisfying, as opposed to an argument required to satisfy a sceptic.

Emphasis, in a problem solving environment, should also be placed on reflection and consideration. Reflection on differences in approach or in method deepens the awareness of the pupil's own understanding and capabilities and can extend his/her own repertoire of procedures for solving problems.

Leone Burton suggests that the teacher's role is to ensure that reflection is both possible and valued. Questions such as:-

"What difference will that make?"

"What did you do to arrive at that conclusion?"

"Is there another way of doing that?"

all cause pupils to evaluate the methods which they have applied. A wide use and understanding of mathematical language will enable children to implement this strategy on a more sophisticated level, allowing them to have positive procedures to recall and apply in problem solving activities on future occasions. An example of mathematical language is a checklist for use with children who have learning difficulties, this can be found in the appendix (2). It is one of many lists which are available for teachers to use.

Problem solving is best seen as a group activity, where pupils are encouraged to collaborate - pooling understanding, knowledge and skills. Group activity can encourage co-operative work habits. Communication skills are developed and there are many opportunities for making and explaining of conjectures. Persistence in the exploration of problems is also promoted. Practice in these skills is advocated by Cockcroft in the development of strategies for problem solving and investigation.

Leone Burton states that mathematical explorations and investigations are of value in their own right because:-

1. They enthuse and excite pupils.
2. They provide opportunities for creativity.
3. They can be attacked at various levels of sophistication so everyone can enjoy and achieve something.
4. They build confidence and independence.
5. They develop collaborative learning.
6. They enable pupils to recognise and apply what they already have stored.
7. They shift the focus of attention from what is learned, to how that learning is used.
8. They give meaning and value to the study of mathematics. (p.18)

All are valid in promoting the development of a problem solving approach and all rely heavily on sound mathematical language competencies.

To talk mathematically means to think mathematically. Acquiring the vocabulary, making sense of the concepts, appreciating the structures, evaluating the issues; these are what learning to talk in the subject of mathematics means. Learning to talk mathematically therefore is learning to learn mathematically and this ability will facilitate the understanding of the processes, concepts, skills and attitudes which mathematics encompasses. The Bullock Report (DES 1975) argued that in order to help the growth of children's language competence a teacher must be able to:-

"examine the verbal interaction of a class or group in terms of an explicit understanding of the operation of language."
(24)

Mathematics as a subject will have its own particular conventions for observing and assessing talk. In spite of this when assessing devopment in children's mathematical talk it is helpful to bear in mind the following:-

Working with others

Does the pupil:

listen and respond to what others have to say?

respect other speakers contributions?

help to resolve difficulties?

Using Mathematical Talk

Are the pupils contributions relevant, accurate and clear to those listening?

Do they show:

depth and breadth of understanding of the basic topic being studied?

show a sense of the direction and purpose of the task?

an ability to select points and make connections?

knowledge of the appropriate words?

In considering the above in relation to publications outlined in this study the writer was guided towards the possibility of introducing to school a computer language for children, to be used as a vehicle for developing their problem solving skills and improving the quality of mathematical language used in group activities.

Chapter 5

A Computer Language

Dr. Seymour Papert and a team of American computer scientists, based at the Artificial Intelligence Laboratory of the Massachusetts Institute of Technology (M.I.T) in Boston developed LOGO as a computer language for children. LOGO has been promoted as the ideal computer language for children, since it was specifically devised to make it easy for children to create their own programs. The philosophy behind the development of LOGO is fully explained in Papert's book "Mindstorms: Children, Computers and Powerful Ideas."

In 1958 Papert started to work with Jean Piaget, renowned for his work in developmental psychology. Papert was to spend five years at his Centre for Genetic Epistemology in Geneva.

Papert was greatly influenced by the work of Piaget, becoming convinced that it is the culture in which a child grows which influences the development of the mind and on the order in which the Piagetian stages occur.

It was while working with Piaget that he arrived at the conclusion that children found certain ideas difficult to assimilate, not because of their underdeveloped minds but from the limited nature of their experiences. He believes that a particular kind of culture produces a distinctive pattern of learning development and from this he concludes that changing the culture is likely to alter the ways in which thinking develops. Papert is of the same opinion that cultural change can be brought about in a computer rich society. He believes this "computer culture" has a liberating potential which should be disseminated as widely as possible. He promotes the view that the use of computers will eventually make traditional educational systems obsolete. Children would move from teaching situations where they are forced to listen to other people's explanations to situations which allow freedom to find out for themselves, where learning becomes the perogative of the individual with his/her computer. Papert also believes that the computer can be used as a tool for overcoming deficiencies in schools when they are properly used as a means to encourage a new way of learning. It was this belief that led him to the development of LOGO. It is claimed that LOGO will assist in the development of a child's thinking skills by making him actively react mentally to learning situations. It offers opportunity for familiarisation with and general use of the computer. LOGO is designed to be easy to use and understand and it makes available a wide range of facilities. It is also claimed that LOGO offers children an introduction to computer programming which is highly structured and which encourages the careful construction of programs through analysis and breakdown of the problem to be solved or goal to be achieved. This in turn develops good thinking and programming habits, both skills necessary for the development of higher grade computer skills needed in secondary education and also useful in improving thinking processes needed in other areas of mathematics such as geometry. It is claimed that one of the values of LOGO in the development of children's problem solving skills stems from the necessity of "debugging ". Debugging procedures and programs enable a pupil to analyse the components of the problem and this leads to the development of a constructive attitude rather than of a destructive or negative attitude which can often occur when a child believes s/he has failed. Often the unexpected outcome of a program encourages a child to investigate and expand their learning in other directions. The analysis of the problem and the resulting opportunities for language development can stimulate and encourage the children and in so doing they can develop a positive and investigative attitude to things different from that which they had planned.

Many teachers who have used LOGO in their classrooms state that it is stimulating and enjoyable for children thereby leading to increased motivation and enjoyment.

It is claimed that LOGO is most effective when used in groups where discussion and debate is encouraged. Through the contribution of ideas and suggestions and efforts to understand the points of view of others the skills of oral fluency and coherence are developed. Group members learn from and help each other. Learning to compromise, learning to accept and value each other as working contributors to a team effort and result are also important skills necessary for a working life in a technological society - all, it is claimed, can be developed through the use of LOGO.

Since this study began the National Curriculum has been introduced to our schools. The three core subjects of English, Science and Mathematics and accompanying seven foundation subjects are intended to give children in schools a structured, balanced education which allows for continuity and progression at the same time giving opportunitiy for discussion and debate. Oral coherence, confidence, the ability to get on with others and work in a team are identified as important skills. Opportunities for their acquisition are available through the programmes of study. The introduction of LOGO is seen as being desirable.

"Good opportunities for using mathematics in a variety of contexts arise from using micro-computers. Primary children who have mastered the simple LOGO commands. FORWARD, BACKWARD, LEFT AND RIGHT, might be asked to use them (in conjunction with a printer or a turtle) to draw pictures, sketches, or diagrams that stem from other areas of work. In this way, pupils can use their mathematics in a variety of contexts provided by topics they are working on and also develop and practise their skills with LOGO procedures."
(25)

In recent years a variety of LOGO studies have been undertaken. One of the first studies was made by Pea, Kurland and Hawkins, in New York. The study took place over a two year period in 1984 and concentrated upon looking at whether LOGO experience enhances general thinking skills such as problem solving or planning. After a two year period they were of the opinion that there was little conclusive evidence to show that the use of LOGO enhanced general thinking skills. The conclusions of the research aroused controversy. The advocates of LOGO claimed that the methods used by researchers were not adequate to test the benefits of LOGO. Seymour Papert and his supporters argued that "objective" educational researchers look for measurable results whilst ignoring factors which are difficult to measure such as happiness, confidence, interactiveness, oral coherence, debate and attitudes. Interpretive and qualiative methods of research may prove to be more useful in identifying positive factors in the use of LOGO.

The Walsall LOGO Project was set up in 1983 and was funded by the LEA. The emphasis of the project was not on LOGO as a vehicle for mathematics teaching but as a stimulus to learning in many areas with the emphasis on language development. The project involved six schools and was school based. The local Teacher Centre became a centre for in-service work, regular workshop sessions were held for teachers. Teachers personal experiences were used as a stimulus for new activities.

The participant teachers believed their project to be a success. They claimed it had a clear educational philsophy in mind which was based on a climate of trust in the classroom which enabled the child's natural curiosity to act as an incentive to learn. Children were treated as thinking, understanding, contributing individuals, thereby enabling themselves to approach decision taking confidently. It was claimed that as a result of the project the children developed independent work habits and thinking skills. A further claim was that LOGO initiatives will succeed best where there is maximum involvement from all facets of education, that is, Local Education Authority, teacher, parent and child.

Papert's overall claim in creating LOGO was not merely to provide a more attractive way into mathematics but to provide a means which would encourage joyful and independent learning. The ability to create programs using graphics and sound effects gives children the opportunity to use their mathematics creatively. Since problems are set and solved by the children themselves they and their teachers can learn together in a partnership which does not rely on a set curriculum. By building up programs the child is able to learn in what Papert terms "mind sized" chunks, he claims that his system gives the initiative to the child. Papert theorises that many people hate mathematics because it has been taught in a traditional way with the emphasis on logical, coherent patterns of thinking, ways which compartmentalise the subject artificially from other areas of the curriculum such as language and movement which use other modes of thinking. Papert holds the view that if mathematics is to be accessible it must be continuous and personal and it must enable the child to work at meaningful and relevant projects which could not be satisfactorily achieved without it. Papert claims that LOGO can be used as the vehicle to meet those requirements. He does acknowledge that learning strategies do exist to encourage independent systems of thought which pre-date the computer but he believes that it is the facility offered by the use of debugging strategies within LOGO and the subsequent improved attitude towards problem solving which makes LOGO a more attractive tool to use in the development of thinking skills.

The possibility of using LOGO to promote the development of children's language competencies and problem solving skills excited the writer, however difficulties relating to finance and logistics had first to be investigated. At the beginning of the study only one computer was available for use by 120 children and there was no printer. The school was in a poor socio-economic area and finances and resources were limited. At that time a full LOGO chip was approximately £70. This figure could not be met by the school which was saving hard to purchase a printer. Lack of school staff knowledge relating to the facilities offered by LOGO and the apparent initial complexity of becoming familiar with its use coupled with restraints of time, all became significant factors in the decision to reject LOGO as the means on which to base the study.

It was at that point that the writer turned towards DART which is a subset of LOGO written in Basic. It can be used to operate a floor turtle, again a resource the school did not possess and it provides some of the graphics facilities of a full LOGO. It does not offer features such as list processing, sprites, music or control technology. Knowing the resource limitations in relation to both staff expertise and equipment the decision was made that DART should not be readily dismissed. Further investigations showed certain disadvantages. DART has insufficient memory necessary to hold all the subprocedures required for more complex projects. It is claimed that the syntax is not logical, a feature deemed important when children go onto investigate list processing, then it is important to have the same logic all the way through. It has also been alleged that the mathematical potential of DART is narrow. However though limited in nature it can still offer stimulating challenges and as the central concern was that of finding a vehicle to develop problem solving techniques and one which could promote situations in which to develop language it appeared to be appropriate. DART had distinct advantages for the writer who had no LOGO experience, the programme is relatively simple and straightforward. This can be seen as an important factor in encouraging practising teachers to use the program, many who may feel daunted by the apparent initial complexity of LOGO and time needed to acquire basic LOGO skills. Mounting classroom pressures and constraints of time are factors which could also deter teachers from assimilating LOGO in to their teaching philosophy and classroom practice.

The final and most important factor was that of cost. For the price of a disk DART could be obtained from the Local Education Authority which had purchased the license.

All of these factors, coupled with the belief that DART was clearly able to provide a natural access to the world of problem solving and could offer many opportunities for the development of language and problem solving skills led to the final decision being made. DART was to be used as the vehicle on which to base the study.

Chapter 6

Evaluation Techniques

"He that judges without informing himself to the utmost that he is capable cannot acquit himself of the judging amiss."
(26)

One of the problems regarding the outcomes of this study is that of not being a qualified, or specially trained evaluator. In tackling the question of evaluation a study of the variety of roles that the evaluator may be called upon to play was necessary. One of the common roles is that in which the evaluator can be responsible for gathering and organising the reactions of teachers and pupils to the innovation. The evaluator can also be expected to act as a critical friend to the project and through the work can question the basic philosphy of the project and the appropriateness of materials used in the study. Using these tactics the evaluator may be able to sharpen the definition of the project objectives. A task of prime importance is the responsibility for selection of tests and other instruments to measure the success of the undertaking. The evaluator also has a descriptive role, s/he must explain to teachers and head teachers all the factors involved in the innovation and what can be expected from them. The work of an evaluator is therefore of a flexible nature. It might be argued that the evaluator should be concerned with more long-term aims, such as the children achieving better educational results or becoming better citizens than those working on more traditional lines. This is a difficult field, but not one which should be neglected.

Attention was turned to the task of finding efficient procedures and instruments for evaluation. If evaluation is reduced to the testing of pupil learning then it is quickly found that the range of available measures is limited. Tests of cognitive skills are usually characterised by factual recall. The model of curriculum development frequently used is the objective approach where clearly defined objectives have been stated leading to desired pupil/teacher outcomes. Ralph W. Tyler in "Basic Principles of Curriculum and Instruction," suggests that there are a number of sources on which to base wise and comprehensive decisions about the objectives of a school. They are:-

a) studies of the learners themselves as a source of educational objectives,

b) studies of contemporary life outside the school,

c) suggestions about objectives from subject specialists,

d) the use of a philosophy in selecting objectives,

e) the use of a phsychology of learning in selecting objectives,

f) stating objectives in a form to be helpful in selecting learning experiences and in guiding teaching.

Content and method can be derived from these objectives. Later the evaluator measures the extent to which the pre-specified objectives have been reached.

Tyler states:-

"The process of evaluation is essentially the process of determining to what extent the educational objectives are actually being realised by the programme of curriculum and instruction. However, since educational objectives are essentially changes in human beings, that is, the objectives aimed at are to produce desirable changes in the behaviour pattern of the pupil, then evaluation is the process for determining the degree to which these changes in behaviour are actually taking place.

Evaluation has come to have a strong emphasis on the measurement of pupil outcomes, on meaures of behavioural change." (27)

It was decided after further investigation and discussion to use the Bristol Achievement Mathematics Test 3, for children aged 10-11 years, as a means of assessing the children's mathematical skills.

This particular test includes skills which are deemed important in recent mathematical publications.

PART 1 - examines the understanding of number from the stage of conservation to the level of binary and directional number.

PART 2 - is concerned with sets and series and with inductive and deducative reasoning.

PART 3 - examines spatial discrimination and judgement and overlaps to some extent with PART 4

PART 4 - is primarily concerned with measurement and measuring units

PART 5 - concedes the need to examine knowledge of conventions and arithmetic laws and processes, but avoids becoming tied to computational accuracy.

All parts of the test must be administered at one sitting to achieve total scores, which are differently balanced over the various levels. The size of the school seriously limited the number in the sample of children to be used in the research. It was therefore particularly important that the test chosen for use with the children used standardised test scores which have been based on a very large number of children throughout the country and from all stratas of socio-economic backgrounds.

Using a standardised test score has the following advantages:-

1. Each child's score is compared with the scores of a standard sample of children of the same age (within a two months interval).

2. Whatever the age and whatever the test, the average score is always 100.

3. The distance of the child's score from the average is always measured in a standard deviation, which is 15 points of standardised score.

4. There is a direct relationship between the standardised score and the proportion of children who have in the standard sample achieved that level of score.

Most achievement tests specify age as the discriminating variable for selecting the level of test to employ. The Bristol Achievement Tests, in addition to age variable, also incorporates a "length of schooling" variable. Level 3 refers to those children who were ten but not yet eleven. Testing may be carried out at any time of the year, as a result children may range in age from 10:0 at the beinning of the year, to 11:9 at the end of the year. The test is standardised over the age range 10:0 - 11:11. Parallel forms at each level enable re-testing to take place. Thus

Level 3, Form A, would be employed for testing at the beginning of the year and Level 3, Form B, later in the year.

Conditions in which testing is to take place are clearly stated in the Administrative Manual for the Bristol Achievement Tests. Obvious factors such as, temperature, lighting, seating arrangements and previous activity which could influence testing outcomes were to be considered by the administrator. Less obvious factors were also to be considered, they included demeanor and clarity of speech of the administrator, friendliness and firmness of manner and efficient preparation of the room for testing.

The time control is an essential aspect of the test performance and is particularly important for the profile of part scores.

All of the above factors were considered by the administrators of the test used in the study. Since it was hoped that attitude was also going to be assessed a search was made for a definition as well as tests of attitude.

G.W.Allport provides the following definition:-

" Attitudes; A mental and nueral state of readiness organised through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it related." (28)

Attitudes are thus the key to what people are likely to do, how they "feel" about something. Attitude measurement, essentially involves the administration of a questionnaire which requires the subject to indicate either:-

a) a rating evaluation of a "feeling" about something;

b) the likelihood of the individual behaving in a particular way;

Kretch, Crutchfield and Bellachy in "Individual and Society" suggest that attitudes have:-

1) A Cognitive Component - knowledge or belief about an object/state of affairs. The issue then becomes what information is avialable.

2) An Affective Dimension - the emotional "content"; like or dislike.

3) A Conative Dimension or "action" tendency; the disposition to take action towards the object of the attitude.

Attitude measurement aims to produce a quantitative measure of a mental state which is held to be an indication of a propensity to behave in a different way.

However commentators agree that there is a gap between measured attitude and actual behaviour which are:-

a) centrally related to the self concept of the individual (ego defensive functions)

b) related to values and morality - people will say the right thing if asked questions, but behave differently.

These factors must be considered when evaluating responses to questions on an attitudinal questionnaire in order to make valid inferences about actual levels of interest, attitude or likely behaviour.

In the final analysis it was decided that in addition to the Bristol Achievement Mathematics Test A and B the children at the conclusion of the study period would be given the Assessment of Performance Unit's Mathematics Attitude Questionnaire. It was felt important that careful examination of the results of the questionnaire was to be made in an effort to note if a general positive attitude towards mathematics could be indentified. Hitherto in the research school a lack of enthusiasm towards the subject had been noted over a period of years and this was reflected by poor examination results achieved by past pupils in their comprehensive school. Only one child had gone on to further education to study a course with a specific mathematics link. If it is to be believed that positive attitudes towards mathematics developed early in the primary years help ensure success in later stages of the education process then analysis of the attitude questionnaire, in spite of the limited size of the sample, should not be overlooked or disregarded.

The statements in the questionnaire were chosen by the Assessment of Performance Unit to measure attitude towards mathematics. However it must be noted that the Assessment of Performance Unit is concerned with large scale surveys and not, as in this instance, with a very small sample of children who had been known to the researcher for a substantial period of time. The questionnaire was used in an effort to identify whether pupils liked the subject, saw it as being useful, and how difficult they thought it was. In addition to the questionnaire the research sample of children were to be asked to write a personal opinion of their work with DART. The children had from the beginning of their junior education been encouraged to express themselves in written form and from these writings to discuss and clarify their thoughts and feelings with the teacher. It was believed that the children would not be inhibited in their written accounts nor would they be influenced unduly by "pleasing the teacher syndrome" , that is, that they would write positive statements in an effort to gain teacher approval.

Throughout the study the children were encouraged to verbalise honestly about their involvement.

Chapter 7

The Study Begins

The control group used in this research came from four primary schools in Cleveland. All schools in the research project used the Scottish Primary Mathematics Scheme and the children came from a variety of socio economic backgrounds.

The control group were all at stage four in the Scottish Primary Mathematics Group scheme and all were aged between ten and eleven years.

At level four the children are required to work on aspects of number, length, weight, area, volume, time and shape. To encourage this development the teacher is able to draw from support materials which include work cards, work books and text books.

It was decided that the teachers concerned with the work of the control group would all follow the scheme carefully. It was essential that all the children had an equal weighting of mathematics. The control group were to concentrate solely on Scottish Primary Mathematics Group scheme the experimental group would use DART as well as the Scottish Primary Mathematics Group scheme. Both the control group and research group were small mixed ability groups of ten, eleven year olds.

The research was designed to answer questions about the cognitive and social impact of DART in the primary classroom.

Specific questions raised were:-

a) Does learning to program affect the development of positive attitudes towards mathematics?

b) Will language competencies be improved by computer based group problem solving activities?

c) Will programming experience result in greater facility with the art of "heuristics", that is, explicit approaches to problem solving which can be transferred to and foster the understanding of higher order mathematical concepts?

The children were allowed to decide who they wanted to work with. The researcher felt that it was important that time and care was spent in the self selection of the children into working teams. It was felt that if children were to be encouraged to be independent and skills of co-operative work were to be developed then the importance of group dynamics was not to be overlooked. The children divided themselves up into two groups of three and two groups of two. Polya's theory of group work discussed earlier was to be given every opportunity to succeed.

On analysis of group membership it was interesting to note that the three girls formed a group on their own despite the fact that there was a wide divergence in academic ability between them. This group contained both the most intelligent child in the class and one of the least able. Their group had been formed on a gender bias as the children did not have strong friendship links. The boys on the other hand appeared to cluster in ability groups. The less able gravitated towards each other as did the more average children. Despite the fact that they had been given free choice, the only proviso being that once formed, peer group membership must remain the same during the designated period of computer worktime, the children appeared to have been influenced by the mathematics group system of working employed by their class teacher. The "labelling" syndrome had its effect in the formulation of the group of boys.

Four groups emerged:

Group A	Graham Steven C.
Group B	Anne Marie Beth Michelle
Group C	Peter Richard David
Group D	Michael Steven L.

The initial proposal was that the children would be given instruction in how to get started. A workcard was made from the DART instruction manual (Appendix 3) and presented to the children in their small groups.

After initial brief explanation of the card the children were all given hands on experience of the computer. There was much enthusiasm, hitherto the children had only very limited experience. One computer to be shared by a whole school, even a small school, poses problems of access and logistics. The children were made aware that they were to be involved in "a computer project" and as such accepted that by so doing would have the privilege of using the computer for a six month period. The rest of the school were pacified in the knowledge that the arrival of a second computer was imminent.

Once all of the children were confident and capable of loading the disk and using the first basic commands, they were given the second workcard, (Appendix 4). The children tackled the card with confidence and enthusiasm. Without exception they all talked positively about their work. It was the intention from the outset that the children would be encouraged to set their own problems, to find solutions by exploring and adapting previously learned commands and seeing the need to learn or create new ones. Talking about difficulties or ease of solution was to be encouraged.

In order that the work be monitored the children were given an exercise book. In it, they had to date and record the commands used and then draw the picture produced. At this stage the school did not have access to a printer, this came later in the study. Initially each group spent sessions of between one hour - one hour and fifteen minutes on the computer. Groups had three sessions per week. After each session the children had to write a comment about their work. They had long been encouraged to speak their own opinion and had also, during language activities, been given opportunities to be forthright in their views, whether it be about a book they had read, a playground incident or an item of news under discussion. Giving their opinion, however brief or inarticulate was therefore nothing new to them.

It was anticipated early in the study that the amount of work covered by each group of children would vary. This quickly proved to be true. Appendixes 5,6,7,8, were completed by one group in one session and Appendixes 9 and 10 by another in a session of equal length.

The amount of work covered by individual groups was to be arbitrary. If children were to be motivated to develop their ideas to the full, to become instrumental in their own learning and in so doing develop methodical work patterns thereby establishing their own code of behaviour and discipline, then judgements should not be made on numbers or quality of pieces of work produced during a specific period of time.

The computer was housed in the school's mathematics workshop. A spare classroom had been re-organised into topic bays, that is, shape, volume, number, weight, area, time. Each bay housed items of equipment needed to implement the Scottish Primary Mathematics Group scheme. As the children were used to working in the workshop for certain activities and only occasionally under the direct supervision of the teacher, it seemed natural for the computer to occupy a bay in the workshop. The children would be able to verbalise freely about the task in hand and would not interfere or cause a distraction to other children in the class. The children were made fully aware that their task was important and that unruly behaviour and time wasting would be reflected in their work, that is, they would have nothing to show for their time using the computer.

During the initial stages of the study, the researcher, because of classroom committments, was unable to act as a non-participant observer of the children at work. Interviews with the children in relation to their workbooks was to be used as part of the evaluation procedure. Of the research interview techniques available to use, an unstructured interview conducted in either classroom or mathematics workshop was chosen as best satisfying the research requirements.

In order to analyse in greater detail the progress of individual children and development of the study as a whole, two groups were focused upon.

Group B was made up of three girls, one of above average intelligence, one average and one of below average intelligence.

Group C consisted of three boys, all of average ability. All children in both groups were friends and worked co-operatively together.

Group A and D consisted of two pairs of boys of matched ability. Whilst work produced by Groups A and D contributed to the data used in the research project it was decided that as there were significant similarities between two groups it would prove more enlightening for the purposes of the study to focus on groups with greater differences, hence the choice of Groups B and C.

The first interview was conducted in the mathematics workshop at the end of Group B's (girls) first "real" work session, that is, work was recorded in a book for the first time. It was the children's playtime but they appeared reluctant to leave the room and were obviously keen to talk about their activities.

Researcher: "Well, what have you been up to? Did you get anywhere with your task?" (Workcard 2 - Appendix 4).

Beth: "'Course we did - it was easy."

Anne Marie: "Eeh, you fibber - Miss. that's not right. Beth kept mixing up her lefts and rights."

Beth: "I know, we all did, anyway I wrote that in my book."

Researcher: "Let me have a look." Beth had indeed recorded her inability to sort her lefts from her rights. (Appendix 5)

Researcher: "Do you know why you found it difficult?"

Beth: "Not really - I haven't thought about it - I suppose I thought it would be the other way round, like a mirror - then the more I thought about it the more I got mixed up."

Anne Marie: "Then we laughed at her - it was funny."

Researcher: "Did Beth laugh?"

Michelle: "Yes - we got the giggles."

Beth was an intelligent girl who hated to make mistakes. Her inability to cope with failure had often been the cause for distress and concern.

Researcher: "Beth, didn't you mind making mistakes?"

Beth: "No, it didn't matter, cos we could talk about it and try to put it right again and again on the computer till we could find out where we went wrong and put it right. Anyway it didn't leave a mess - not like on paper."

Michelle: "We won't forget for next time."

This line of thinking was in line with Polya's heuristics discussed in detail earlier, that is,

Understanding the problem

Devising a plan

Carrying out a plan

Reviewing the situation

Having fully discussed their activities and having surmounted their difficulties or solved their own indentified problem, for example, sorting out their lefts from their rights, the children went happily out to play.

On closer examination of the children's work it was revealed that by working together in a team they had successfully managed to produce commands which drew a square, rectangle, triangle and hexagon. The comments the children had written were virtually identical. On examination of the transcript it appeared that Beth had been instrumental in guiding the group through the morning's activities. Michelle, a child of low ability, with a short term memory span appeared to have taken a back seat. In an effort to discover if she had indeed assimilated and retained anything of the morning's work an effort was taken later in the day, in the classrooom, to engage her in conversation.

Researcher: "Michelle come and tell me because I've forgotten - what were the names of the shapes you made with the others this morning?"

Michelle: "You mean with DART?"

Researcher: "Yes."

Michelle: "We did a square, a rectangle and a triangle."

Researcher: "I thought your group had done four shapes.?"

Michelle: "We did - the other one was a - was a - it had six angles."(child hestitated).

Researcher: "I'll give you a clue - it starts with "h"."

Michelle: (shouted),"hexagon."

Researcher: "Well done. I am pleased with you. How did you remember it had six angles?"

Michelle: "It was me who said let's make a harder shape after we did the triangle. Then Beth said a hexagon. When her and Anne-Marie finished I counted and it had six."

Despite previous difficulties relating to her short term memory span, Michelle had successfully remembered the shapes created that morning and used in the correct context the word angles. She had also obviously participated actively in the group work, that is, by suggesting they make a harder shape. Again this refelects Polya's heuristics, that by sharing in the formulation of the problem students are encouraged to work harder. Thereby cultivating desirable attitudes.

The children were again time-tabled for DART the following day.

At this early stage the researcher felt it was important not to encumber the children with too much information relating to new commands rather wait for the child to request assistance or identify the need for knowledge of new commands. As a result the children were given a personal task of drawing a parallelogram.

The researcher felt that this particular group should have more practice in producing geometric shapes.

Translating physical movements into lines on a screen is quite an abstract task,this group needed time to consolidate previously learned commands and adapt to a new way of thinking and learning.

At the end of the session the children returned to the class. They had completed the set task, that of drawing a parallelogram. The group also produced a kite shape (Appendix 11,12). On reading their comments it was obvious that they were still not ready to proceed to new commands. At this point it could be noted that the children were at different stages of development. Michelle appeared to be at Piaget's stage of logical operations with concrete materials. This precedes Piaget's period of formal operations which normally begins at the age of eleven or twelve.

This can be illustrated by examination of Beth's written comment relating to the construction of a pole produced later that week (Appendix 13). She commented,

"The pole was very easy but we picked the pole for Michelle to do and she said what she thought to me and I moved in that direction on the floor."

Both Beth and Anne-Marie had acquired the ability to translate physical movements directly onto the screen. They were at the period of formal operations. They had also identified Michelle's need for support, she still needed to physically put the DART commands into sequential order.

At this stage of the research project the children were exhibiting work habits deemed desirable both by Cockcroft and outlined in Mathematics from 5-16 which were quoted earlier this study. Whilst this study is not intended to be a psychological disseration, to ensure as many points as possible and complete coverage of the area of research, deliberation was again given to Papert's view which he formulated whilst working with Piaget himself, that the reason most children found some ideas difficult was not because their minds were immature as Piaget would have said, but because their experiences in a computer-starved culture were inadequate. It was for this reason that the researcher decided to monitor Michelle's progress further.

Papert's view that a child learns spontaneously when left to itself appeared to be validated in a comment written by Beth in relation to Michelle's progress, (Appendix 14)

"The van shape was very easy so we let Michelle do it and now she is used to it." (Appendix 14)

Michelle had indeed gained in confidence and showed tremendous enthusiasm when computer sessions were about to begin.

Papert's claims that computers can be used as a vehicle for exploring abstract ideas in a concrete and personal way seemed to be authenticated. At this juncture it seemed appropriate to introduce further commands to the children. The repeat command was presented to the children in the form of a workcard, (Appendix 15). The children were left very much to their own devices in an effort to give them every opportunity to develop independent work habits. The research group had to become initiators, they were in the sole control of the computer. It was they who would be programming, using a computer language with power and a definite consistant structure.

The children appeared quickly to identify learning strategies suited to their own personal needs.

Beth's comment on learning the repeat command,

"This pattern was very easy but it gets us used to the repeat." (Appendix 16)

Once the children had mastered the ability to create abstract shapes and were motivated to create more complex projects - pictures of space ships, houses, people and things from life - they were introduced to the more complicated task of building up procedures, that is, the breaking down of an identified problem into smaller pieces. This would lead the children to quite difficult programs made up of a number of procedures. These activities were to be rooted in the children's own experience and based on a purely personal choice. The researcher did not attempt to interfere with the children's choice of task. The children were allowed to modify their pre-determined plan to fit in with what they actually drew or they could change it at any point.

Group C (Boys) followed a similar pattern to that of the girls, they too made geometric shapes:- square, rectangle, triangle and pentagon. On the whole the comments made by the boys about the work was more positive, they did not class second, third or fourth attempts as being "mistakes" as had the girls; rather as inaccurate quesses or estimates which had missed their mark. This can be illustrated by a comment from Peter in relation to his work on triangles, (Appendix 17),

"I enjoyed doing this particular shape because it was the hardest shape as you can see by all the rubbing out."

There was a similar comment from Richard about the same shape:-

"I enjoyed doing this because it took a lot of thinking about all of the time."

The boys also began to set their own challenges and began to time themselves for specific tasks. They quickly moved from making simple geometric shapes to more complex tasks, for example, that of drawing a robot. The first robot the boys attempted to draw resulted in the following written comment from Peter,

"I thought this object was the hardest thing we have done. We got the legs wrong but we will try to improve it next time."

The boys were significantly more enthusiatic in trying to improve upon their first attempts. Richard's comment about the same task was,

"I thought this object was the hardest thing we have done. We got mixed up on doing the legs otherwise it was good. I hope we can try again next time."

Comments made always reflected positive enthusiasm for next time.

It seemed appropriate to interview the boys during the daytime following their next computer work session. The discussion went as follows:-

Researcher: "My goodness are you three still busy?"

Richard: "Yeah it's been great."

Peter: "We've made a robot and it's brill."

Researcher: "Let me have a look, what have you got there?"

David: "We made a plan 'cos last time we messed up the legs."

They had drawn a plan on a piece of paper. The various parts of the robot had been carefully labelled head, body, arms and legs. Clearly they had decided to break the picture down into sections and draw a piece at a time.

Researcher: "Whose idea was this?"

Peter: "Mine - we..."

David: "No it wasn't"

Peter: "Well it was everyone's really - we were talking about it in the yard - because last time we couldn't get the legs right and we wasted time - so we decided to have a plan."

Researcher: "Did the plan work as you expected?"

Richard: "Better 'cos we all had different jobs."

Researcher: "Tell me more."

Richard: "Well, we talked about it first and looked at our notes from last time."

Peter: "We decided what instructions to use again and what needed changing."

Richard: "Tell her about the jobs."

Peter: "Yes I'm coming to that - then we all took different jobs. I gave the orders, Richard typed them in and David wrote the order down on paper and I kept Richard right."

Researcher: "What do you mean - kept Richard right?"

Peter: "Well, if Richard typed something in wrong I told him to put it right.

Reasearcher: "That seems like a sensible plan - did it work?"

David: "Yes it did, look at the robot we made."

Researcher: "What was the most important thing that you did to help you succeed?"

Long pause

Peter : "Well I suppose it was talking about it together in the yard."

Richard: "Yes - 'cos when we came in we knew what we wanted to do - it's been great."

The boys were obviously evolving strategies to ensure the formulation of a successful program. They still had only a limited grasp of how to make shapes in direct drive on the screen but they clearly understood the necessity of breaking down the problem into pieces which could be solved. They were like the girls using Polya's heuristics but unlike the girls they appeared to develop more confidence and a more positive attitude towards their work. The boys had unknowingly to themselves adopted top-down planning strategies. They were creating a plan from successively refining the goal into a sequence of subgoals for achievement in sequence. Bottom-up planning strategies, on the other hand, note the emergent properties of the plan and add data - driven decisions to the plan throughout its development. The girls in this research did not attempt to use "Top-down" planning strategies. They favoured "Bottom-up" programming.

The LOGO Mathematics Project (1983-6) (Hoyles and Sutherland,1989) paid attention to modes of working and cognitive styles between the sexes. They found no evidence of any difference between girls and boys with respect to their facility with a top-down or bottom-up approach to planning.

As the study progressed the boys understanding of the DART program continued to grow they readily memorized facts, rules and procedures relating to the programming. They assimilated and used new computer associated language quite naturally and were able to transfer learning from one context to another. It seemed that the boys were motivated to learn by seeing the relevance and use for the new learning. for example, accepting the need to learn procedures and knowing why to use them. The boys approach to learning and use of new language used in correct context appeared to give support to both Lerman's and Burton's view on the nature of learning and use of language discussed earlier in this study. The same could not be said of the girls, they appeared to lose interest and became less motivated than the boys. This observation raised questions relating to the social influences affecting attitudes to computer use and girls - The Royal Society - Institute of Mathematics and its Applications, 1980 provides disturbing statistical evidence that girls, as a group, are seriously underparticipating and underachieving in mathematics in comparison to boys. There is no convincing or conclusive evidence that this can be attributed to innate or genetic disability. The girls involved in the study had been given equal amounts of computer time. Teacher praise, support and discussion were also balanced. Outside factors were taken into consideration.

Of the three girls in this study, in group B, only one had access to a home computer. That computer had been bought for her brother by her father. When questionned about what the computer was used for the answer received was war/space and adventure games. The girl's brother was four years older and attended comprehensive school, she expressed the opinion that her brother would prefer to use his computer with his friends rather than his sister. She also stated that she wasn't particularly bothered anyway that she would rather play her recorder. The difference in age would probably signify that the games purchased and used by her brother would possibly be of a too difficult level for her. Despite the obvious enjoyment her brother gained from using the games it in no way encouraged the girl to either buy her own games or ask for them to be purchased for her.

Prior to the Christmas period four of the boys in the study already had computers. After Christmas all the boys claimed that they had access to a computer at home. When questionned about software used most frequently at home it fell into the adventure game category. The titles used indicated a strong gender bias.

The boys enthusiasm for their DART work in school continued to grow, the girls needed a great deal of encouragement. The arrival of a printer did little to revive the girls interest yet motivated the boys still further. It would appear that in the world outside school there are strong pressures for girls to conform to sexual stereotypes, traditional perceptions of mathematics and computers as "male" subjects persist and these perceptions hinder girls achievements in mathematics and computer studies. This is an area which needs further research.

Chapter 8

Analysis of Work Samples

At the beginning of the Spring term and during the research period, classroom circumstances changed. The researcher had to leave her class and take the position of Acting Head. The children did not readily accept their new teacher and as a result some significant behavioural problems in class were reported and had to be addressed.

Despite the change in class the DART work appeared to progress smoothly. There were no obvious or reported behaviour problems within the Mathematics Workshop. One can make the assumption that the work sufficiently motivated and interested the children that they felt no need or desire to misbehave, with or without supervision, whilst working on their project.

At the end of the research period the children were asked to prepare a selection of work and a written comment about their opinion of the DART work. The written comment was to be used as a basis on which to base second interviews.

On examination of the work of Group B and C, it was immediately evident that the initial interest shown by the girls did not develop significantly. Much of their work was in direct drive. They selected only two pieces of work for presentation, both of a very simple nature. (Appendix 18 and 19) Both were simple drawings. When asked why they had selected the pieces Beth spoke for the group, "We picked the house-boat 'cos we liked the frame and we put Sammy the square tortoise in 'cos it only took us half an Oour to do and we enjoyed it but that was ages ago anyway."

The comments were hardly prolific and gave very little insight into the children's thinking.

Despite the waning enthusiasm for DART / computer work a special form of collaboration appeared when the girls were working together in a group. Throughout the research the two more able girls were perceptive to the needs of Michelle, they prompted, supported and encouraged her in all she did on the computer.

From the beginning of the research the children were given the freedom to select their own goals and develop their own problem solving strategies. Intervention was aimed to focus on process and to encourage the pupils to predict and reflect.

From discussions with the girls it would appear that they favoured more open-ended tasks. These tasks were characterised by the lack of a pre-planned structure, evolving out of exploratory activities. They built up their goal whilst interacting with the computer. The open-ended, "bottom-up" tasks allowed them to assume responsibility for devising and trying out different approaches to the task in hand. The tasks upon which the children worked allowed for the mix in ability and for the development of language. The children appeared to be relatively confident in what they did, yet they never showed any desire to progress beyond the simple picture making at which they were proficient.

One can question whether the girls were given enough encourgement to take up challenging ideas but the researcher believes they were. However whether a non-participant observer would agree will remain an unanswered question.

During the course of the research it had been noticed that the boys appeared to favour more complicated graphics work than did the girls. They also had produced intricate moving patterns and screen messages.

The boys DART sessions had been characterised by high levels of concentration, collaborative problem solving and a great deal of discussion. The boys were also more keen to write about their work, without pressure from the teacher.(App.20)

This was reflected in the quantity and variety of work presented by the boys for examination and discussion. All the children had a free choice as to the pieces of work selected. Group C gave samples of their work which showed progression from beginning to end. On each piece of work was written a very brief comment. Appendix 21 showed their first attempt to draw using the printer for a finished result. Despite the obvious failure the boys were keen to discuss the inclusion of the particular piece of work. When asked why it had been included the answer given was, "We wanted to show how good we've got!"

The rest of the work (Appendix 22-27) did indeed represent a cross section of their efforts and showed patterns and pictures. The samples produced incorporated the use of a number of different commands and the use of procedures.

Peter's written comment on appendix 22,

"This is my first picture I drew on the printer. I chose it because it joins up in the middle and the dark makes it look brilliant."

This was typical of much of what the boys wrote - always very positive. Scribblings on backs of pieces of work could be found which reflected positive attitudes and group dynamics. Peter classed himself as No.1. Computer Genius, Richard as No.2 Genius and David as the computer apprentice.

Throughout the research period Group C remained highly motivated and showed a significant degree of persistance in trying to meet a particularly challenging goal. They also showed a great deal of initiative.

They appeared to thrive and enjoy the collaborative atmosphere which they created in the mathematics workshop.

"What do you think?"

"Why don't we....?"

"Shall we try?"

"Come on, let's have a go at this."

were all comments which could frequently be heard when Group C were working together. They quickly mastered the ability to use the ideas of structured programming when working on a clearly defined task.

The procedural nature of DART allows for well defined goals which can result from following a pre-planned structure leading to a specific picture. An example of this by the boys was a drawing named Cobra (Appendix 23),

Whilst quantity was never the object of the exercise the boys produced significantly more in both volume and quantitiy than did Group B, the girls. Much of the work produced by the boys involved a high degree of quite complex mathematical problem solving and investigation. The work covered by all the children also had a definite geometric basis.

The biggest difference between the girls Group B and the boys Group C was in terms of confidence. This was apparent from confident behaviour exhibited by the boys during interviews and in exhibited behaviour in the mathematics workshop. However this view is unsupported as the school did not have access to a video camera.

Watching the children work provided insight into behaviour patterns and social interactions which would have been hitherto neglected.

On analysis of the children's written opinions it would appear that, with the exception of Beth, all of the children had by the end of the study claimed to have enjoyed their work. Beth was firm in her view that the work was on the whole boring. Three of the children claimed that they initially thought that DART would be boring. Four children claimed that they later became bored. This word had not been used in the first interviews. When asked what they meant by the word "bored" a certain commonality appeared in their responses,

"Well when you came to a hard bit, you get stuck then you get bored."

"When you get a problem you get bored with it."

The children appeared to associate the word bored with difficulty. One child wrote,

""After that it got boring a bit but now I can understand it better I enjoy it a lot more."

Only one child, a boy, claimed to have enjoyed DART throughout. Four of the children thought at first it was difficult. This group coupled with the three who believed it to be at first boring would suggest that the bulk of the children had originally strong reservations about the work. This did not show in initial conversations or interviews with the children, all had indicated that they were enthusiastic about the work. However nine out of the ten children in the research group all claimed at the end of the project to have enjoyed the work. The children associated success with enjoyment and boredom with difficulty.

Further similarities between both boys and girls emerged during discussions about their work. Both boys and girls judged their own performances favourably and appeared proud of their work. There was nothing to suggest in any of the discussions with any of the children that would support the view that attitudes related to gender differences influenced the children.

Chapter 9

Consideration of Attitude Questionnaires

Following the examination of the children's written opinions of the DART work the researcher was keen to discover if the children's completed A.P.U. Mathematics attitude questionnaires reflected an overall positive attitude towards the subject.

It must be stressed once more that these particular attitude measures have hitherto only been used on large national samples. Inferences from small scale studies should therefore be made with caution. The A.P.U. suggests that the computation of a total score for the statements should be resisted. The implications being that the feelings measured in the statements constitute a single trait and statistical analysis has revealed that this is not so. The questions and answers were examined to see if there was an overall positive bias towards mathematics rather than of a negative bias. It was also decided to compare negative responses to the A.P.U. attitude questionnaire with the scores on the B paper of the Bristol Achievement tests to see if a low opinion correlated with a low or decreased standardised test result.

The introduction of programming as a research tool to the children in the study was based on many findings of computer studies and of the recommendations made by

Cockcroft, that is, to endeavour to make mathematics teaching more exciting, practical, real and more child directed. The use of DART had been selected with those aims in mind, if successful then one would anticipate a more positive attitude from the children towards mathematics.

The attitude questionnaire contained forty five statements. Briefly these were concerned with:-

Enjoyment - how much pupils like mathematics

Utility - how useful pupils see mathematics as being

Difficulty- the pupils perception of how difficult mathematics is as a subject.

Statements are scored from 5 down to 1 or 1 up to 5 depending on whether a positively or negatively loaded statement is being rated.

Prior to the completion of the attitude questionnaire the children were given a list of sixteen words to learn for homework, they were told they were for a spelling test. All the words were taken from the questionnaire. Although the language used in the questionnaire was within the competence of most of the children there were those who would have been hindered in their comprehension of the statements. In order to ensure the questionnaire was completed accurately and not merely as an indiscriminate tick list, it was important that all the children were competent in reading fluently the statements contained in the questionnaire.

The words selected were:- difficulties, useful, subject, surprised, important, usually, quickly, interesting, textbook, understand, complicated, disappointed, remember, relief, normally, ordinary.

The meanings of the words were discussed. All the children had to write one sentence to include each of the above words in their rough book.

Having been satisfied that the children could adequately comprehend the reading matter in the questionnaire, it was duly administered in the mathematics workshop. Each child occupied an individual table. Care was taken so that children were well separated from each other, they were obviously not allowed to confer. Care was taken to stress the point that the questionnaire was not a test. Honest answers were to be given to the statements and that there were no "right" answers. The children followed the instructions and filled in the questionnaires.

As suggested by the A.P.U., computation for the total score was resisted on the grounds that the feelings measured in the statements did not constitute a single trait, statistical analysis had revealed this not to be so.

Separate scores were computated for the three scales:- enjoyment, utility and difficulty. The results from each scale appear overleaf, each will be dealt with singly, beginning with the utility scale. A copy of the questionnaire can be found in the Appendix (28).

UTILITY / USEFUL SCALE

QUESTION	12	16	20	23	28	33	36	40	42	46	50	52	TOTAL	POS.T	%
GROUP A															
GRAHAM	5	5	3	4	4	4	5	4	2	3	4	4	47	60	78.3
STEPHEN C	5	5	4	5	4	5	5	1	4	4	5	5	52	60	86.6
GROUP B															
BETH	5	5	5	5	5	5	5	5	5	5	5	5	60	60	100
MICHELLE	5	4	2	5	4	5	4	5	5	4	5	5	53	60	88.3
ANNE-MARIE	5	4	5	5	4	5	4	5	5	5	5	5	57	60	95.0
GROUP C															
PETER	5	5	2	4	4	2	2	2	4	4	4	5	43	60	71.6
DAVID	5	3	3	2	4	2	4	5	4	5	1	4	42	60	70.0
RICHARD	5	4	4	4	4	4	4	4	2	3	4	3	45	60	75.0
GROUPD															
MICHAEL	5	4	2	2	3	3	3	2	4	2	2	2	34	60	56.6
STEPHEN L	5	2	2	2	4	1	3	2	5	3	3	3	35	60	58.0

High score indicates high/positive feelings relating to usefulness

	%				%
1. Beth	100	*a	6. Richard		75.0
2. Anne-Marie	95.0		7. Peter		71.6
3. Michelle	88.3	*b	8. David		70.0
4. Stephen C	86.6		9. Stephen L		58.0
5. Graham	78.3		10. Michael		56.6

*a denotes most able child
*b denotes least able child

DIFFICULTY SCALE

QUESTION	11	14	21	26	30	35	38	43	48	51	53	TOTAL	POS.T	%
GROUP A														
GRAHAM	3	3	2	3	2	3	3	3	4	4	4	34	55	61.8
STEPHEN C	3	4	2	2	1	2	2	2	3	3	3	27	55	49.0
GROUP B														
BETH	2	2	2	1	2	2	2	1	4	3	3	24	55	46.6
MICHELLE	3	4	5	2	2	4	2	2	4	4	3	35	55	63.6
ANNE-MARIE	2	1	1	2	5	1	1	2	5	4	4	28	55	50.9
GROUP C														
PETER	2	4	4	2	4	4	2	2	2	4	4	34	55	61.8
DAVID	4	3	5	5	5	2	5	2	3	5	3	42	55	76.3
RICHARD	3	4	2	2	2	2	3	3	2	3	4	30	55	54.5
GROUP D														
MICHAEL	4	2	2	2	2	4	3	2	2	4	5	32	55	58.0
STEPHEN L	3	4	2	4	3	4	4	2	2	5	5	38	55	69.0

High score indictates child believes subject to be difficult
Low score indicates ease

	%		%
1. David C	76.3	6. Michael	58.0
2. Stephen L.	69.0	7. Richard	54.5
3. Michelle	63.6	8. Anne-Marie	50.9
4. Graham	61.8	9. Stephen C	49.0
5. Peter	61.8	10. Beth	46.6

ENJOYMENT SCALE

QUESTION										
10	4	4	5	5	5	4	4	4	2	2
13	2	3	5	4	5	2	1	2	2	1
15	4	4	3	5	5	4	4	2	2	2
17	2	4	1	4	2	2	1	2	2	2
19	3	3	1	4	5	4	4	2	1	5
22	4	5	2	4	4	4	4	3	4	3
24	3	2	4	2	5	1	5	2	1	1
25	2	3	5	3	2	4	4	2	3	1
27	5	5	4	5	5	4	2	2	2	2
29	4	4	4	5	5	4	4	3	2	3
31	4	5	1	5	4	2	3	4	3	4
32	3	3	5	2	2	2	1	2	2	1
34	4	4	4	5	5	4	2	2	1	1
37	3	4	2	1	5	2	3	2	2	5
39	5	2	3	5	5	5	2	2	1	1
41	4	3	3	5	5	2	1	2	1	1
45	3	3	3	5	5	2	3	2	1	1
47	3	3	3	5	5	2	4	2	1	1
49	4	4	5	5	5	4	3	4	2	1
TOTAL	66	68	63	79	84	58	55	46	35	38
POSS.T	95	95	95	95	95	95	95	95	95	95
% TOTAL	69.4	71.5	66.3	83.0	88.4	61.0	57.8	48.4	36.8	40.0
GROUP	[	A]	[	B	]	[	C	]	[D	]

GROUP [A] Graham
Stephen C

GROUP [B] Beth
Michelle
Anne-Marie

GROUP [C] Peter
David
Richard

GROUP [D] Michael
Stephen L

High score indicates high level of enjoyment
Low score indicates negative attitude/feelings

continued over:-

ENJOYMENT SCALE

INDIVIDUAL TOTAL PERCENTAGES

1.	Anne-Marie	88.4%
2.	Michelle	83.0%
3.	Stephen C	71.5%
4.	Graham H	69.4%
5.	Beth	66.3%
6.	Peter	61.0%
7.	David	57.8%
8.	Richard	48.4%
9.	Stephen L	40.0%
10.	Michael	36.8%

The most positive responses concerned the utility or usefulness of mathematics. Scores ranged from 56.6% to the unexpected high of one child whose score was 100%. The least able child in the class gave an 88% positive response to this section. Every child in the group scored 5 for their response of "Strongly Agree" to the statement, "Mathematics is a very useful subject."

Despite the fact that all children, without exception, agreed that mathematics was a useful subject the statement which they scored lowest (total 32 out of a possible 50) related to the statement, "I use mathematics to help me in lots of ways in school." The children appeared to have compartmentalised mathematics to a specific subject area and failed to notice cross-curricular links. This is an important point for practising classroom teachers. Children should from the earliest primary stages of education, be given maximum opportunity for using and applying mathematics across the curriculum.

Nine out of the ten children rated highly the statement, "I can use mathematics to solve some everyday problems." The score for this statement was 40. As it appeared to contradict the previously quoted example, the researcher asked the children for further explanation. They all responded similarly and stated that "problems" were word sums. The explanation was satisfactory.

Overall there was a very high positive response to statements concerning the usefulness of mathematics. Both sexes recognised the utility of mathematics. Interestingly enough, the girls showed more certainty than the boys, scoring 100%, 95%, 88.3%. A high score on the difficulty scale indicated that the child believed the subject to be problematic and a low score inferred that the child perceived mathematics to be easy.

An interesting fact emerged. The children who scored the three lowest scores (indicating ease) scored the three highest scores in the Bristol Achievement Test A. The same three children occupied the top three positions on the enjoyment scale (high score indicating enjoyment) with scores ranging between 71.5% and 88.4%. The same children were within the top four positions on the utility scale. For these three fortunate children's scores showed that they were mathematically able, saw the usefulness of the subject, were confident and enjoyed using mathematics.

The child who scored the lowest on the Bristol Achievement Test A was in the top three scores in the scale of difficulty. She scored 63.6% , indicating that she viewed the subject as being troublesome.

Knowing of the difficulties the child normally experienced in mathematics the score of 63.6% was lower than expected.

This led to a further examinaton of the questionnaire. The child scored 2 for four of the statements, a relatively low mark indicating ease. Analysis of the statements showed why:

			Score
26	I can usually understand my mathematics textbook	[agree]	2
43	Mathematics books are hard to follow	[disagree]	2

Michelle did not use the same textbooks as the majority of the class. The textbooks she worked from were matched to her ability level.

38	There are far too many things to remember at a time	[disagree]	2

Michelle's work and tasks were always individually set and usually made up of small achievable steps. On completion of each step or stage she reported to the teacher for marking, support and further explanation.

30	I get lost if I miss any mathematics work.	[disagree]	2

Again, Michelle always worked individually or in a very small group and always under supervision of the teacher. As a result the child would never feel that she missed any work in mathematics.

Michelle's responses to the statements were made with thought and judgement.

Despite her acknowledgement of the subject as posing difficulties to her, this in no way appeared to affect her enjoyment of the subject. She scored the second highest percentage of 83%. She also saw the usefulness of the subject scoring 88.3%.

On the whole 80% of the children indicated that they found difficulty with the subject.

The statement which scored the highest adverse response, indicating difficulty, was:-

51 I find mathematics an easy subject.

Most children stated that they disagreed with this statement.

Overall a general trend of difficulty linked with dislike and liking with ease, could be detected. This was to be expected.

On analysis of the enjoyment scale a very obvious link could be seen with the utility scale. Like the utility scale a high score indicated a positive response, that is, in this case a high score indicated a high level of enjoyment. 80% of the children scored above 48.4% indicating a high degree of liking for the subject.

The children who occupied places in the first five on the enjoyment scale also occupied places in the first five on the utility scale. With the removal of Richard from the list of the remaining five children on both the utility scale and the enjoyment scale the list would read identically, that is, Peter, David, Stephen and Michael. There was a high relationship between enjoying the subject and seeing the utility of the subject.

Despite the smallness of the sample, the same conclusion as Primary Survey Report No.2 was arrived at, that the extent to which children perceived a subject as being useful influenced their inclination to find it an agreeable or conversely, a disagreeable one. Whilst the scales used gave only a measure of general feelings towards mathematics, they all showed overall that the majority of the children had a positive attitude towards the subject and that all saw the usefulness of mathematics.

In contrast to the research group's responses the answers to the questionnaires completed by the control group were found not to be consistent. A positive or negative attitude could not be proven. Within the questionnaire were three statements relating to gender, they were not intended for scoring, however having discussed the question earlier of the possible cultural association of males with computers/mathematics, it was felt a worthwhile task to evaluate the children's responses.

The children had to address the following three statements:-

A) I think that girls and boys are equally good at maths?

B) I think that girls are normally better than boys at maths?

C) Boys are normally better than girls at maths?

The children had to tick the responses they felt to be appropriate, that is, Strongly agree, Agree, Disagree, Strongly disagree or Unsure.

The responses proved most interesting. With the exception of one child, a boy, the whole group made balanced statements, that is, Beth strongly agreed with the statement A, but strongly disagreed with statements B and

C. Richard disagreed with statement A but ticked the box marked unsure for B and C.

The exception was David, who agreed with statement A, then contradicted himself by then agreeing that girls were normally better than boys. When asked to clarify his statement A, he immediately replied that he really meant that sometimes girls and boys were the same at maths. but most times it was girls. He then cited the name of the most able child in mathematics in the class, who happened to be a girl.

Of the ten children who completed the questionnaire, six either strongly agreed or agreed with statement A. Two children disagreed and were unsure as to whether girls or boys were better at mathematics. The two remaining children thought that girls were better at mathematics than boys. No one thought that boys were better than girls. Overall the children appeared to believe that there was no overall significant difference between the capabilities of boys and girls in the subject of mathematics. Any slight bias appeared to be towards girls, this may well have had to do more with the female role models the children saw in school. All positions of authority were filled by women, the teacher who had responsibility for the computer was a woman and as mentioned earlier the most able child mathematically was a girl.

If the children perceived no significant difference in the mathematics capabilities of boys and girls why then did the boys reflect a positive attitude towards computer use and the girls a negative attitude? The relevance of this is important when one considers that the computer work the children were involved in was mathematically based and the computer was housed in the mathematics workshop, thereby indicating a link with the subject at the time of the study. Research is needed to investigate the social influences affecting attitudes of girls to computers.

Some research has already been completed in this area and presented as a series of papers, edited by Celia Hoyles, in "Girls and Computers." She too urges more research in the area acknowledging that with increasing use of computers in society all children should have equal opportunity to reach their maximum potential in achieving computer skills.

Chapter 10

Bristol Test Results

The control and research groups both took the Bristol Test of Mathematical Achievement before the research began. The standardised mean scores were 108.8 and 108.5 with standard deviations of 11.45 and 10.54 respectively. A T-test indicated that there was no significant difference between the groups (P=0.952). (Appendix 29)

The two groups were well matched overall as a summary of the statistics given below shows.

Area	Group	Mean	T Value	2 -Tailed Probability
Number A	Control	4.1		
	Research	4.9	-0.79	0.44
Reason	Control	4.6		
	Research	5.8	-1.04	0.313
Space A	Control	6.0		
	Research	5.8	0.18	0.862
Measure A	Control	4.5		
	Research	2.5	1.66	0.115
Laws A	Control	4.1		
	Research	4.0	0.08	0.94
Standardised Score A	Control	108.5		
	Research	108.8	-0.06	0.952
Percentage A	Control	67.6		
	Research	67.6	0.00	1.00

The largest difference between the groups occured in the measurement part of the test where the 2-tailed probability was only 0.115 - but still well above the usual 0.05 level. The overall scores as indicated by Standard Score Test A and Percentage Test A were well matched.

On analysis of the Bristol Test Result it was noted, with disappointment, that all of the children in both the research group and the children from the control group showed a decrease in the Standardised Scores on Test B. The overall decrease in Test B scores raised questions relating to the choice and suitability of the Bristol Test. Was what the children had to do to achieve a higher score on the Bristol Test covered in the Scottish Primary Mathematics Group scheme?

and

Was the area of the work fully covered and consolidated by the class teacher?

A cursory look at the test indicates that the work which the test would expect to cover during the six month period is not covered specifically by the Scottish Primary Mathematics Group scheme in the same period. Work at level four includes area, length, weight, number, volume, time. This work is compatible, though not strictly related to, the Bristol Test. There the topics are labelled as being number, reason, space, measure and laws. However the validity of the test could also have been questionned if the children had been taught precisely to meet the requirements of the test. Of the tests available at the time of the study the Bristol Test was selected as being best suited to fulfill the research requirements. The test was to be used in an attempt to discover if computer developed problem solving skills were transferable to other areas of mathematics and not merely to test the success or failure of the Scottish Primary Mathematics Group scheme. The second question concerning the work covered and consolidated by the class teacher can only be answered speculatively. The research group of children did not have the same class teacher throughout the study period.

The control groups work was not subjected to the same change. No indication was given to suggest that the mathematics work was not covered normally. However, unforseeable circumstances could not have been catered for during the design stage of the research, when efforts had been made to ensure similar learning and testing conditions for all the children involved in the study.

A table of results for both the control group and research group follows. The first figure is the pre-test score, Test A, and the figure in brackets is the post test score, Test B.

Non Logo (Control Group)

	Number		Reason		Space		Measure		Laws		SS	%
	TA	TB	TA	TB	TA	TB	TA	TB	TA	TB		
Kelly	8	(7)	9	(8)	8	(5)	7	(6)	6	(4)	124(111)	95(76)
Rachel	4	(6)	8	(7)	9	(7)	7	(8)	6	(5)	121(108)	92(70)
Mark	5	(2)	5	(5)	9	(4)	7	(6)	6	(4)	118(99)	88(48)
Mathew	5	(5)	6	(6)	8	(7)	7	(7)	7	(5)	115(106)	84(66)
Daniel	4	(1)	5	(1)	7	(6)	2	(2)	0	(3)	108(96)	70(39)
Nicholas	4	(5)	2	(4)	6	(5)	6	(1)	0	(4)	105(96)	63(39)
Tracy	4	(1)	3	(1)	0	(1)	2	(1)	4	(0)	96(83)	39(13)
Susan	1	(1)	3	(3)	3	(2)	2	(2)	4	(3)	100(94)	50(34)
Robert	3	(4)	5	(5)	7	(7)	3	(0)	8	(3)	104(92)	61(30)
Louise	3	(0)	0	(1)	3	(0)	2	(0)	0	(0)	94(73)	34(4)

10 children in group: 5 boys

5 girls

Research Group

	Number		Reason		Space		Measure		Laws		SS	%
	TA	TB	TA	TB	TA	TB	TA	TB	TA	TB		
Beth	7	(6)	9	(6)	9	(7)	6	(4)	6	(4)	131(111)	98(76)
Anne-Marie	7	(6)	8	(4)	5	(7)	7	(4)	2	(0)	120(101)	91(52)
Stephen C	6	(5)	8	(2)	6	(2)	3	(4)	7	(4)	116(99)	86(48)
Peter	7	(6)	7	(2)	7	(5)	2	(1)	5	(0)	114(100)	82(50)
David	8	(6)	5	(4)	8	(4)	0	(5)	2	(3)	108(99)	70(48)
Richard	3	(2)	6	(4)	5	(3)	3	(5)	7	(3)	107(98)	68(45)
Michael	6	(5)	1	(0)	5	(0)	0	(4)	5	(0)	99(88)	48(21)
Graham	1	(2)	6	(2)	6	(8)	2	(2)	6	(3)	99(93)	48(32)
Stephen L	1	(4)	5	(2)	5	(2)	0	(1)	0	(3)	99(93)	48(32)
Michelle	3	(0)	3	(0)	2	(4)	0	(0)	0	(0)	95(77)	37(6)

10 children in sample

Close examination of the tests showed that the three children from the research group who achieved high standardised test scores on Test A showed a marked decrease on Test B.

	Standardised Score		
Beth	A 131	B 111	Loss 20
Anne-Marie	A 120	B 101	Loss 19
Stephen C	A 116	B 99	Loss 17

The three initial high scorers from the control group also showed a decrease

	Standardised Score		
Kelly	A 124	B 111	Loss 13
Rachel	A 121	B 108	Loss 13
Mark	A 118	B 99	Loss 19

Using children from the research group a comparison was made with the enjoyment scale in the Attitude Questionnaire to see if a low enjoyment score correlated with a large drop in the Standardised score on Test B. Both Anne-Marie and Stephen C. had scored 88.4% and 83.0% on the enjoyment scale. This indicated very positive feelings towards the subject of mathematics. Beth the highest scorer and also the child with the highest drop in score, scored 66.3% on the enjoyment scale. Not as high as might have been expected but, nevertheless, still positive.

In the research group the two boys who decreased their scores on Part B the least, both with a reduction of six, were in the bottom group of three children who scored least. The two boys had a standardised test score of 93.

One of the boys had achieved a low score of 40% on the enjoyment scale, indicating a negative attitude towards the subject. The other had rated it highly, with a score of 69.4%

The child who scored the least on both Test A and Test B also showed a high drop of 18 on the Standardised Score on Test B. This child had indicated a high degree of liking for the subject on the enjoyment scale, where she had scored 88.4%

The child who showed the least liking for the subject at 36.8% showed a drop of 11 in the Standardised Score on Paper B from 99 to 88.

The remaining three boys presented the following picture:-

	Standardised Score			
Peter	A 114	B 100	Loss 14	Enjoyment 61%
David	A 108	B 99	Loss 9	Enjoyment 57.8%
Richard	A 107	B 98	Loss 9	Enjoyment 48.8%

There appeared to be no evidence to prove that a low enjoyment score correlated with a large drop in Standardised Score on Paper B or vice-versa

Certain factors which may have influenced the research group's fall in scores must now be considered in greater detail. A possible important cause may have been due to the change of class teacher, this was mentioned earlier in the study. The new teacher did have background knowledge of the content, use and implementation of the Scottish Primary Mathematics Group scheme. She also had detailed records of the children's work and was able to discuss the children's progress, or lack of it, with the researcher who was now Acting Head. What she did not have was the control, trust and confidence of the children. One child in the class, not involved in the study, proved particularly problematic. He caused severe disruption and ruined the working atmosphere in the classroom. He was subsequently transferred to a boarding school for maladjusted children. Other children in the class also took opportunities created by the disruption to misbehave themselves.

Whilst the teacher was establishing herself and the children were coming to terms with another adult classroom personality, all areaas of curriculum activity suffered to some degree. The exception was the DART work. This continued normally, monitored by the researcher in the mathematics workshop.

The level to which the children's normal or expected mathematics education and progress was possibly hindered can not be determined. Surfice to say continuity and progression was, to some extent, hindered by the change in teacher.

On further examination of the results a disconcerting trend emerged in a research group's scores in the area of reasoning, an area closely identified with problem solving. All of the children, without exception, showed a decrease in their score in this area. The highest drop belonged to a boy with a decrease of 6. The lowest was a drop of 1. The area of reasoning showed the highest overall decrease in score.

This pattern could not be detected in the control group's scores in the area of reasoning.

It would seem that, far from improving the children's problem solving skills, the programme of work based on DART had in fact possibly contributed to a decrease, according to the Bristol Test.

Across the whole area of mathematical problem solving skills covered by the test, that is, number, space, measure, arithmetic laws and processes, the results showed an overall general decrease in Standardised Score both for the control group and the research group.

In order to show a balance in comparison between the two groups a T-test was used again to further evaluate the Bristol Achievement Test B. The statistics for the B Test are summarised below.

Area	Group	Mean	T Value	2-Tailed Probability
Number B	Control	3.2		
	Research	4.2	-0.96	0.349
Reason B	Control	4.1		
	Research	2.9	1.16	0.261
Space B	Control	4.4		
	Research	4.2	0.17	0.864
Measure B	Control	3.3		
	Research	3.3	0.00	1.000
Laws B	Control	3.1		
	Research	2.0	1.38	0.183
Standardised Score B	Control	95.8		
	Research	95.9	0.02	0.983
Percentage B	Control	41.9		
	Research	41.0	0.09	0.927

As with the Pre-test there is no significance overall between the two groups. Hence the null hypothesis that the means are equal is not rejected. What is of interest and suggests the need for further research is that the standardised score has decreased. A T-test on the standard scores for each group gives a probability of less than 0.005 for both groups.

Whilst some reasons for this have been indicated for the research group there is no obvious reason for the difference with the control group. The result however is supported by previous research by K. Cann 1988, "The Effects of the Use of the Computer Language LOGO on Primary Children's Mathematics" for the control group but not the research. It was suggested that perhaps the expected improvement with age on the scores of the Bristol Achievement Mathematics Test 3 are in areas not covered in the Scottish Primary Mathematics Group work in level 4.

These results for the research group are at variance with the research of K. Cann. Here the non-rejection of the null hypothesis supports the case that there is no improvement in mathematics generally when the LOGO type program DART is used. Indeed this is supported by earlier research conducted by Pea, Kurland and Hawkins in 1982. Their work supports the view that the acquisition of thinking and planning skills is not guaranteed by the use of LOGO as a programming language. Whilst Hawkins and her colleagues were unable to support the view that an increase in transferrable problem solving skills could be noted or quantified they did report that:

".....there was more task-related interaction during computer activity than during other non-teacher directed classroom activity. Most dramatically, there was more task-related talk around the computer than during other activities........in short, children seemed to be talking more about their work and doing so in a collaborative way when they were using the computer than when they were doing other classroom activities. Such differences were surprising in classrooms in which children are often encouraged to work together." (29)

Much the same conclusion could be drawn from this particular study.

As a non-participant observer it was obvious that within the Mathematics Workshop the children, working in small groups, were indeed acquiring skills of independent learning. The children could be seen encountering and dealing with situations not usually associated with normal classroom activities. They proved, by the volume and quantity of work produced that they could work without being supervised by an adult. This was in stark contrast to what was actually happening within the confines of the classroom during the period of adjustment to the new teacher. The children at all times in the workshop had to rely on their own initiative to choose a suitable plan of action in order to achieve success in their self directed set tasks. The use of language and application of communication skills was at the heart of all the children did. The improvement in the children's language competencies was reflected in their written language. The written opinions about their DART work reflect this improvement and are evidence of their abiltiy to write in sequence and express clearly their own thoughts. Samples of their work can be found in Appendixes 30 - 39.

Claims that LOGO leads to an improvement in problem solving and general mathematical ability have been difficult to prove. A reason for this may be that at this point in time there is no good measure of problem solving ability.

Initial research by the Brookline LOGO project (1978) would appear to validate this claim. This project was funded by the United States National Science Foundation. Its intention was to take a detailed look at children's use of LOGO. Non-standardised problem solving and mathematics tests formulated by staff teaching on the project produced inconclusive results.

In this project the Bristol Test was used as an objective test, one which gives measurable results. The children did not show improved progress. The test, however, is not intended to measure other factors which may be of a subjective nature and difficult to quantify. Improvements in the children's powers of concentration, use of mathematical language, planning, confidence and thinking skills are all valuable competencies which must be nurtured and developed. All these points were observed during the study period but could not be quantified by tests used by the researcher. DART gave the children the chance to acquire these skills. Their work showed that they could think and express their thoughts in a logical and structured way. It also gave the children openings to communicate clearly amongst themselves as well as with the computer. Clarity of thought showed itself in the children's written work and in their well balanced responses to the questionnaire.

The computer work also allowed the children opportunities to be inventive and creative. Opportunities which would have been difficult to provide in the classroom.

Overall the children enjoyed the DART work. The results of the A.P.U. questionnaire reflected the children's positive attitude towards mathematics. However the contention that in explicitly programming the computer to produce or perform a set task illuminates and develops the child's thinking and related problem solving skills is not proven or born out by the results of the Bristol Achievement Tests. Greater facility in the art of heuristics did not appear to be developed by the explicit nature of programming. No proof emerged after a lengthy period using DART that the children could somehow spontaneously show an increase in understanding of mathematics and in other related areas of learning.

Self discovery approaches to learning appears to ignore, or undervalue, standardised assessment procedures. Without a baseline measure there is no criteria for evaluating when the learning process has occurred or has been fully understood and assimilated.

The use, by the children, of DART as a programming language did not seem to produce more ordered transferable thinking skills necessary for the development of higher level intellectual ability, nor did it show itself to accelerate the children's cognitive development.

Recommendations

This particular study illustrates the need for more elaborate measuring instruments in the areas of attitudes, language acquisition, confidence and problem solving. Only when mathematical development and achievement incorporating these skills can be accurately measured will problem solving gain its place as an important component in the average British primary classroom.

All round systematic mathematical growth needs well planned, direct instruction over a long period of time. This should be coupled with intensive and extensive practical activity where children have the opporunity to use previously taught, learned and assimilated experiences in a variety of problem solving activities.

The development of problem solving skills should not be undervalued or left to haphazard and unreliable measures. The ways in which the children's cognitive structures are transferred from task to task must first be identified if the value of programming as a tool to foster higher order concepts is to gain credence and acceptance.

This also has implications for future teacher training programmes, students and practicing teachers alike should be made aware of the problem solving process and given encouragement and support to develop problem solving opportunities for children using the computer in school.

Guidance on when and how to intervene during such activities should be given. Planning, managing. monitoring and evaluating of problem solving activities must also be considered if opportunities which are available through programming are to be fully utilised.

Until this is so, doubt will remain that the transfer of problem solving skills will occur in the absence of direct instruction or long periods of intensive learning.

APPENDIX 2 - CHECKLIST OF MATHEMATICAL LANGUAGE

September
October
November
December
Spring
Summer
Autumn
Winter
zero/nothing/nought
one
two
three
four
five
six
seven
eight
nine
ten
eleven
twelve
thirteen
fourteen
fifteen
sixteen
seventeen
eighteen
nineteen
twenty
thirty
forty
right angle
equilateral
blunt
hollow
almost
nearly
between
next to
every
the same as
many
makes
estimate
tally
unit/long/flat/block
bead
counter
brick
peg
pattern
together
double
half
third

measure
pour
arrow
sign
count
sequence
increase
decrease
shape
solid
cube
cone
cuboid
cylinder
sphere
prism
tetrahedron
plane
square
triangle
rectangle
oblong
circle
diamond
oval
ellipse
polygon
pentagon
hexagon
octagon
quadrilateral
rhombus
round
spiky
tough
across
crooked
pointed
match
equivalent
sort
equal/unequal
quarter
times
shop/shopping
sell/sold
buy/bought
spend
change
penny
pence
pound
coin
area
volume

few/fewer/fewest
fill/full/fuller/fullest
empty/emptier/emptiest
upright/level
up/down
under/over
left/right
odd/even
before/after
below/above
equal/unequal
vertical/horizontal
inside/outside
behind/in front of
underneath/on top of
tesselate/tessellation
symmetry/symmetrical
reflect/reflection
rotate/rotation
translate/translation
slope/sloping
parallelogram
trapezium
diagonal
circumference
perimeter
line
edge
corner
vertex/vertices
face
surface
add/addition
subtract/subtraction
multiply/multiplication
divide/division
partition/partitioning
map/mapping
difference
take away
remainder
share
capacity
mass
weight
gram
kilogram
metre
centimetre
litre
millilitre
balance
day
season
pyramid

THE DRAWING COMMANDS

Getting Started

After you have loaded DART and typed RUN you will need to press the RETURN key.

The screen will clear and leave a DART in the middle of the picture, pointing upwards.

If you want the DART to move forward you can type:

FORWARD 40

The DART will draw a line on the screen 40 units long.

(After every command you have to press the RETURN key. There must also be a space between the FORWARD and the 40. There must always be a space between the command and the number.)

If you want the DART to point in a different direction, try typing:

LEFT 70

This will turn the DART to the left.

Try typing this and see what happens after each command:

FRESH

FORWARD 50

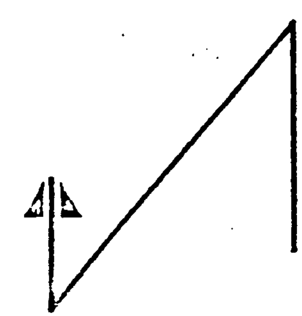
RIGHT 40

BACKWARD 80

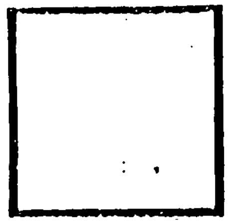
LEFT 40

FORWARD 30

You should end up with this:

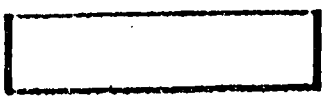


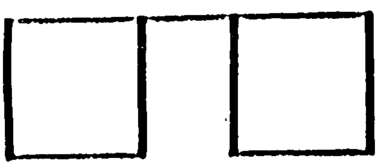
Can you draw a picture of a square?

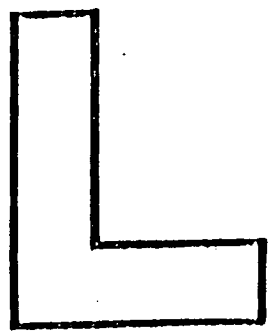


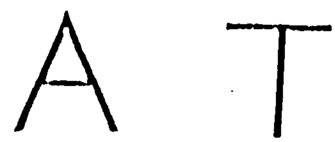
What do you have
to do at the corners?

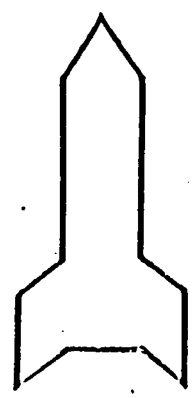
Can you draw these shapes?

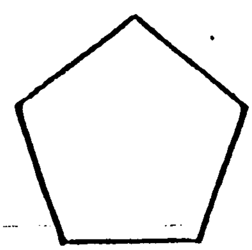












If you want the DART to move without drawing a line, then you can use PEN UP.

Try this:

FRESH

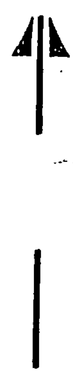
FORWARD 20

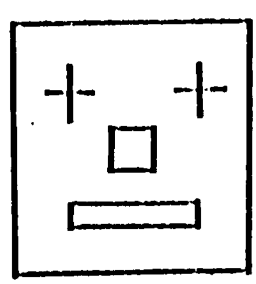
PEN UP

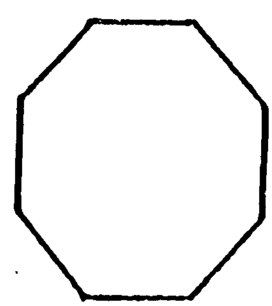
FORWARD 20

PEN DOWN

FORWARD 20







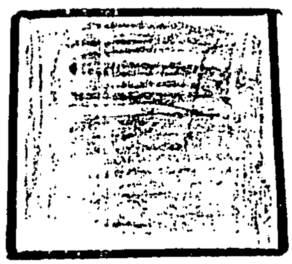
You now know enough to draw any shapes you wish.

Don't make them too complicated to begin with.

Here are some ideas:–

Square 6.11.'86

F 50
L 90
F 50
L 90
F 50
L 90
F 50



Coment.

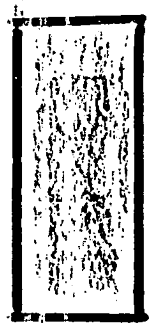
I enjoyed doing the squre becaus it was quite easy but I kept getting mixed up with my lefts and rights.

APPENDIX 5

Rectangle

6.11.'86

50
90
100
90
50
90
100



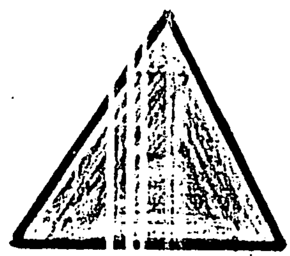
Coment.

I enjoy making the rectangle but I still got mixed up with my lefts and rights but I started to get used to them.

APPENDIX 6

Triangle 10 11 '86

L 45
R 50
L 90
R 50
L 135
R 75



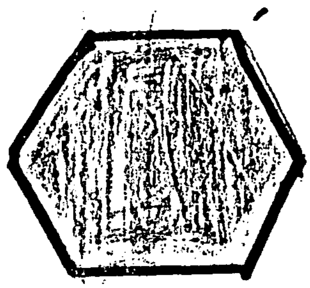
Coment

I got used to my lefts and rights but it was difficult to get my angles right at the point

APPENDIX 7

Hexagon. 6 11 86

R 45
F 50
R 45
F 50
R 45
F 50
R 45
F 50
R 45
F 50
R 45
F 50
R 45
F 50
R 45
F 50



Comet

The angles were quite hard but when we got the first bit it was quit easy

7.11.86 PARALLELOGRAM

Tried and tried but to hard.
Problem overcome. It was fun.

PENUP	L90 F27
L90	L90 F20
F100	R45
B20	F50
R90	F20
R90	L45
PEN DOWN	F100
F100	L90
F20	F50

APPENDIX 9

7.11.86 SQUARE

F50

L90

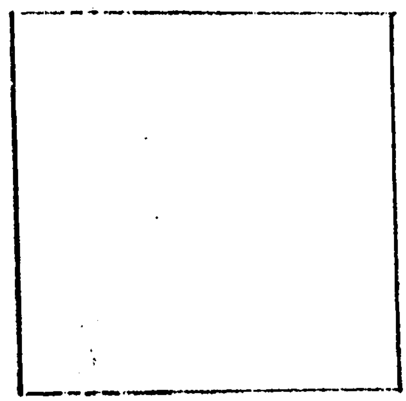
F50

L90

F50

L90

F50



It was easy and fun.

Padllegram 7.11.86

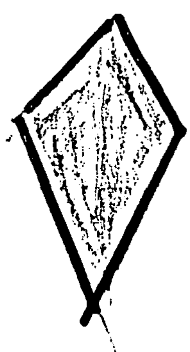
25
50
65
75
115
50
115
75

Comment

The parllegram was very hard even though Mrs Firth gave me the shape cause all the angles were different.

<u>kité</u> <u>7.11.'86</u>

rt 25
fd 50
lt 70
fd 50
lt 90
fd 50
lt 70
fd 75
lt 125
fd 35



<u>Coment</u>

We started to do ehe shape of a rombus but when we fenished is was the shape of a kite. It was very hard

Pole 10.11.'86

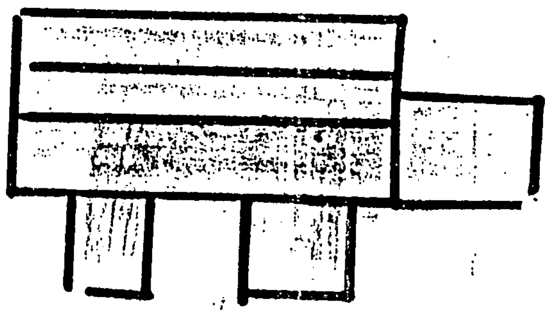
F 50
L 90
F 25
L 90
F 50
L 90
F 25

Coment

The pole was very easy but we picked the pole for Michelle to do and she said what she thought to me and I moved in that direction on the floor.

APPENDIX 13

Van   Time 35 mins



Coment

The van was very easy so we let Michelle do it and now she is used to it.

Up 90
[illegible]
Up 70
[illegible] 10
[illegible]
[illegible]
Up [illegible]
[illegible] 10
[illegible] 10
[illegible] 15
R 10
Up 15
R 90
Up 15
[illegible] 90
Up 30
[illegible] 90
Up 15
R 90
Up 15

R 90
Up 15
L 90
R 90
Up 60
Up 30
L 90
Up 25
L 90
Up 30
L 90
Up 10
R 90
Up 70
L 90
Up 10
R 90
Up 10

WHEN YOU GET BORED WITH THAT . . .

— YOU CAN REPEAT . . .

If you have already tried to draw a square you will have done something like this:

```
FRESH
FORWARD 50
LEFT 90
FORWARD 50
LEFT 90
FORWARD 50
LEFT 90
FORWARD 50
LEFT 90
```

There is an easier way of doing this using the **REPEAT** command.

First, you tell the computer you want to repeat something by typing **REPEAT 4**

Then you type the instructions you want to repeat.

When you have finished the list of instructions you must give the **END** command.

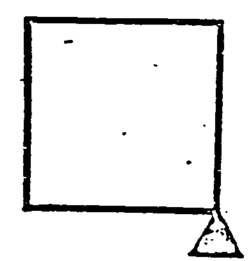
Try this example:

```
REPEAT 4
→ FORWARD 50
→ LEFT 90
→ END
```

You will see that nothing gets drawn until you give the **END** command.

The computer then obeys your instructions, in order, and shows you what it is doing at every stage.

You should end up with a square.

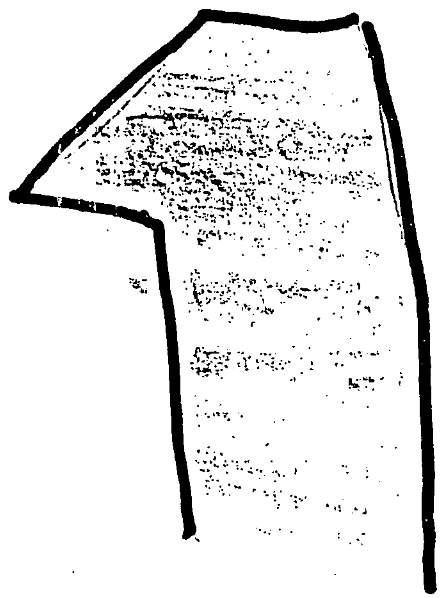


Pattern

[illegible] 50
[illegible] 88
[illegible] 88
[illegible] 30
[illegible] 70
[illegible] 70
[illegible] 10
[illegible] 10
[illegible] 10
[illegible] 120

Repeat 10

END



Coment.

this pattern was very easy but it gets as used to the Repeat

Triangle 6.11.86

L 90

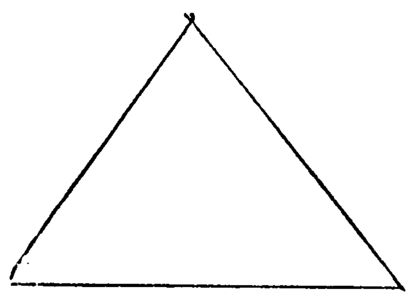
F 57

R 125

F 57

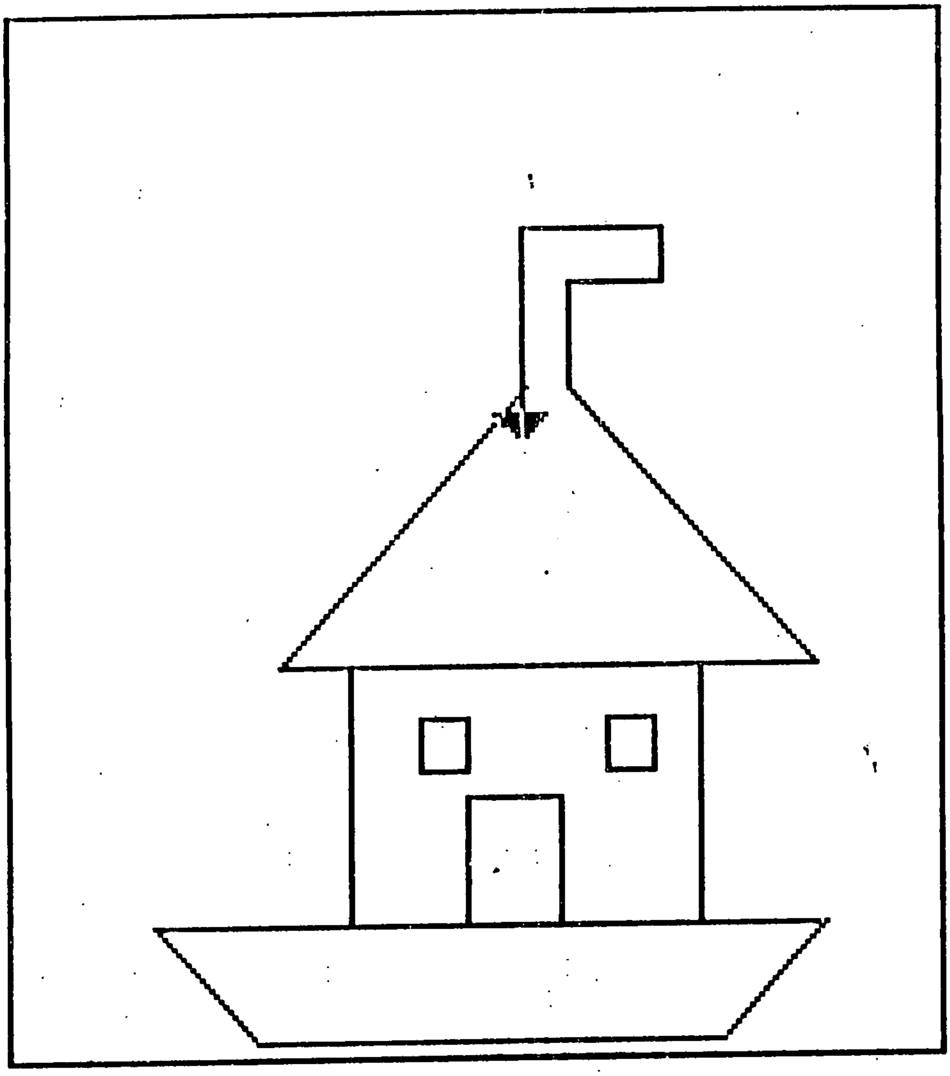
R 125

F 56



I enjoyed doing this perticular shape ~~bec~~ because it was the hardest shape as you can see by all the rubbing out.

APPENDIX 17



By

Beth Huntingdon
Michelle Gustard
Anne-Marie Kenny

APPENDIX 18

```
FCH."DART02"
7ZZZZZZZ7ZZZZZZZZZZZZZZZZZZZZZZZZZZZZZk
 5      5Creating pictures by   /
 5DART 5moving a 'dart' around /
 5       5the screen and a turtle/
 5       5robot around the floor./
uppppppppuppppppppppppppppppppppppppppz

          Operating System 1.2

      Based on Oxfordshire County
      Council copyright material

   PressSPACEif you want help.
   This is your only chance to see the
   help pages.

   If you want to copy this program,
   pressESCAPEand do it now.

   PressRETURNwhen you want to start
   drawing.
Version 2.3    Copyright AUCBE 1984
```

```
For the list of commands type COMMANDS
:
:LEFT 90
:FORWARD 70
:LEFT RIGHT 90
:FORWARD 35
:RIGHT 90
:FORWARD 70
:RIGHT 90
:FORWARD 35
:RIGHT 90
:FORWARD 10
:LEFT 90
:FORWARD 20
:RIGHT 90
:FORWARD 10
:RIGHT 90
:FORWARD 20
:LEFT 90
```

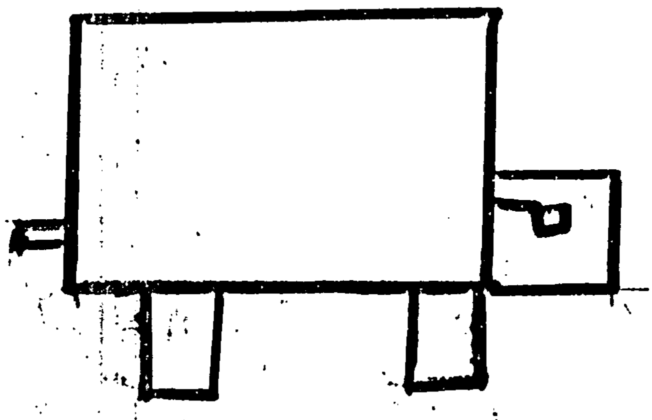
Sammy the Square tortoise looks like this.

```
:FORWARD 30
:LEFT 90
:FORWARD 20
:RIGHT 90
:FORWARD 10
:RIGHT 90
:FORWARD 20
:LEFT 90
:FORWARD 20
:RIGHT 90
:FORWARD 5
```

Time 30mins.

```
Missing
number
:RIGHT 90


:LEFT FORWARD 10
:LEFT 90
:FORWARD 5
:FORWARD 10
:LEFT 90
:FORWARD 20
:LEFT 90
:FORWARD 30
:LEFT 90
:FORWARD 10
:LEFT 90
:FORWARD 15
:RIGHT 90
:FORWARD 5
:LEFT 90
:FORWARD 5
:LEFT 90
:FORWARD 5
:LEFT 90
:FORWARD 20
:
```



Bell

```
:FORWARD 10
:LEFT 90
:FORWARD 30
:RIGHT 90
:PEN DOWN
:FORWARD 10
:LEFT 90
:FORWARD 10
:LEFT 90
:FORWARD 10
:LEFT 90
:FORWARD 10
:PEN UP
:RIGHT 90
:FORWARD 30
:PEN DOWN
:FORWARD 10
:RIGHT 90
:FORWARD 10
:RIGHT 90
:FORWARD 10
:RIGHT 90
:FORWARD 10
:PEN UP
:BACKWARD 20
:RIGHT 90
:FORWARD 9020
:PEN DOWN
:FORWARD 20
:RIGHT 45
:]RIGHT 90



]RIGHT isn'tunderstood
:RIGHT 90



:FORWARD 75
:BACKWARD 75
:RIGHT 90
:RIGHT 45
:LEFT 90
:FORWARD 115
:LEFT 45
:LEFT 90
:FORWARD 75
:RIGHT 45
:FORWARD 20
:RIGHT 90
:FORWARD 20
:LEFT 90
:FORWARD 10
:LEFT 90
:FORWARD 25
:FORWARD 5
:RIGHT 90
:LEFT 180
:FORWARD 10
:FORWARD 10-
:FORWARD 20
:FINISH
```

```
:RIGHT 45
:PEN UP
:BACKWARD 100
:RIGHT 90
:PEN DOWN
:FORWARD 100
:BACKWARD 200
:LEFT 90
:FORWARD 200
:RIGHT 90
:FORWARD 200
:RIGHT 90
:FORWARD 200
:PEN UP
:BACKWARD 25
:RIGHT 90
:FORWARD 525
:LEFT 45
:PEN DOWN
:FORWARD 31
:RIGHT 45
:FORWARD 100
:RIGHT 45
:FORWARD 31
:RIGHT 90
:RIGHT 45
:FORWARD 142
:BACKWARD 25
:LEFT 90
:FORWARD 50
:LEFT 90
:FORWARD 75
:LEFT 90
:FORWARD 50
:LEFT 90
:FORWARD 25
:LEFT 0090
:FORWARD 25
:RIGHT 90
:FORWARD 20
:RIGHT 90
:FORWARD 255
:PEN UP
```

We all chose this because we liked it and it was quite hard.

APPENDIX 19

4.6.97 Using the Printer

Today I went on the computer. I set up the printer as usual and set to work. I pressed control and B, typed CH."VARD", return twice and it all typed out on the printer. I got the 3 disks and gave myself a long task I had decided to print out a disk. I put in the disk that was full of procedures, and typed *cat, it printed and so did the list of procedures. I typed CHANGE COBRA and then a cursor key and all the commands for cobra came onto the printer, I used up all the paper ~~so~~ after a while ~~so~~ so I got some more and started work. The procedures on the disk are:

1) star
2) solar
3) Bigstar
4) sun
5) gjjp
6) cobra
7) avio
8) groovy
9) shape
10) shape1
11) shape2
12) shape3
13) shape 4
14) shape 5
15) tunnel

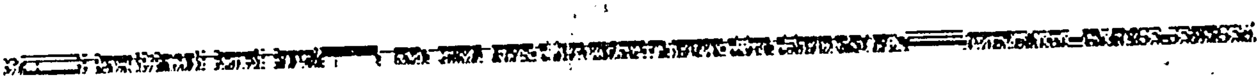
and I was on with number 12, shape3. I typed the rest out in about

half an hour so you
can tell how long it
would take to do them
all.
I think DARTO is excellent
and I really like working
on it. The only thing I
don't like is sometimes
when you work for about
half an hour building
a picture, when you
finish you put it on
BUILD and spend another
half hour on it and it
does not work.

Peter

APPENDIX 20

CH,"DARPRIN",."DARPRIN"

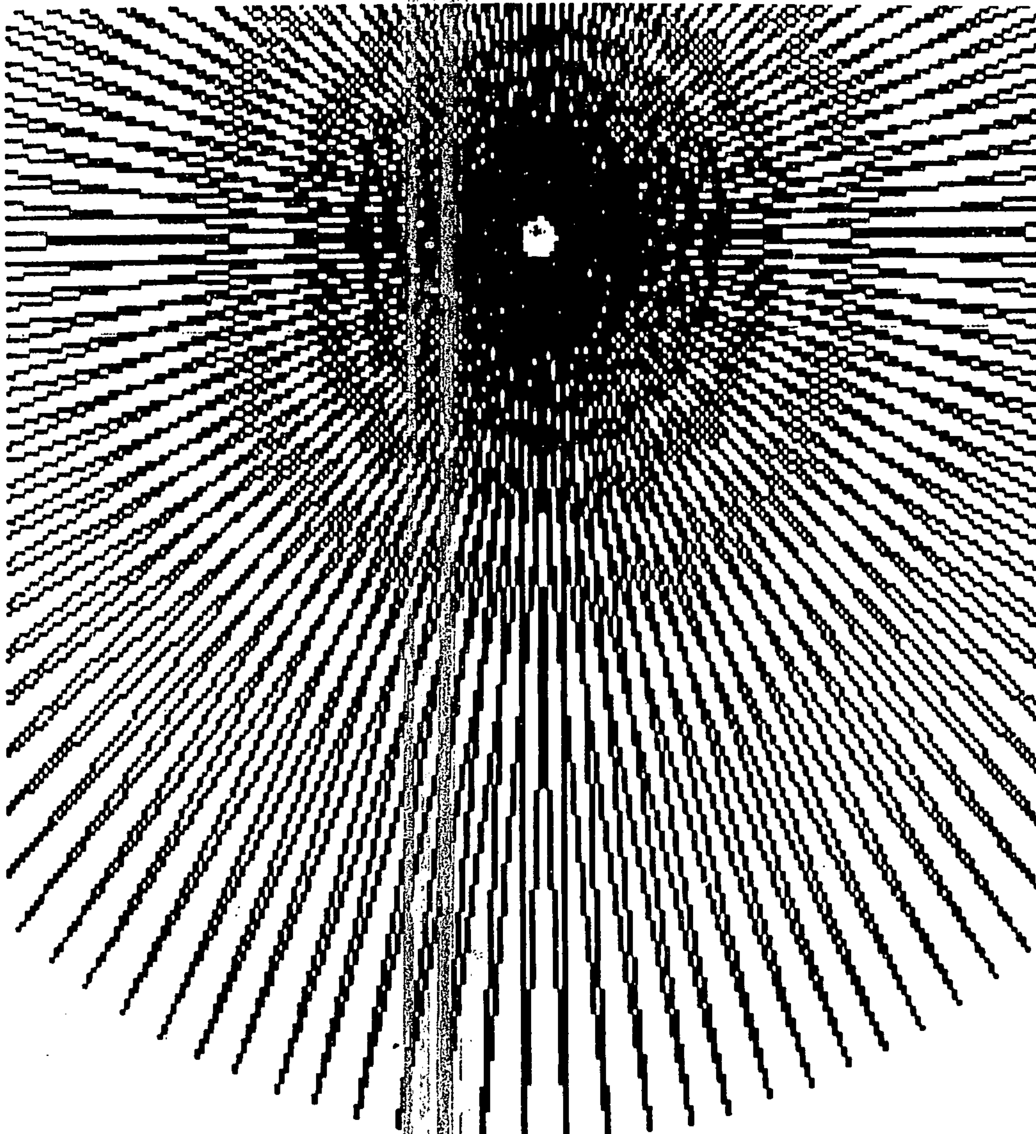


This was our ~~f~~ very first attempt

to draw on the printer

Richard and Peter

APPENDIX 21



Peter

This is my first
Picture I drew on the
Printer. I chose it
because it joins up
in the middle
~~to~~ and the dark makes it look
brilliant

APPENDIX 22

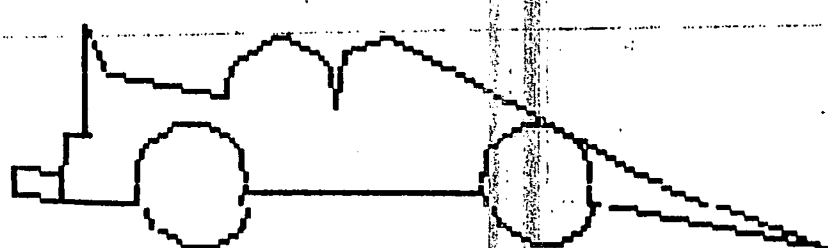
```
F500 isn't
understood
:FORWARD 500
```

```
:FINSHFINISH
>CH."DARPRIN"
```

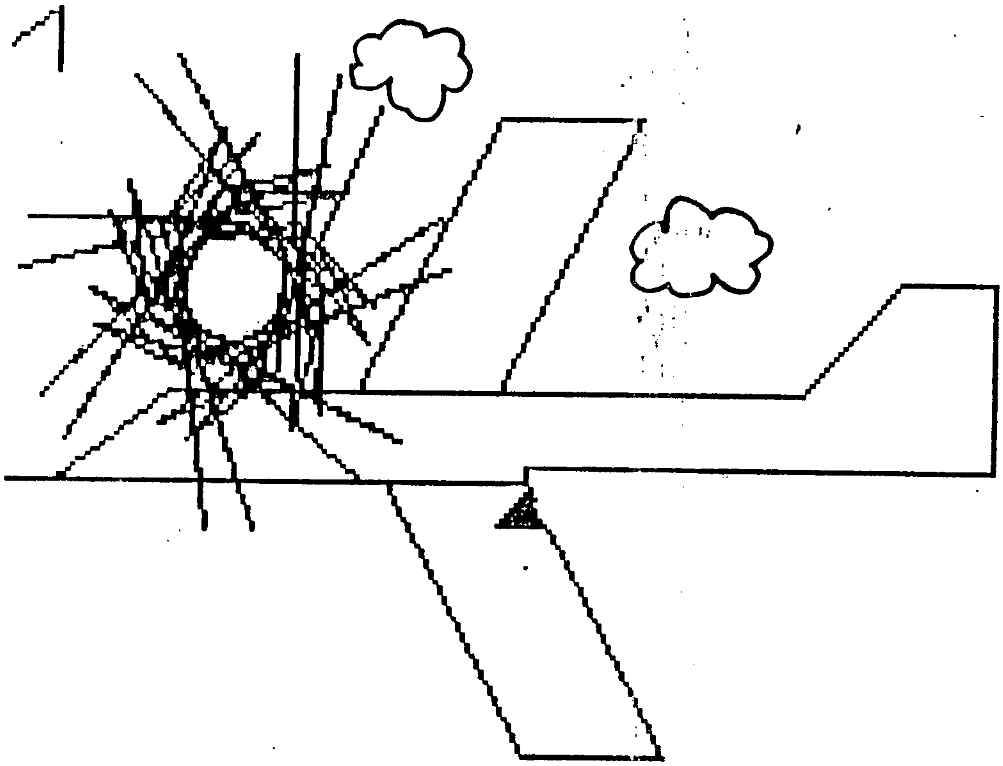
David

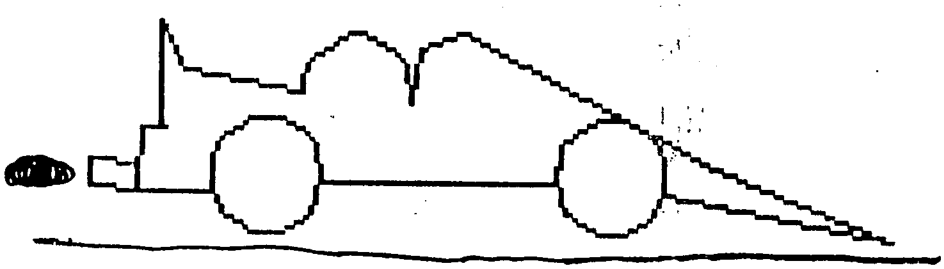
computer apprentised

This is my 2nd
print out.
This is hard
but fun



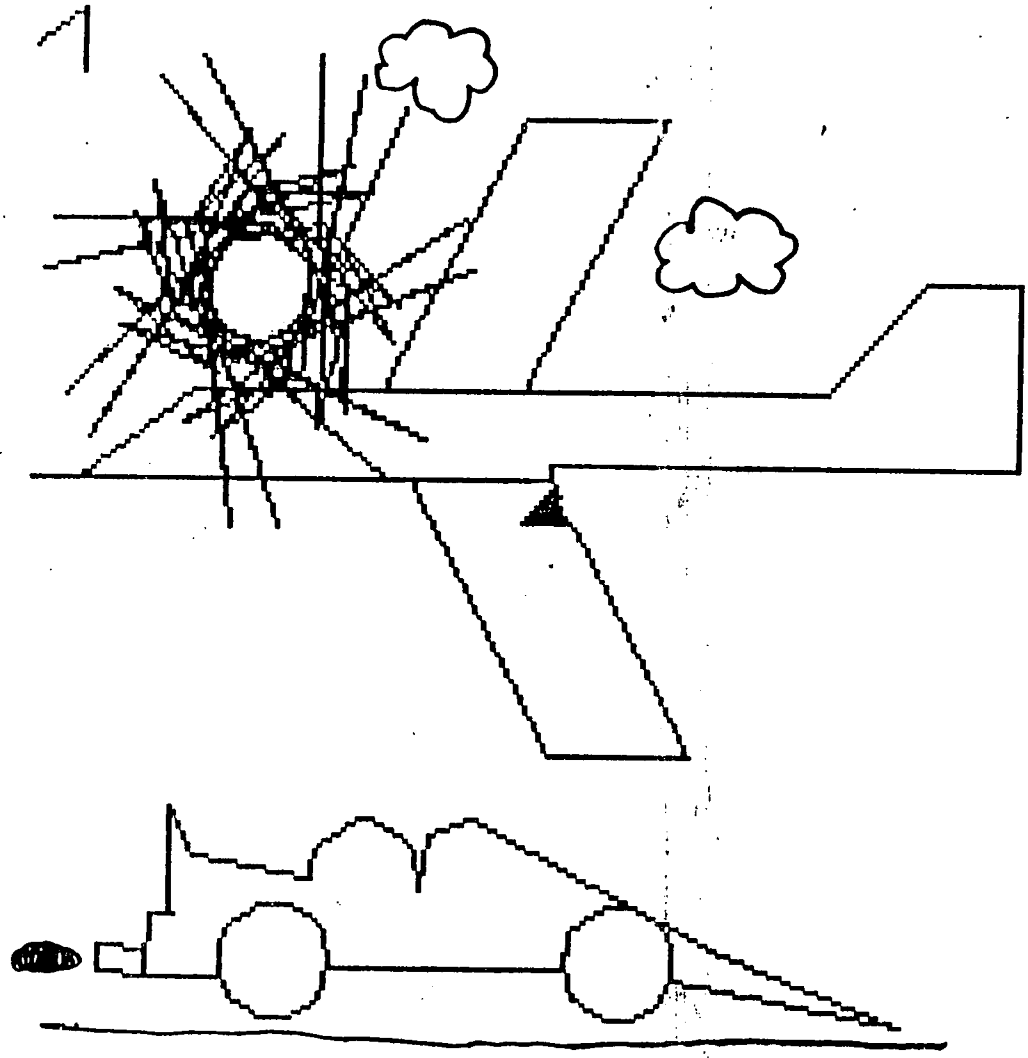
APPENDIX 23





I chose this as my Second picture to be drawn on the printer

APPENDIX 24

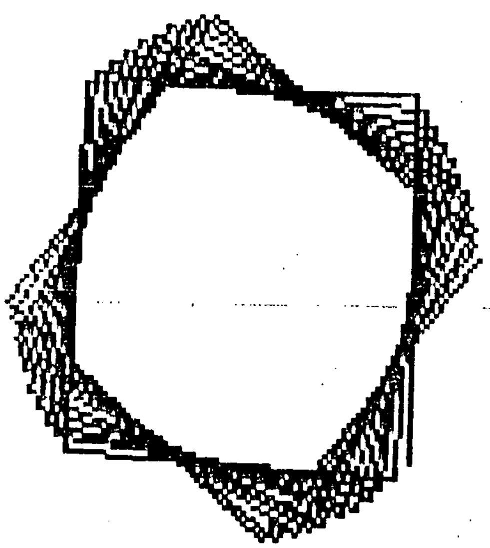


I chose this as my
Second picture tobe
drawn on the printer

APPENDIX 24

```
:
:REPEAT 144


mREPEAT 144
m FORWARD 70
m LEFT 89
m END
:PEN UP
:FORWARD 300
:FINISH
>CHAIN DARPR"DARPRIN"
```



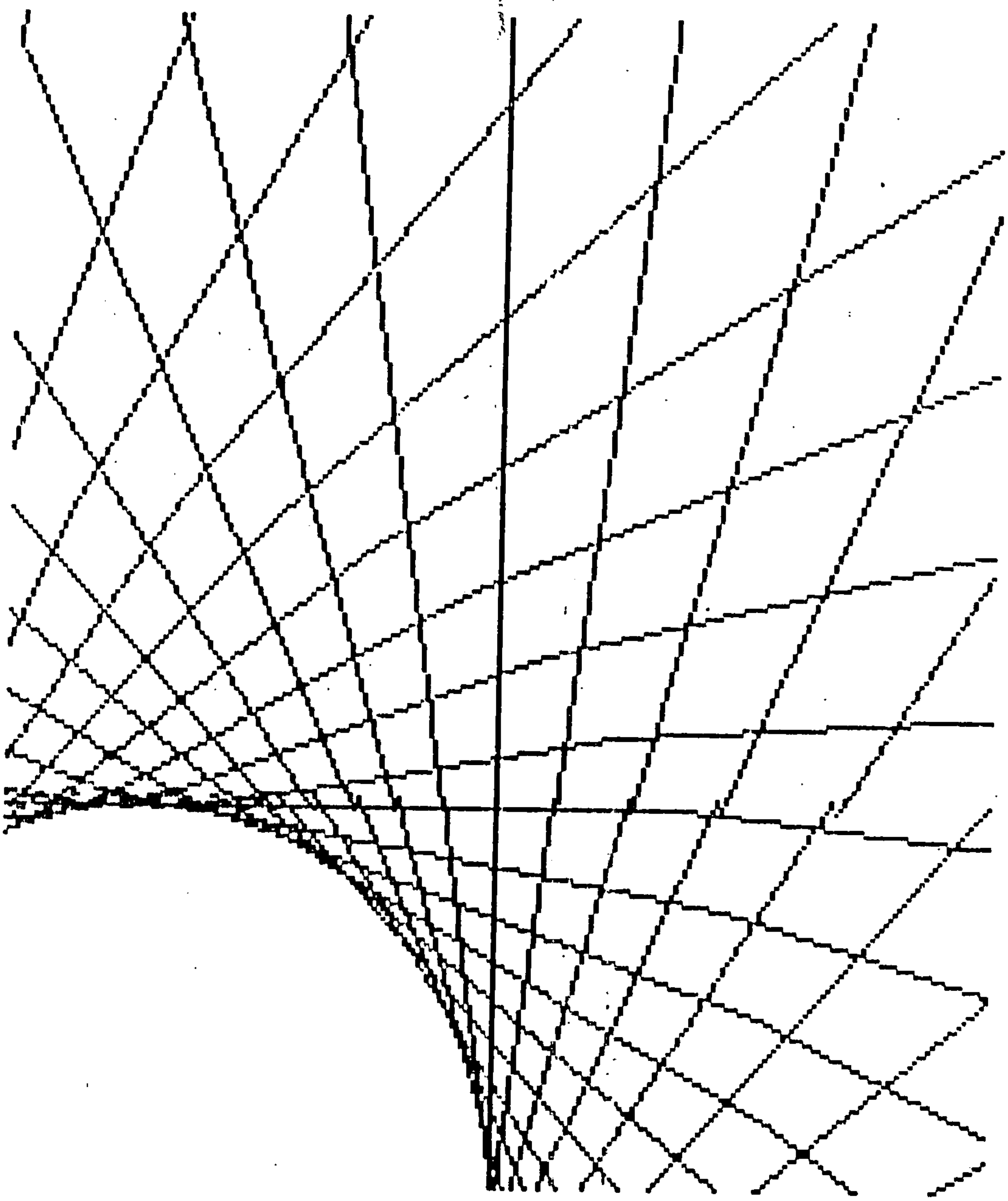
This was my
3rd printout

Peter

APPENDIX 25

```
Procedures:
GROOVY

Room for 14
more
:GROOVYFORWARD 534
:FINISH
>CHAIN "DARPRIN"
```



David

APPENDIX 26

This is hard and good.

```
Procedures:
COBRA
AERO
GROOVY
TUNNEL
STAR
BIGSTAR
SHAPE
SHAPE1
SHAPE2
SHAPE3
SHAPE4
SHAPE5
SUN
SOLAR

Room for 1
more
:CHANGE SOLAR
```

Richard and Peter
This is all the things that we done on the disk

```
CHANGE

Press / to remove a line   m to insert
      o to move up          n to move downCOPY to change stores     ESCAPE t
SOLAR
PEN UPBACKWARD 90PEN DOWNREPEAT 72 FORWARD 345 LEFT 543END REPEAT 72 FORWA
 LEFT 543END REPEAT 72 FORWARD 345 LEFT 543END REPEAT 72 FORWARD 345mmmmmm
mmmmmSOLAR
PEN DOWNREPEAT 72 FORWARD 345 LEFT 543END REPEAT 72 FORWARD 345 LEFT 543EN
AT 72 FORWARD 345 LEFT 543END REPEAT 72 FORWARD 345 LEFT 543END mmmmmmmmmm
mmmmmmmmmmmmmmmmm

:LOAD GJJS
Loading GJJS

Procedures:
COBRA
AERO
GROOVY
TUNNEL
STAR
BIGSTAR
SHAPE
SHAPE1
SHAPE2
SHAPE3
SHAPE4
SHAPE5
SUN
SOLAR
GJJS

No more room
:CHANGE GJJS
```

APPENDIX 27

APPENDIX 28

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 28

STATEMENT	Strongly Agree	Agree	Disagree	Strongly Disagree	Unsure	
I can use maths to solve some everyday problems.						2
Even when I can do maths I don't like it.						2
I get lost if I miss any work in maths.						3
I like it when there is something new to learn in maths.						3
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

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 ind 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

APPENDIX 29

```
 3 Apr 90   SPSS-X RELEASE 3.0 FOR IBM MTS
                                                    Page    1
10:04:38    University of Durham

For                         University of Durham             License Number 614640
This software is functional through May 31, 1990.

Try the new SPSS-X Release 3.0 features:
* Interactive SPSS-X command execution              * Improvements in:
* Online Help                                        *    REPORT
* Nonlinear Regression                               *    TABLES
* Time Series and Forecasting (TRENDS)               *    Simplified Syntax
* Macro Facility                                     *    Matrix I/O
See SPSS-X User's Guide, Third Edition for more information on these features.

   1  0  DATA LIST FILE=DAT100 /ID 1-3 GP 5 N1 7 N2 9 R1 11 R2 13 S1 15 S2 17 M
 19
   2  0                         M2 21 L1 23 L2 25 SS1 27-29 SS2 31-33 P1 35-36
2 38-39
THE COMMAND ABOVE READS   1 RECORDS FROM DAT100
          VARIABLE   REC  START    END         FORMAT  WIDTH  DEC

          ID           1      1      3         F          3     0
          GP           1      5      5         F          1     0
          N1           1      7      7         F          1     0
          N2           1      9      9         F          1     0
          R1           1     11     11         F          1     0
          R2           1     13     13         F          1     0
          S1           1     15     15         F          1     0
          S2           1     17     17         F          1     0
          M1           1     19     19         F          1     0
          M2           1     21     21         F          1     0
          L1           1     23     23         F          1     0
          L2           1     25     25         F          1     0
          SS1          1     27     29         F          3     0
          SS2          1     31     33         F          3     0
          P1           1     35     36         F          2     0
          P2           1     38     39         F          2     0
END OF DATALIST TABLE

   3  0  SET LENGTH=72
   4  0  SET WIDTH=80
   5  LIST CASES TO 20
There are 63776 bytes of memory available.
The largest contiguous area has 63776 bytes.
      672 BYTES OF MEMORY REQUIRED FOR LIST PROCEDURE.
      144 BYTES HAVE ALREADY BEEN ACQUIRED.
      528 BYTES REMAIN TO BE ACQUIRED.
```

ID	GP	N1	N2	R1	R2	S1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P1	P2
1	1	8		7	8	8	5	7	6	6	4	124	111	95	76
2	1	4	6	8	7	9	7	7	8	6	5	121	108	92	70
3	1	1	2	5	5	9	4	7	6	6	4	110	99	88	48
4	1	5	5	6	6	8	7	7	7	7	5	115	106	84	66
5	1	4	1	5	1	7	6	2	2	0	3	108	96	70	39
6	1	4	5	2	4	6	5	6	1	0	4	105	96	63	39
7	1	4	1	3	1	0	1	2	1	4	0	96	83	39	13
8	1	1	1	3	3	3	2	2	2	4	3	100	94	50	34
9	1	3	4	5	5	7	7	3	0	8	3	104	92	61	30
10	1	3	0	0	1	3	0	2	0	0	0	94	73	34	4
11	2	7	6	9	6	9	7	8	7	6	4	131	111	98	76
12	2	7	6	8	4	5	7	7	4	2	0	120	101	91	52
13	2	6	5	8	2	6	2	3	4	7	4	116	99	86	48
14	2	7	6	7	5	7	5	2	1	5	0	114	100	82	50
15	2	8	6	5	4	8	4	0	5	2	3	108	99	70	48
16	2	3	2	6	4	5	3	3	5	7	3	107	98	68	45
17	2	6	5	1	0	5	0	0	4	5	0	99	88	48	21
18	2	1	2	6	2	6	8	2	2	6	3	99	93	48	32
19	2	1	4	5	2	5	2	0	1	0	3	99	93	48	32
20	2	3	0	3	0	2	4	0	0	0	0	95	77	37	6

Control

Research

NUMBER OF CASES READ = 20 NUMBER OF CASES LISTED = 20

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page
10:04:42 University of Durham

PRECEDING TASK REQUIRED 0.06 SECONDS CPU TIME; 0.53 SECONDS ELAPSED

6 T-TEST GROUPS=GP(1,2) / VARIABLES=N1 TO P2
There are 64256 bytes of memory available.
The largest contiguous area has 63680 bytes.
THE T-TEST PROBLEM REQUIRES 784 BYTES OF WORKSPACE

Comparison between control + research group for each part of the test

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- T - T E S T -

GROUP 1 - GP EQ 1
GROUP 2 - GP EQ 2

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
N1				
GROUP 1	10	4.1000	1.792	0.567
GROUP 2	10	4.9000	2.644	0.836

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
2.18	0.262	* -0.79	18	0.439	* -0.79	15.83	0.440

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
N2				
GROUP 1	10	3.2000	2.486	0.786
GROUP 2	10	4.2000 .161	2.150	0.680

F VALUE	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.34	0.673	*	-0.96	18	0.349	*	-0.96	17.63	0.349

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

GROUP 1 - GP EQ 1
GROUP 2 - GP EQ 2

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
R1				
GROUP 1	10	4.6000	2.716	0.859
GROUP 2	10	5.8000	2.440	0.772

		*	POOLED VARIANCE ESTIMATE			*	SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.24	0.755	*	-1.04	18	0.312	*	-1.04	17.80	0.313

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
R2				
GROUP 1	10	4.1000	2.558	0.809
GROUP 2	10	2.9000	2.025	0.640

		*	POOLED VARIANCE ESTIMATE			*	SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.60	0.497	*	1.16	18	0.260	*	1.16	17.10	0.261

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

GROUP 1 - GP EQ 1
GROUP 2 - GP EQ 2

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
S1				
GROUP 1	10	6.0000	3.018	0.955
GROUP 2	10	5.8000	1.932	0.611

* POOLED VARIANCE ESTIMATE * SEPARATE VARIANCE ESTIMATE

APPENDIX 29

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
G2				
GROUP 1	10	4.4000	2.591	0.819
GROUP 2	10	4.2000	2.573	0.814

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.01	0.984	* 0.17	18	0.864	* 0.17	18.00	0.864

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

GROUP 1 GP EQ 1
GROUP 2 GP EQ 2

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
H1				
GROUP 1	10	4.5000	2.461	0.778
GROUP 2	10	2.5000	2.915	0.922

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.40	0.622	* 1.66	18	0.115	* 1.66	17.51	0.115

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
H2				
GROUP 1	10	3.3000	3.093	0.978
GROUP 2	10	3.3000	2.214	0.700

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.95	0.333	* 0.00	18	1.000	* 0.00	16.30	1.000

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

	GROUP 1	10	4.1000	3.071	0.971
	GROUP 2	10	4.0000	2.749	0.869

F VALUE	2-TAIL PROB.	* POOLED VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* SEPARATE VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.25	0.746	* 0.08	18	0.940	* 0.08	17.78	0.940

VARIABLE		NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
I2					
	GROUP 1	10	3.1000	1.792	0.567
	GROUP 2	10	2.0000	1.764	0.558

F VALUE	2-TAIL PROB.	* POOLED VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* SEPARATE VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.03	0.963	* 1.38	18	0.183	* 1.38	18.00	0.183

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10:04:43 University of Durham

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

GROUP 1 - GP EQ 1
GROUP 2 - GP EQ 2

VARIABLE		NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
SS1					
	GROUP 1	10	108.5000	10.544	3.334
	GROUP 2	10	108.8000	11.448	3.620

F VALUE	2-TAIL PROB.	* POOLED VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* SEPARATE VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.18	0.810	* -0.06	18	0.952	* -0.06	17.88	0.952

VARIABLE		NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
SS2					
	GROUP 1	10	95.8000	11.526	3.645
	GROUP 2	10	95.9000	9.012	2.850

* POOLED VARIANCE ESTIMATE * SEPARATE VARIANCE ESTIMATE

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- - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - -

GROUP 1 - GP EQ 1
GROUP 2 - GP EQ 2

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
P1				
GROUP 1	10	67.6000	22.006	6.959
GROUP 2	10	67.6000	21.376	6.760

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.06	0.932	* 0.00	18	1.000	* 0.00	17.98	1.000

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
P2				
GROUP 1	10	41.9000	23.718	7.500
GROUP 2	10	41.0000	19.230	6.081

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.52	0.542	* 0.09	18	0.927	* 0.09	17.26	0.927

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10:04:43 University of Durham

PRECEDING TASK REQUIRED 0.12 SECONDS CPU TIME; 0.72 SECONDS ELAPSED

```
7  TEMPORARY
8  SELECT IF (GP EQ 1)
9  T-TEST PAIRS=N1 N2
```

There are 64128 bytes of memory available.
The largest contiguous area has 63888 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

Comparison between pre a post test for each part of test

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 1
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- - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
N1				
	10	4.1000	1.792	0.567

APPENDIX 29

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 1
0:04:43 University of Durham

RECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.19 SECONDS ELAPSED

```
 10  TEMPORARY
 11  SELECT IF (GP EQ 1)
 12  T-TEST PAIRS=R1 R2
```

here are 64128 bytes of memory available,
he largest contiguous area has 63104 bytes.
HE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 1
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\- - - - - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - - - - -

ARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
1				
	10	4.6000	2.716	0.859
	10	4.1000	2.558	0.809
2				

DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
0.5000	1.650	0.522	* 0.806	0.005 *	0.96	9	0.363

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 1
0:04:44 University of Durham

RECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.26 SECONDS ELAPSED

```
 13  TEMPORARY
 14  SELECT IF (GP EQ 1)
 15  T-TEST PAIRS=S1 S2
```

here are 64128 bytes of memory available.
he largest contiguous area has 63888 bytes.
HE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

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0:04:44 University of Durham

\- - - - - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - - - - -

ARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
1				
	10	6.0000	3.018	0.955
	10	4.4000	2.591	0.819
2				

DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.6000	1.713	0.542	* 0.824	0.003 *	2.95	9	0.016

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME;

APPENDIX 29

```
 16  TEMPORARY
 17  SELECT IF (GP EQ 1)
 18  T-TEST PAIRS=M1 M2
There are 64128 bytes of memory available.
The largest contiguous area has 63104 bytes.
THE T-TEST PROBLEM REQUIRES        64 BYTES OF WORKSPACE

 3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS                      Page  1
10:04:45  University of Durham

- - - - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - - - -
```

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
M1	10	4.5000	2.461	0.778
M2	10	3.3000	3.093	0.978

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.2000	1.751	0.554	* 0.825	0.003 *	2.17	9	0.058

```
 3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS                      Page  1
10:04:45  University of Durham

PRECEDING TASK REQUIRED      0.06 SECONDS CPU TIME;      0.59 SECONDS ELAPSED

 19  TEMPORARY
 20  SELECT IF (GP EQ 1)
 21  T-TEST PAIRS=L1 L2
There are 64128 bytes of memory available.
The largest contiguous area has 63888 bytes.
THE T-TEST PROBLEM REQUIRES        64 BYTES OF WORKSPACE

 3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS                      Page  2
10:04:46  University of Durham

- - - - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - - - -
```

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
L1	10	4.1000	3.071	0.971
L2	10	3.1000	1.792	0.567

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.0000	2.789	0.882	* 0.442	0.201 *	1.13	9	0.286

```
 3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS                      Page  2
10:04:46  University of Durham

PRECEDING TASK REQUIRED      0.05 SECONDS CPU TIME;      0.42 SECONDS ELAPSED
```

```
The largest contiguous area has 63104 bytes.
THE T-TEST PROBLEM REQUIRES          64 BYTES OF WORKSPACE

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10:04:46  University of Durham

- - - - - - - - - - - - - - - - - T - T E S T- - - - - - - - - - - - - - - - -

VARIABLE     NUMBER                    STANDARD   STANDARD
            OF CASES       MEAN       DEVIATION     ERROR
------------------------------------------------------------------
SS1
                 10      108.5000      10.544      3.334

                 10       95.8000      11.526      3.645
SS2
------------------------------------------------------------------
(DIFFERENCE) STANDARD    STANDARD    *        2-TAIL  *     T     DEGREES OF  2-TAIL
    MEAN    DEVIATION      ERROR     * CORR.  PROB.  *  VALUE     FREEDOM     PROB.
-----------------------------------------------------------------------------------------
   12.7000     4.498       1.422     * 0.921 0.000 *    8.93         9        0.000
-----------------------------------------------------------------------------------------

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10:04:47  University of Durham

PRECEDING TASK REQUIRED        0.05 SECONDS CPU TIME;        0.33 SECONDS ELAPSED

   25   TEMPORARY
   26   SELECT IF (GP EQ 1)
   27   T-TEST PAIRS=P1 P2
There are 64128 bytes of memory available.
The largest contiguous area has 63888 bytes.
THE T-TEST PROBLEM REQUIRES          64 BYTES OF WORKSPACE

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10:04:48  University of Durham

- - - - - - - - - - - - - - - - - T - T E S T- - - - - - - - - - - - - - - - -

VARIABLE     NUMBER                    STANDARD   STANDARD
            OF CASES       MEAN       DEVIATION     ERROR
------------------------------------------------------------------
P1
                 10       67.6000      22.006      6.959

                 10       41.9000      23.718      7.500
P2
------------------------------------------------------------------
(DIFFERENCE) STANDARD    STANDARD    *        2-TAIL  *     T     DEGREES OF  2-TAIL
    MEAN    DEVIATION      ERROR     * CORR.  PROB.  *  VALUE     FREEDOM     PROB.
-----------------------------------------------------------------------------------------
   25.7000     7.409       2.343     * 0.950 0.000 *   10.97         9        0.000
-----------------------------------------------------------------------------------------

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10:04:48  University of Durham

PRECEDING TASK REQUIRED        0.06 SECONDS CPU TIME;        0.53 SECONDS ELAPSED

   28   TEMPORARY
   29   SELECT IF (GP EQ 2)
   30   T-TEST PAIRS=N1 N2
There are 64128 bytes of memory available.
The largest contiguous area has 63104 bytes.
```

Group 2   REsearch group

test

- - - - T - T E S T- - - - - - -

APPENDIX 29

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
N1	10	4.9000	2.644	0.836
N2	10	4.2000	2.150	0.680

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
0.7000	1.636	0.517	* 0.786	0.007 *	1.35	9	0.209

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 2
10:04:49 University of Durham

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.32 SECONDS ELAPSED

```
31  TEMPORARY
32  SELECT IF (GP EQ 2)
33  T-TEST PAIRS=R1 R2
```

There are 64128 bytes of memory available.
The largest contiguous area has 63888 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 2
10:04:49 University of Durham

- - - - - - - - - - - - - - - - T - T E S T- - - - - - - - - - - - - - - - -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
R1	10	5.8000	2.440	0.772
R2	10	2.9000	2.025	0.640

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
2.9000	1.524	0.482	* 0.782	0.007 *	6.02	9	0.000

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 2
10:04:49 University of Durham

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.12 SECONDS ELAPSED

```
34  TEMPORARY
35  SELECT IF (GP EQ 2)
36  T-TEST PAIRS=S1 S2
```

There are 64128 bytes of memory available.
The largest contiguous area has 63104 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:49 University of Durham

- - - - - - - - - - - - - - - - T - T E S T- - - - - - - - - - - - - - - - -

10	5.8000	[illegible]	[illegible]
10	4.2000	2.573	0.814

S2

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL * PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.6000	2.675	0.846	* 0.322	0.365 *	1.89	9	0.091

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:50 University of Durham

PRECEDING TASK REQUIRED 0.06 SECONDS CPU TIME; 0.46 SECONDS ELAPSED

```
37  TEMPORARY
38  SELECT IF (GP EQ 2)
39  T-TEST PAIRS=H1 H2
```

There are 64128 bytes of memory available.
The largest contiguous area has 63888 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:50 University of Durham

- T - T E S T -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
H1				
	10	2.5000	2.915	0.922
	10	3.3000	2.214	0.700
H2				

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL * PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
0.8000	2.394	0.757	* 0.594	0.070 *	-1.06	9	0.318

pr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10: 1:50 University of Durham

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.22 SECONDS ELAPSED

```
40  TEMPORARY
41  SELECT IF (GP EQ 2)
42  T-TEST PAIRS=L1 L2
```

There are 64128 bytes of memory available.
The largest contiguous area has 63104 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:50 University of Durham

- T - T E S T -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
L1				
	10	4.0000	2.749	0.869

MEAN	DEVIATION	ERROR	* CORR.	PROB. *	VALUE	FREEDOM	PROB.
2.0000	2.625	0.830	* 0.390	0.266 *	2.41	9	0.039

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:50 University of Durham

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.16 SECONDS ELAPSED

43 TEMPORARY
44 SELECT IF (GP EQ 2)
45 T-TEST PAIRS=SS1 SS2
There are 64128 bytes of memory available.
The largest contiguous area has 63088 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:51 University of Durham

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
SS1	10	108.8000	11.448	3.620
SS2	10	95.9000	9.012	2.850

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
12.9000	5.384	1.703	* 0.888	0.001 *	7.58	9	0.000

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:51 University of Durham

PRECEDING TASK REQUIRED 0.05 SECONDS CPU TIME; 0.26 SECONDS ELAPSED

TEMPORARY
SELECT IF (GP EQ 2)
T-TEST PAIR=P1 P2
There are 64128 bytes of memory available.
The largest contiguous area has 63104 bytes.
THE T-TEST PROBLEM REQUIRES 64 BYTES OF WORKSPACE

3 Apr 90 SPSS-X RELEASE 3.0 FOR IBM MTS Page 3
10:04:51 University of Durham

- - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - -

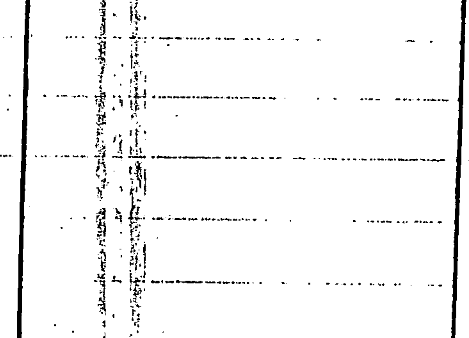
VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
P1	10	67.6000	21.376	6.760
P2	10	41.0000	19.230	6.081

APPENDIX 29

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	* CORR.	2-TAIL PROB. *	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
26.6000	8.249	2.609	0.933	0.000	10.20	9	0.000

... opinion about
Dart

Hello. My name is Stephen and I am here to explain what Dart is and what my opinion is about Dart. First of all I'll explain just what Dart is. Dart is a maths proggram for computers to teach children and grown-ups about angles. When me and my partner where on Dart we thought it was good. Eventually we thought it was brilliant because even though it was fun it was teaching us how to use angles and to build pictures on the screen. Our very first shape was a square. Here is a diagram. ↓



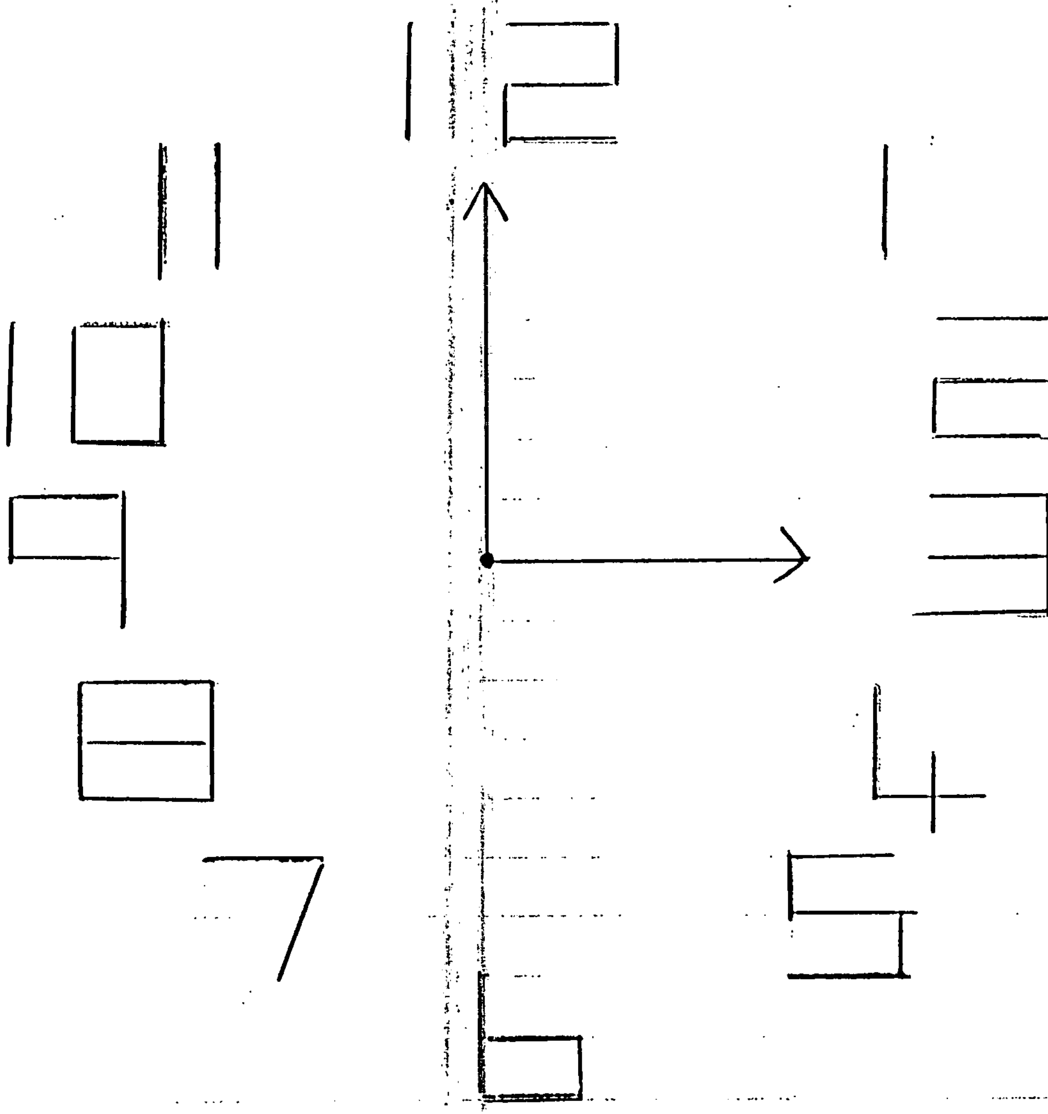
This was quite easy.

Dart was very difficult at first but it soon got a lot easier. Our biggest success was "Hello Mrs Firth", which we got Mars Bar for. Here is another diagram.

Our most interesting picture was the clock. This took a very long time and was very hard. This was our greatest picture. Here is a diagram.

GROUP A

APPENDIX 30



This was brilliant and so is Dart.

GROUP A

APPENDIX 30

An Opinion About Dart Graham

GROUP A

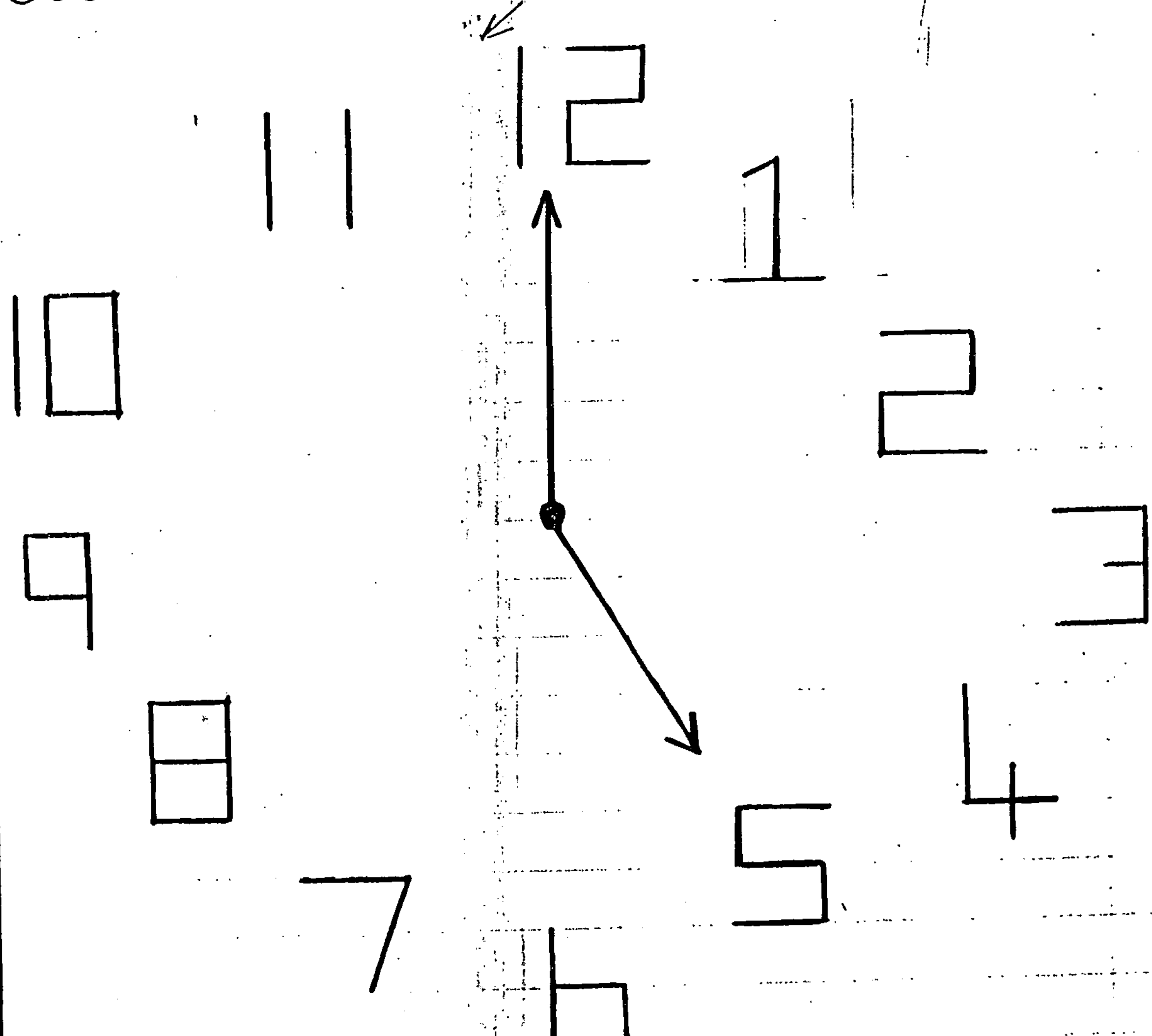
APPENDIX 31

Hello my name is Graham I'm going to tell you about my succes on Dart. By the way Dart is a maths programme which helps teaches and childen about mathmaticle angles. At the beginning when Ms Feith told us about Dart I thought it sounded ~~B~~ quite difficult, but succese ly I could learn more abou t angles in pogess. one of the best things I did was this subject in trying to write on Dart.

HELLO MRS

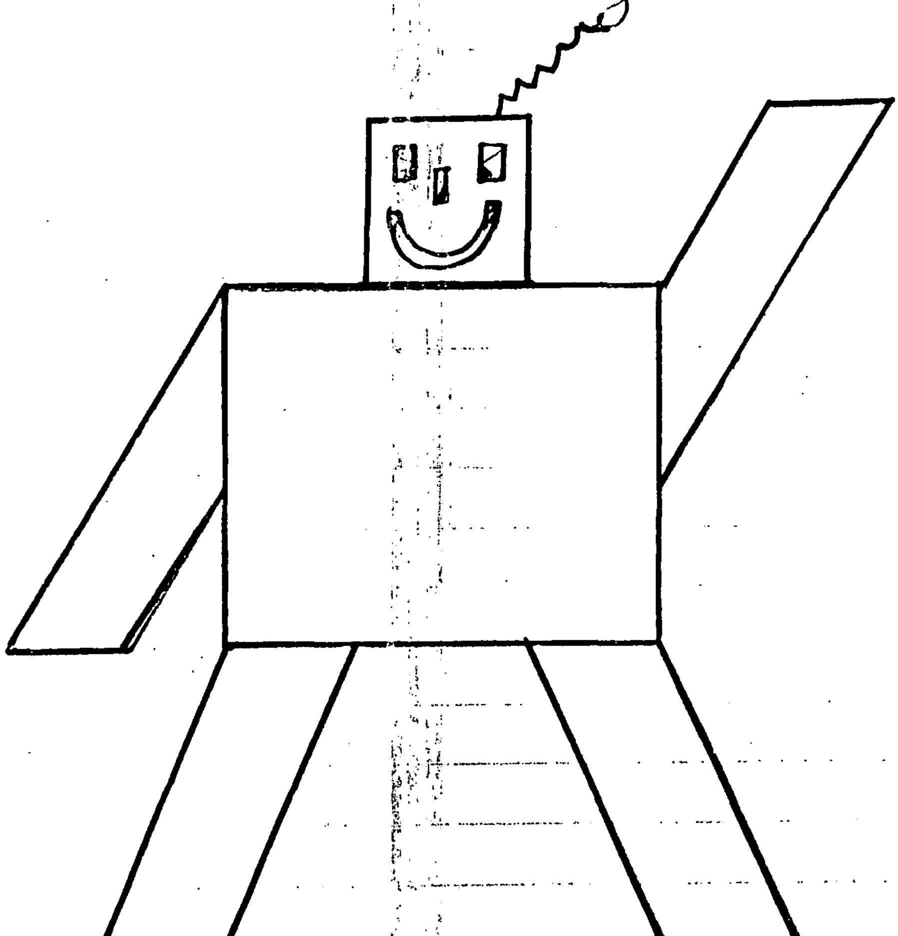
FERTH

Ms Feth is our head teacher, for doing that pogramme Ms feth gave me and my partner a mars bar. After that it got boring abit, but now I can understan d it better I enjoy it alot more. Me and Stephen mad e a disk but dessapointed ly it was lost. I enjoyed another programme we did it was called clock here is a diagramme of what it looked like.



My opinion has changed about Dart because I can understand it, and when I grow up I hope to have a very good education for a job. I liked the clock the best and I disliked my deathstar because it had no afection to dart. My best achiever

-ent must have been the clock because it was very effective and was a succes-s in neatness. My favourite drawing was the Robot it was very hard but fun here is a diagramme of it



This was hard but fun.

My opinion of Dart is a great activets to learn about maths, and keeps you in working for a job. I think its worth while doing and its fun.

Beth

GROUP B

APPENDIX 32

An Opinion about Dart.

When I first started using dart I thought it was exellent. We drew different shapes like a square. After a few weeks it started to get boring. We had made all the shapes that we could think of. Every time it was Anne-Maries, Michelles and my turn I used to hate it. After about three month I realiesd how much I had come on with my angles and degrees. I realised how much dart had brought me on. For about the next month I loved dart. We made a ship, a house on a hill and many more interesting things, but then things started to go ~~on~~ wrong we wernt writing it down right and we could not think what to make, and once again

Beth

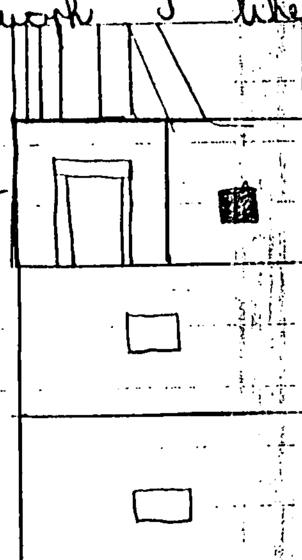
it started to get boring. Now and again we would make something good. Once we made a calculator it was a disaster. First of all we got the right shape but it came to the end of the lesson so the next time we had to start again six times because of typing mistakes. The next lesson we lost the paper with the instructions on so we threw all the other papers in the bin. The best thing we ever drew was Sammy the square tortoise. I know that dart teaches you good maths but on the hole I think it is quite boring.

Anne-Marie

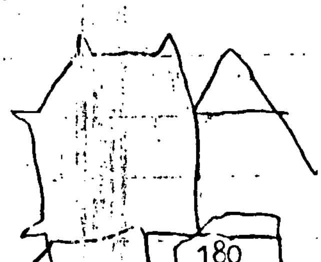
An opinion about Dart

At first I used to think Dart was hard, because of the right and left angles and words like change, bild, make, fresh, and ~~brake~~. After a while I got used to these & different words and keys. At first Beth Michelle (my partner for the dart proggramme) and me started on shapes like squares, and triangles. Then we started to do things like patterns and pictures. I enjoyed makeing things on the computer especially when Mrs Firth got the printer out. When I learned more about the computer I started to enjoy Dart even more than, before. The things I like about the computer is that if work hard enough you can make some realy good things. This is my piece of work I liked best and enjoyed doing the most. It is a unite. It has 2 large drawers, one small drawer a shelf for books and another shelf, this ~~shlf~~ shelf has a mirror on it.

brake



This is a piece of work that was hard but quite short and it is a piece of work I dont like very much.



My opinion of Dart now is very different from when I first started it. I think it is brilliant and is very educational I also enjoyed doing it,

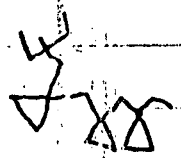
GROUP B

APPENDIX 33

Michell

GROUP B
APPENDIX 34

An opinion about Dart

I thought dart was hard when I first saw dart on the computer. but when Anne-Marie and Beth and I had to go on the computer I whached Anne-Marie and Beth Beth thaught of the angals Anne-Marie tiped. I wrote. as I whached then I began to no how to us Dart. Now we all no how to us Dart quite well now. We started making simple things like squars and triangels then as we grew more flonger ~~wit~~ with dart we started to do houses, book shelfs pictures. My favirote was the book self we made it looks a bith like this.  We did lots more thing that I liked. Soon we ran out of ideas and it becan a bit boring. But now we have found new ideas which we did not think of befor I like simple things such as trees bucs. cars, trains. We ~~were~~ are not so good at paterns, spirous. ~~sun~~ one is the one I hate the most it looks a bit like this.  Anne-Marie likes the shelf best as well. Im not sure a-bout Beth. We have been working with dart a long time and we have made lots of

'Michelle'

things and we have enjoyed making then. I have leant a lot from starting work on Dart. Soon we will be going to a new school and ~~will~~ will not be working on dart after the holidays and the 3rd years will be working on Dart they have learnt sone of Dart were they have beeing working with some of the 4 years. I liked working with dart and I hope the 3rd years do

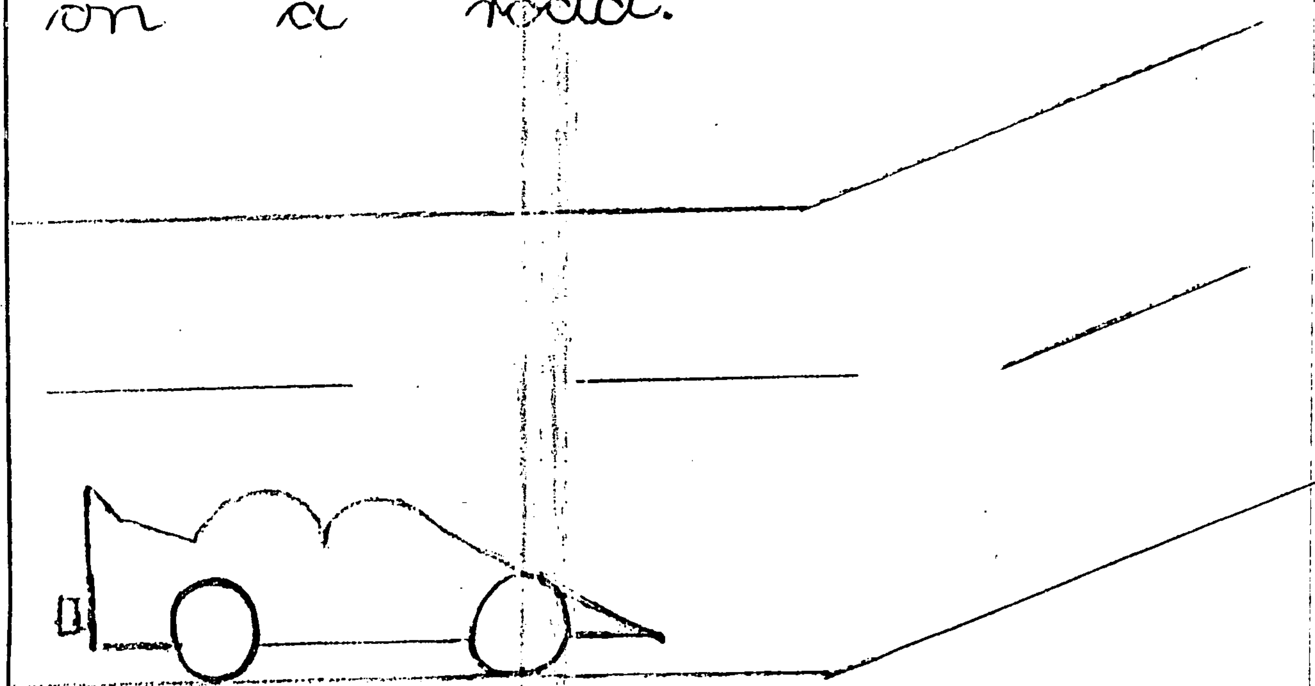
GROUP B

APPENDIX 34

David

An Opinion About Dart

The first time I done Dart I thought it was good. Dart is a maths program. You find out where to put and move angles. I work on dart with Peter and Richard. The first thing I done on dart was a Ninja and a death-star. The esayest thing I done on dart was the deathstar because it had 4 commands. My best achievement was a car on a road.



My name for this car is called Cobra. I like on the computer the best is draw on the printer.

We drew Cobra, Groovey, Area and lots more. Now 9 thing dart is brilliant. It is brilliant because we can draw better things and do better things.

GROUP C

APPENDIX 35

Peter

An Opinion About Dart

GROUP C

APPENDIX 36

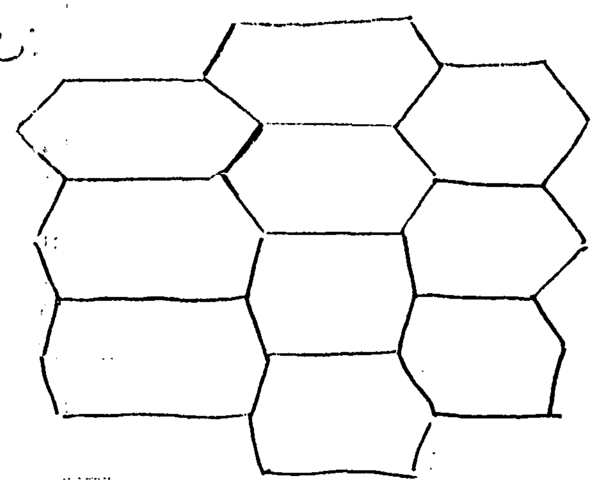
When Mr. Headly brought the Dart programme, excitment was in the air. For those of you who don't know what Dart is, it is a programme for the computer that is all about angles and degrees where you draw pictures of all sorts eg: a square

Forward 50
Left 90
Forward 50
Left 90
Forward 50
Left 90
Forward 50

In the beginning I thought that Dart would be boring, but I soon changed my opinion when Richard and I became Dart moniters.
When Mrs. Firth got the printer all of the fourth years tried it out printing down their procedures, and then Mrs. Firth told us that you could draw your pictures on the printer. Everyone tried to work it out but couldn't, until a year later when I found it out a week before I and all the other fourths years are leaving. I remember the time when our Dart disk was wipped because we left it on the computer. the Thing dislike about Dart is that you can't change the colour

of one line then another, it is yellow all the time. The thing I like about Dart is the way you can build anything on it. I think Dart is excellent.

My best shape:

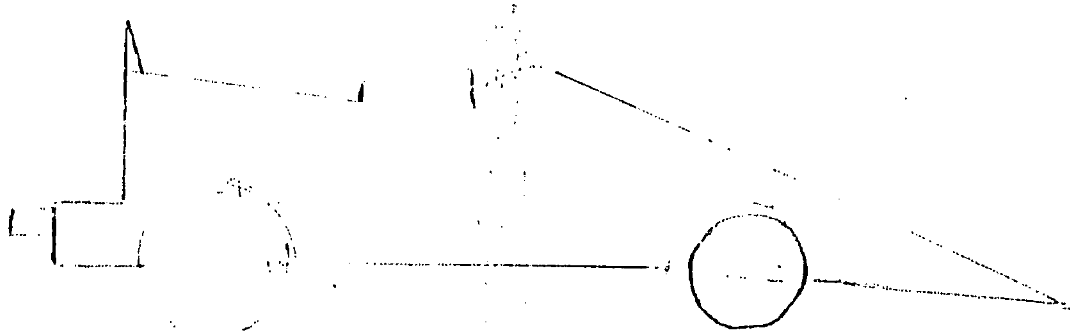


My Opinion about Dart

GROUP C

APPENDIX 37

Hello my ~~is~~ name is Richard I work on a maths subject called dart. I work with two ~~per~~ persons called David and Peter. Dart is all abought different angles. At first when we started Dart I thought it was boring, but when we had being useing it a bit we got ~~u~~ used to it here is a picture of one of the drawings.



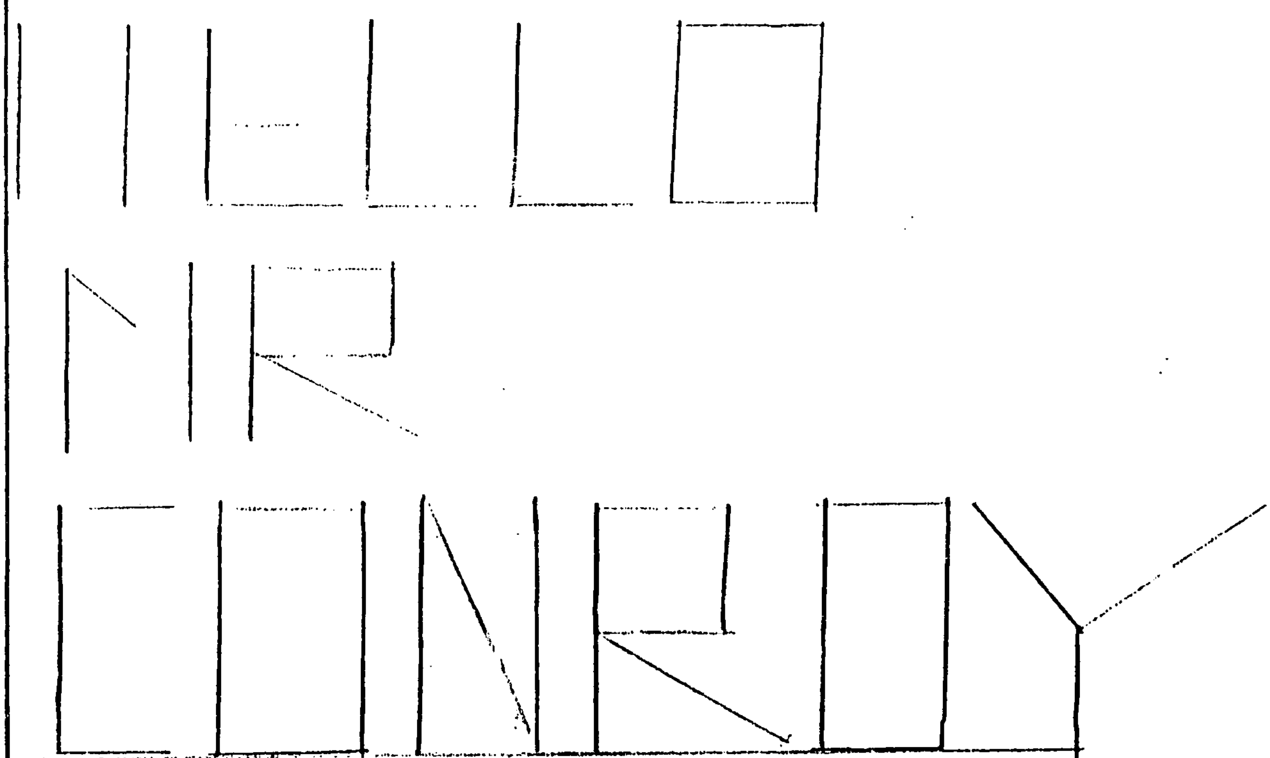
We named this cobra

The most diffcult task was fixing the Printer. On the Printer was a ribon it I had been clodged up we took the whole thing out and folowed the instructions ~~afe~~ after we fixed the Printer we had

GROUP C

APPENDIX 37

it a problem geting it back. I think that Dart is a big success. I enjoyed ~~doing~~ doing dart. Here is a picture of our best shape.



Michael

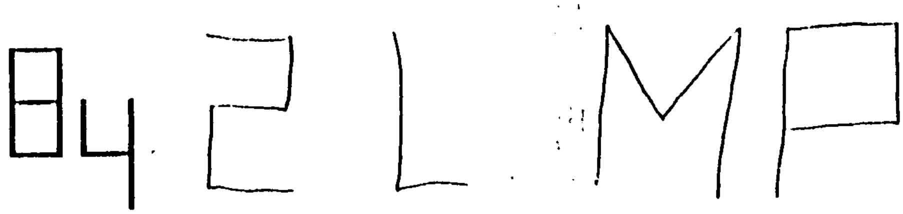
An apinion about Dart

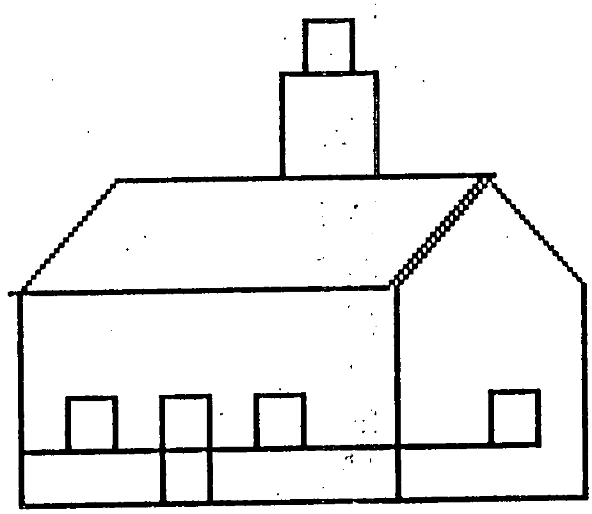
When I first went on Dart I thought it was very hard but it was really easy. The first thing I ever made was a scquare and other easy things. And then I went onto the more complecated things. The first complecated thing I did was a church. By SL. MP. I was thrilled with the programe I did and so was the teacher. My apinion on Darto now Is very good because when you are older you will have to think just as hard as we do because you mite just get a job as a banker and you have to think very very hard just incase you give them the wrong money. I think Darto is a very mathamatic subject and every body should like it because I sertenly do.

```
:FORWARD 10
:LEFT 90
:FORWARD 10
:BACKWARD 20
:FORWARD 10
:PEN UOP
:RIGHT 90
:FORWARD 5
:PEN DOWN
:FORWARD 10
:LEFT 10
:FORWARD 10
:RIGHT 90
:FORWARD 10
:FINISH
>CH."DARPRIN"
```

GROUP D

APPENDIX 39





I picked this programe because it was very interesting and it took a lot of thinking about. I enjoyed this one the best.

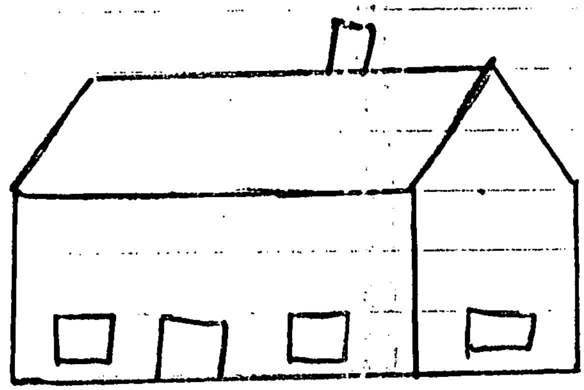
Stephen An Opinion about Dart.

GROUP D

APPENDIX 40

At furst when I furst started Dart I enjoyed ~~D.~~ doing it, but as I progressed it got boring because I was not on it ~~alot~~ alot ~~and~~ ~~more~~ doing more things in the classroom. After I started going on dart more often I started to enjoy it. The longest thing I rote and one of the hardest at furst was this.

By L S.L And M.P



I got 10 team points for this and so did Michael Parkin k who helped me. After bilding this I started to make paterns like stars. Here

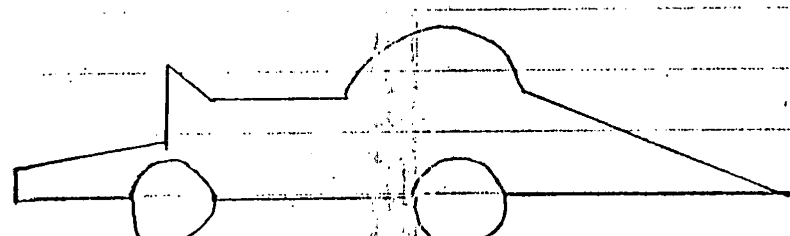
is a demonstration
of one

GROUP D

APPENDIX 40

Repet 36
Forward 90
Left 1000
Backward 10
Right 25
Forward 40
Backward 30
Left 90
Forward 5
END

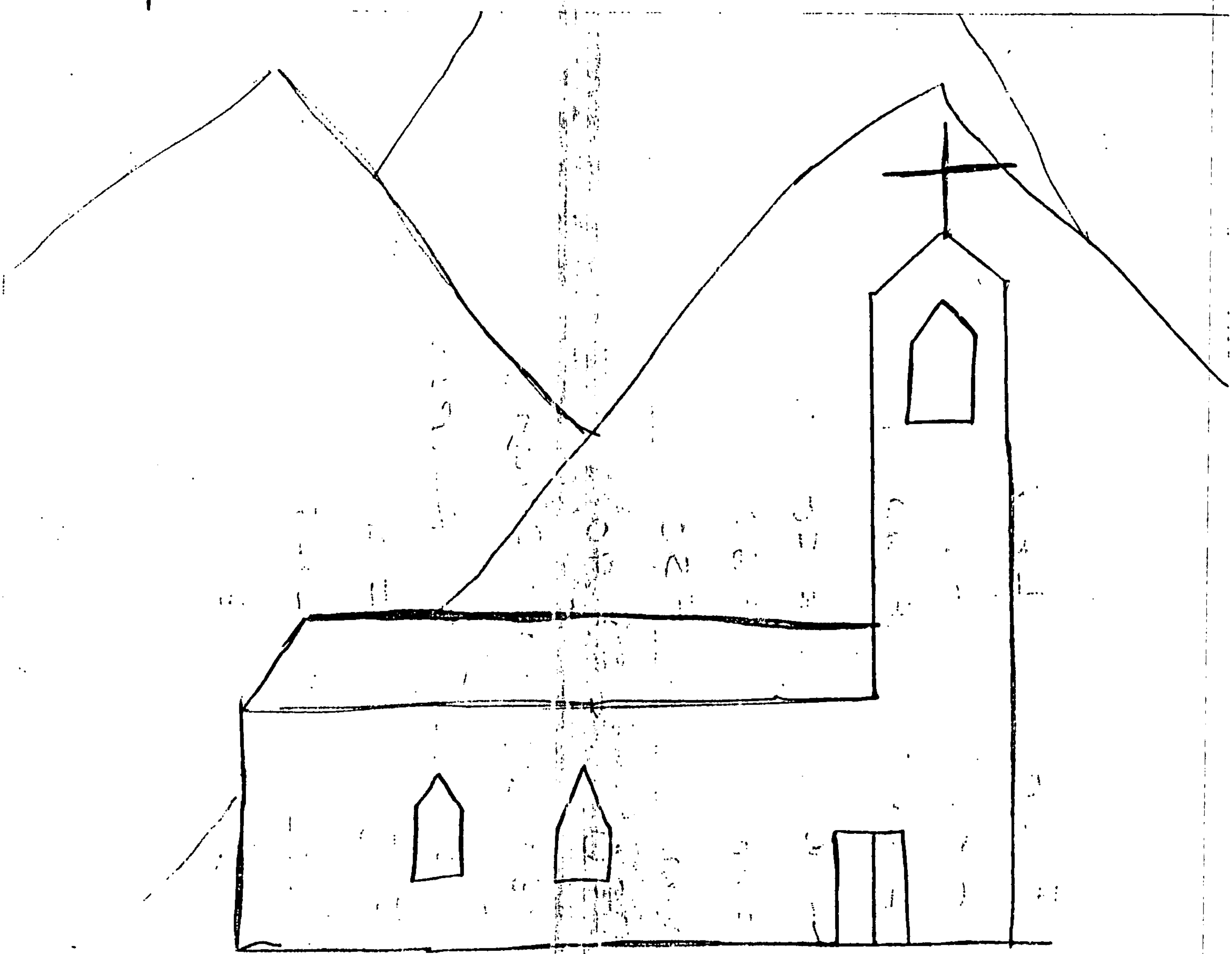
I done these till
Mrs Firth told us not
to do paterns and
tray to do some
pictures. The thing
I have liked doing best
on dart was copieng
a sports cars onto the
printer here is a picture
of it.



GROUP D

APPENDIX 40

The thing I thought was best was a church ~~was~~ I done with hills in the background. The sad thing was that Michael lost his book in wich it was. Michael found his book and when we tried to copie it on to the printer it went rong.



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