Contents

1 Overview of the Thesis

The benefits of Logo, used in a cooperative learning environment, for the development of a deeper understanding of angle and the properties of regular polygons are described in this study. Six children who have difficulties at times, keeping pace with their mainstream class in mathematics, were chosen to undertake a ten-lesson course in the Logo programming language. This course was designed to provide appropriate material to enhance the children's understanding of the aforementioned concepts. The children worked in cooperative pairs for the duration of the course with suitable incentives provided, firstly for the groups to work together and secondly, to ensure individual accountability. As the children were introduced to new aspects of Logo during each lesson, they were given a worksheet designed to provide opportunities to practice implementing these corresponding aspects in a solution to the challenges provided on the worksheet.

The study was carried out according to the 'action research' approach based on the action research philosophy outlined by Jack Whitehead which is based on what he terms the concept of 'living educational theory'. The main purpose of action research is to bring about an improvement in practice. McNiff, Lomax and Whitehead (1996) use the following questions to distinguish action research from other research.

1. *How can I improve the quality of my practice here?*
2. *What is happening here?*

Question one is an action research question while question two is not. Questions of the “How can I improve…?” type indicate a commitment on the part of the researcher to an imagined solution that depends on the researchers own action.

> *Such questions, asked within a professional context, highlight the centrality of your own values as a professional dealing with an issue to which you are committed to finding a solution – (McNiff, Lomax and Whitehead 1996)*

As a teacher who works with children in small groups who have learning difficulties, I was not satisfied with my current practice in relation my teaching of mathematics with the sixth class group. I hoped to use the computer as a means of improving this practice. Logo was chosen as the software package as I had become aware of it through a presentation given by Dr. Sean Close of St. Patrick’s College, Dublin. It appeared to be a package that had great potential in the area of geometry in particular. Other software packages that the children used were limited in terms of the time span of their usage. The children completed the adventure games quickly and tended to get bored with the drill and practice type software sometimes very quickly after repeated use. Logo seemed to provide more scope for extending its usefulness as a piece of educational software.

It was decided to implement Logo in a cooperative learning environment because of a personal belief in children taking responsibility for their own learning and the potential of peer learning and dialogue in children’s learning. The method of cooperative learning used was to a large extent influenced by the work of David and Roger Johnston based at The University of Minesota.

The method of evaluation will take the form of a qualitative analysis. The number of children available would not have provided a sample large enough to undertake any rigorous statistical analysis. It was initially planned to incorporate larger numbers of children into the study for statistical purposes. This would have entailed setting up contrived groupings and false learning situations, which would have been in essence equally invalid. In order to provide rigour to this qualitative analysis, an effort will be made where possible to triangulate the data gathered. Triangulation is where data is gathered about an event from more than one source. Hence data was gathered from the following sources: a daily diary of the lessons as they occurred, videotapes of the lessons, comments from the children, observations from their class teacher, snippets of the children's work, a pre-test and post-test on angle and shape and a Logo test at the end of the study.

2 Cooperative Learning and the Logo Programming Environment

The purpose of this chapter is to examine the literature in relation to cooperative learning in general and assess its strength and weakness. The potential of Logo as a learning environment in which to enhance understandings of Mathematics will also be investigated. Finally research, describing children learning Logo in cooperative groups, will be evaluated to establish potential benefits.

2.1 Cooperative Learning

2.1.1 Background

When the educational potentials of computers were initially proposed much of the focus was on the ability of the computer to individualise learning. Each individual learner could be guided through various courses at their particular level and at a pace best suited to each particular individual. While this reasoning appears rational to most discerning observers, there are and have been problems with this approach to utilising computers in education in general. Schools do not have the resources to provide a computer for each individual. While the cost of the personal computers continue to fall, it is still an impossible goal for most schools to provide a single machine for each individual. This is a goal which may not in any event be necessary. Coupled with this is the fact that the cost of producing software that adapts to learners' progress is prohibitive. These factors have led some researchers to investigate the potential of working in groups with one machine per group. Researchers see this as a means to efficiently accommodate large groups of children with limited numbers of computers (Rysavy and Sales 1991; Seymour WWW1). In a Meta-analysis of research of cooperative learning in relation to computer based instruction Rysavy & Sales (1991) concluded that many positive results can be derived from cooperation at the computer such as cognitive benefits (Bargh & Schul 1980; Slavin 1984, 1990), increasing positive attitudes (Johnson and Johnson 1978; Brush 1978), enhancing esteem (Slavin 1990).

Research has also shown that working individually on computers especially for prolonged periods can lead to increases in boredom, anxiety and hostility (Lepper 1985). However grouping can negate the problem of feelings of isolation, which occur while working individually for extended time spans (Dalton, Hannafin & Hooper 1989). Brush (1997) in a study based on using an Integrated Learning System found that issues of isolation and boredom were negated by working in cooperative pairs on an ILS. On a similar vein research has shown that separation from peers is undesirable and less effective than small-group work. (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981: Moskowitz, Malvin, Schaefer, & Schaps, 1983; Peterson & Janicki, 1979,Slavin, 1980)

2.1.2 What is Cooperative Learning

Cooperative learning is not easily defined in a concise and formal manner. Different authorities differ on what actually constitutes cooperative learning. Generally cooperative learning encompasses more formal structures than the idea of children working together in groups. While no strict definition exists, an attempt will be made to detail the most important characteristics of cooperative learning common across the literature on cooperative learning.

Cooperative learning is a teaching strategy that encourages student success by alleviating overt competition and substituting group encouragement.

Cooperation involves people working together to achieve common goals. Davidson [WWW2] distinguishes cooperative learning from traditional groupwork in that most models conform to the following principles:

- Children work and learn together in small (2-5 member) groups.
- Their task is carefully designed to be suitable for groupwork.
- There is positive interdependence - cooperation is necessary for children to succeed.
- Children are individually accountable for learning and participation.
- Attention and class times are given to interpersonal/cooperative skill building.
- The role of the teacher changes from being the "sage on the stage" to the "guide on the side"

It may be helpful to view groupwork as a general term, which covers any aspect of interaction between children working together. Cooperative learning is a more specific term that applies to a particular type of Groupwork. While benefits that apply to Groupwork in general also apply to Cooperative learning the reverse can not be said to be true.

2.1.3 Cooperative Methods

There are a number of studies cited in literature that have investigated the potential or otherwise of cooperative learning. The focus has been on different aspects such as the significance of different grouping structures on the learning outcomes or what components or elements of cooperative are critical in the learning process. While different models differ in the specifics of structure there is a general consensus in terms of certain key aspects which will now be considered.

2.1.3.1 Group Composition

Considerable research into cooperative learning has focussed on the effects of group composition to the outcomes of cooperative learning situations. Some studies have compared heterogeneous and homogeneous type grouping to investigate if more favourable outcomes result from one over the other. According to (Hooper & Hannafin, 1991) cooperative interaction has a more significant effect on achievement in heterogeneous as opposed to homogeneous grouping for both high and low ability children. This reaffirms an earlier claim that learning effects were consistent across ability levels, suggesting both high and low ability children profited from cooperative learning methods (Dalton, Hannafin & Hooper 1989). Yueh & Alessi (1988), however, found that likely group ability composition is less influential than reward structures in successful cooperative learning situations.

2.1.3.2 Key Components of Cooperation

A variety of cooperative learning models have been proposed in a variety of instructional situations. Slavin (1985) points out that while the implementation may vary the essential elements of cooperative learning are embodied in the well-defined goals, controlled size and dynamics of learning groups, a focus on heightening student engagement during cooperative activities.(Slavin 1984)

According to Yueh & Alessi (1988) rewards fostering both individual accountability and group cooperation are supported by what social psychologists refer to as distributive justice. Thus they state that group reward is crucial to provide a group goal motivating everyone to work well together and *individual accountability* is needed to create a feeling of fairness among group members.

This is backed up by other research that claims successful groupwork with computers depends on a fine balance between pupil interdependence and pupil autonomy (Hoyles, Healy, Pozzi 1994).

Brush (1997) states that the key elements of cooperative learning outlined by the leaders in cooperative learning research field include the following:

Positive Interdependence.

Each student has a key role and a task requires the actions of each member to be achieved.

Individual Accountability

Each individual within a group must be accountable for mastery of the instruction.

Group Rewards

The accomplishments of the group should be rewarded to provide positive incentives for the group to interact constructively.

Group Training

Children must be taught the social skills needed for collaboration and must be motivated to use them.

2.1.4 Effects of Cooperative Learning on Achievement

There appears to be positive aspects of cooperative learning on achievement which is backed up by studies cited in literature. In a Meta-analysis of 185 studies comparing cooperative learning to competitive learning 66% were found in favour of cooperative learning (Johnson & Johnson, 1989). Similarly a review completed by Slavin (1984) found that 63% of cooperative learning studies showed increases in academic achievement. Slavin (1984, 1990) highlights cooperative task structures and cooperative reward structures as the two determining factors in the success of cooperative learning. Not all research concurs with this view. Okebukola (1985) included individual accountability and group goals but found no significant increase in achievement. Similarly Seymour (1994) in a study based on Slavin's cooperative task and reward structures found no significant difference in achievement or satisfaction. Research by Rich, Amir, and Slavin (1986), incorporating individual accountability and group goals showed an actual negative effect on achievement.

More recently Brush (1997) found a significant and positive overall correlation between cooperative interaction and achievement. Brush suggests reasons for improvement: children working in pairs are able to assist each other creating peer support structures and expanding perspectives within the group, pairs tended to stay on task while individuals were more likely to be distracted or to stop working altogether, teachers were able to spend more time with and provide a higher quality of assistance to children working in cooperative groups than to children working individually.

2.1.5 Effects other than achievement of Cooperative Learning Structures

Cooperative learning models have shown that effects other than academic achievement. Some of these include positive attitudes towards schooling (Johnson and Johnson, 1978), more positive attitudes towards content and delivery system (Brush 1997), improving group socialisation and cohesiveness (Slavin, 1990), lessened prejudicial attitudes (Johnson and Johnson, 1978; Slavin, 1990), encouraging risk taking (Johnson and Johnson, 1975) and enhancing self-esteem, (Slavin, 1990). While typically there is a positive correlation between attitudes and perception of success, Dalton, Hannafin & Hooper (1989) found this not to be the case with cooperative groups. Hence the social dynamics of cooperative groups may negate the affective impact associated with academic success.

Brush (1997) suggests that teachers for the cooperative classes had an easier time getting around to all the children that needed help hence improving the quality of the learning situation.

2.1.6 Computer Based Cooperative Learning

In the majority of schools the number of children greatly exceeds the number of computers, yet as mentioned earlier in this review individualistic education has dominated the use of computers. However Mehan (1985) suggests that there is a natural tendency irrespective of adult supervision to cooperate at the computer. Research directly relating cooperative learning with computers seems to be limited. Studies have been undertaken which involve children working together in groups at the computer but very often without some of the principles which distinguish cooperative learning from groupwork in general. However these can prove very useful in highlighting some of the pitfalls or nuances that apply in any situations in which children interact in a learning environment.

Webb (1984) evaluated group effectiveness in the teaching of computer programming to a sample of 35 junior high school children ranging in age from 11 to 14 concluded that learning computer programming can be accomplished successfully in group settings. This is backed up by a study by Dalton, Hannafin, and Hooper (1989), in which the performance of learners who worked cooperatively significantly out performed those who worked individually on a computer based sex education lesson. Similarly Brush (1997) found that children using an Integrated Learning System (ILS) for mathematics instruction performed better on standardised tests and were more positive toward math and the computer math activities when they worked in cooperative groups than when they worked on the same activities individually.

Hoyles, Healy, and Pozzi (1994) in a paper presenting the main findings of a study carried out as part of the ERSC project Groupwork with Computers conclude that successful groupwork with computers stems from a fine balance between pupil interdependence and pupil autonomy. A balance, which they say, can be affected by the social norms in the group, the individual personalities of the pupils, the task and the software.

2.2 What is Logo?

Logo is a computer programming language through which young children can explore concepts and developed ideas through graphics. It was founded in the principle of a "low floor, high ceiling". This means that it is a language that is easy to get started in yet is powerful and extensive.

Initial contact involves learning basic commands or primitives to make an icon to move on screen or a robotic machine to move in pre-specified directions on a floor. Initially Logo was used to control simple robots that looked like a turtle. It later migrated to the computer screen as graphics terminals became available.

The basic movements include Forward, Back, Left, Right, Pen up, and Pen down.

Logo is seen by many as more than a just programming language. Logo is seen as a philosophy of education, which believes in the importance of children being the most active agent in the learning process. (Logo Ar Scoil; Harvey 1982)

2.2.1 Logo-Historical Perspective

Logo was originally developed by Daniel Bobrow and Wallace Feurzeig at Bolt, Beranek and Newman, Inc. with a team that included Seymour Papert at the Massachusetts Institute of Technology in 1967. Logo was inspired by the artificial intelligence language, LISP. Layman and Hall (1989) summarise its conception:

> *(Logo) was designed as part of an experiment to test the idea that children can learn through programming. The first research project was closely linked to mathematics and sought to test the idea that programming might be a useful environment in which to talk about problem-solving… The emphasis of the Logo project was oriented towards young children of about ten or eleven with the expectation that programming in Logo would help them develop mathematical, logical and problem solving skills. To this end the language was designed to appear as natural as possible to the child, to be friendly, easy to use and jargon-free and to provide a motivating environment.*

In 1980 Seymour Papert published "Mindstorms" subtitled *All about LOGO - how it was invented and how it works.*

The book presented an exciting vision of education for the future, involving a meeting of computers and children and leading to a mastery of a powerful technology and powerful ideas (Michayluk 1986). Mindstorms fuelled a Logo boom in the early eighties most spectacularly in the USA. By early 1990's there was a decline in its usage in the USA where it was seen as outdated. However this perception was not confirmed world-wide particularly in places such as Latin America, Japan, England, Spain and Slovakia. More recently there has been renewed awareness and enthusiasm. Sparked by Microworlds developed by Logo Computer Systems, Inc., a more modern version of Logo which supported many extra features such as the creation of multimedia enhanced programs and multi-tasking. (WWW3)

2.2.2 Important Characteristics of the Logo Programming Language

Logo is a dialect of LISP. It eliminates the need for interminable nested parenthesis and other notational nuisances found in other LISPS, giving kids a simple notation consisting of prefix function invocations and infix arithmetic, and adds to LISP a graphical "turtle" and the accompanying finite differential geometry (WWW4). Other important characteristics of the language which enhance its usefulness in an educational setting will now be discussed.

2.2.2.1 Logo is Procedural

Logo is not written as one huge program. Problems are divided into smaller problems and a separate procedure is written for each piece (Harvey 1982). Built-in procedures are provided for such tasks as manipulation numbers, drawing on screen and printing text. Logo has about a hundred procedures of which only twenty have anything to do with “turtle geometry”(Howe et al 1987)

The fact that Logo is procedural has very important implications. It allows the programmer to break the program down into smaller more manageable units. This means that each procedure can be checked to make sure it is working correctly before embedding it into the overall procedure. (Moller 1984)

2.2.2.2 Logo is extensible

Rather than being restricted to built-in procedures, an extensible language allows users to create their own procedures that are syntactically indistinguishable from the built-in or primitive procedures. This extensibility is valuable in an education setting as it allows teachers the possibility of providing their own language extensions and teaching them as if they were primitives. This means that certain procedures, that would be beyond the scope of the children in terms of the levels of Logo expertise that the children could be expected to have reached, can be incorporated into projects. The student need not understand the coding of the procedure but simply requires knowledge of the name of the primitive and any additional input variables.

2.2.2.3 Logo is interactive and interpreted

There is no edit-compile-link-run cycle with its inherent delay in providing results. Logo performs housekeeping operations such as memory management transparently. (WWW4) A logo-interpreter does not create a permanent machine-language translation version of your program. Each Logo statement is translated and executed every time the statement is supposed to be executed. The interpreter does not produce a machine-language representation of your program but simply carries out the machine language steps itself. (Harvey 1982)

Harvey (1982) also points out that interpreted languages can be interactive and that the most important form of interaction involves program development. In relation to interactive debugging he states that even though a compiler might make a program run faster, an interpreter is likely to make the entire debugging process faster. This flexibility is particularly valuable in an educational setting as it's much easier for the children to find and fix mistakes

2.2.2.4 Logo is Recursive

A language is recursive if a procedure can be a subprocedure of itself.

The importance of recursion in computing is that it allows large problems to be stated in terms of simpler versions of themselves, which can lead to very concise programming. It also encourages the user to identify similarities between tasks. (Moller 1984)

2.2.2.5 Logo has List Processing

In addition to Turtle Geometry, Logo can also be used for data processing. In Logo uses a grouping mechanism called a list to group several pieces of information into one large unit as opposed to arrays which form the basis for grouping in many of the main programming languages.

While arrays restrict in the sense that they must have strict size and they must be uniform, a Logo list can be any Logo Object, number, word, or even another list.

While not as efficient in terms of speed of access as an array, logo lists are not so difficult to use (Harvey 1982). In terms of the power and flexibility of the language Logo would not be particularly adaptable or useful were it not for the list-handling procedures (Howe et al 1987).

2.2.2.6 Logo is not typed

In many languages, e.g. C and Pascal, the type of a variable must be explicitly given in a declaration. In Logo, variables are not typed. Typed variables can be awkward to use. The fact that Logo variables are not typed makes for much easier entry into the language initially. This has important implications for education especially for younger age groups.

This aspect of Logo has been open to criticism. Detractors say it encourages bad programming habits. Harvey (1982) points out however that

> *In rejecting typing, the designers of Logo did not mean to encourage the haphazard use of variables for different purposes; rather they built a procedural language in which variables are attached to a particular procedure, rather than being available to the entire program. This encourages the same discipline in a different way.*

2.2.3 Logo and Educational Philosophy

The educational thinking behind Logo is very much steeped in Piaget's Theory of Constructivism.

> *I take from Jean Piaget a Model of children as builders of their own intellectual structures. Children seem to be innately gifted learners, acquiring long before they go to school a vast quantity of knowledge by a process I call "Piagetian learning," or "learning without being taught". (Papert 1980)*

Papert studied with Piaget in Geneva from 1958 to 1963 (WWW4). In his notes section of Mindstorms p217 Papert states that Piaget is at the "center of concerns" for the book. Jones (1994, WWW4) states that “without diminishing the unique contribution of Papert's original thinking and application, …Piaget's ideas are such an integral part of Papert, that virtually everything about Logo has something to do with Piaget”.

More recently (Tuovinen, Hill, Kay, 1991) argued that of the two dominant cognitive psychological paradigms that the information processing model is more useful than the developmental model as a framework for considering the application of Logo as it recognises the social context in which learning occurs. Papert himself disagreed with Piaget on this point. In Mindstorms (1980) he states that he is at variance with Piaget on the role attributed to the "surrounding cultures".

2.2.4 What do Children Learn Through Logo?

2.2.4.1 Logo, Cognitive Development and Problem Solving

The National Council of Teachers of Mathematics (1989) states that problem solving should be the central focus of the mathematics curriculum. They go on to say that the curriculum must give children opportunities to solve problems that require them to work cooperatively, to use technology, to address relevant and interesting mathematical ideas, and to experience the power and usefulness of mathematics.

Papert (1980) espoused that children who experience Logo learn more than a computer language: they learn powerful ideas, skills and heuristics that can be transferred to a variety of situations.

Harvey (1982) provides a very useful summary of Papert's reasoning as follows:

> *A child learns partly by picking up specific facts and skills. Much of existing formal education is about facts and skills: reading, spelling, and the multiplication table. But a more profound kind of learning is the skill of learning itself, which involves the building of mental models of the world, of oneself, and of the learning process. These models are developed through intellectual exploration. That exploration may begin in a weak, haphazard way, but a good learner develops strategies for purposeful exploration. The more one learns, the better the model of learning, and the more able one becomes as a learner… The point about using computers in education is not that everyone must know something about computers, but simply that for many*

people, computer programming can be the arena for this general process of learning to learn. Because the computer is such a general-purpose machine, it can appeal to many different interests. It can draw pictures, make music, write stories, or move robots.

Blosser (1985) points out that thinking skills regarded as "higher order"(critical thinking, problem solving strategies, evaluation and analysis and creativity) will be basic skills needed for the 21st Century. Logo constitutes a valuable learning environment for promoting higher order thinking skills. According to Yelland (1995) children engaged in Logo projects are using a variety of problem solving skills, such as planning, monitoring progress, responding to feedback and changing ineffective strategies.

Papert made a quite controversial claim about the potential of Logo to affect children's cognitive abilities in Mindstorms(1980):

Stated most simply, my conjecture is that the computer can concretize (and personalize) the formal. Seen in this light, it is not just another powerful educational tool. It is unique in providing us with the means us with the means for addressing what Piaget and many others see as the obstacle which is overcome in the passage from child to adult thinking. I believe that it can allow us to shift the boundary seperating concrete and formal.

However not all research concurs with the claims made in favour of Logo's potential as a learning tool. Maddux (1989) concludes from research and experience that it is unlikely that Logo as presently organised can result in a lowering of the boundary between concrete and formal operational thinking.

Similarly Pea, Kurland, and Hawkins (1987) found that children who spent a year programming using Logo did not differ in various developmental comparisons of the effectiveness of their plans and their processes of planning from same-age controls who had not learned to program.

Education Authorities are very much encouraging teachers to teach problem solving as a central part of the mathematics curriculum. This is occurring without evidence from research that teachers in fact have these skills in the first place. In study of student teachers learning Logo, Ahmed & Niess (1991) found that the student teachers were not involved in “powerful” problem strategies as they were learning computer programming. They concluded that if student teachers were not learning problem solving skills in their preparation courses how can they be expected to teach these skills in classrooms?

2.2.4.2 Logo and Mathematics

Hoyles, Sutherland and Evans (1986) concluded, after a year long investigation into using Logo in the Mathematics classroom, that Logo within the mathematics classroom provided a rich context for the use of mathematical ideas and processes.

Claims have been made that Logo can benefit the many areas of mathematics curriculum. Logo ar Scoil (1992), a guide and scheme of work produced by a group of teachers in East Cork claims that Logo can provide enrichment in the areas of Shape, Measurement, Space and Direction. Benefits are specifically envisaged in:

> *the teaching of angle and the law of 360 degrees, the understanding of the relationship between the shapes in the polygon family and for number crunching.*

The use of variables is said to lead to an understanding of elementary algebra and the SETPOS, SETX and SETY primitives can be used to investigate Cartesian Plane and Co-ordinate Geometry. However care must be taken in readily assuming that Logo will provide benefits across the board in these areas. O' Shea & Self (1983) state:

> *To return to school mathematics, it is also clear that some of it does not marry well with Logo. Much schoolwork involves the recall of particular algorithms, e.g. long division, rather than creative problem solving. Many of these algorithms depend on physical layout on paper: writing a program that will do the layout is very difficult and not relevant to an improved understanding of the algorithm.*

On a similar theme Howe et al (1987) draw attention to the following:

> *The problem is that the choice of representation for a maths topic sets limits on what a user can do at this level of competence, and these limits may be too narrow to allow him to draw adequate mathematical parallels.*

2.2.4.3 Logo and Geometry

One curricular area to which Logo would readily lend itself to on first glance is that of geometry. A report (O' Martin, Hickey & Murchan 1992) on the Second International Assessment of Educational Progress which involved 20 countries world-wide, highlighted geometry as an area of concern for Irish schoolchildren,

> *Though Irish students performed approximately at the overall mean in Geometry, they fared poorly in relation to most of their geographical and cultural neighbours.*

One particular geometrical concept that pervades much of what children do while using Logo is that of angle. According to Ainley and Goldstein (1988)

> *Angle is probably the most difficult of the measures that children meet in school, since it is not immediately obvious what is being measured.*

They feel that Logo can provide a useful environment in which to deepen children's understanding of the formal representation of angle as encountered in school texts etc.

Turtle Graphics

The Logo commands that relate to aspects of geometry are often referred to as Turtle Geometry. Turtle Geometry is a set of commands for moving a pen around a drawing space. As mentioned earlier only twenty of Logo procedures relate to what is known as turtle geometry. However it is an integral part of Logo (Papert 1980). Using these commands the children can create a range of regular geometric shapes from basic shapes such as squares, rectangles and triangles to complex spiral and fractal patterns. The advantage of this form of representation is that children already have an intuitive understanding of moving and turning, gained from their own movements through space, so they can use this knowledge to help them plan and debug programs (Howe et al 1987). Papert (1980) referred to this syntonic learning. The Turtle is body syntonic, in that it is firmly related to the children's sense and knowledge about their own body's movement. This provides the child with a certain degree of independence in their learning because when they get into difficulties they can try to resolve them using hand/body actions or walking out the commands as needed.

It is worth noting that Logo may not necessarily lend itself to all aspects of geometry. According to Howe et al. (1987) "*Turtle geometry is not an adequate representational system for modelling irregularity*". Creating irregular shapes such as right-angled triangles requires knowledge of co-ordinate geometry and trigonometry. This knowledge is beyond what can be expected of a twelve-year-old primary school child. That is not to say that it could not be used effectively by a sixteen-year-old child in secondary school as a tool for investigating and learning about the aforementioned areas of the secondary school mathematics curriculum.

2.2.5 Conceptual Difficulties in Logo Learning

While Logo has a 'Low Floor' it has a 'high' if non-existent ceiling. It is important to consider whether there are any particular difficulties children might encounter while learning Logo and whether these are related to a child's level of cognitive development. These are very pertinent questions for teachers of Logo. While no definitive answers are likely general guidelines are necessary to avoid frustrations in student Logo learning situations.

Sparkes (1995) after conducting a 3 year analysis of Year 7 (12-13 year old) children, found pupils could write simple programs involving simple sequences and sub-procedures, however found it difficult to solve problems involving the use of IF… THEN… ELSE structures and the reading of inputs and recommends these be left until the secondary school. This has obvious implications for the extent to which Logo can be used at Primary Level.

Cope, Smith & Simmons (1992), in a study of children aged between 10 and 11 who were given a 12-hour course in Logo, found that in spite of deliberate attempts by the teacher to make the children aware that the external angle is the one through which the turtle moves, that almost all children focussed on the internal angle given in a test at the end of the course. This is the explanation they account for the so called "triangle bug" experienced by many Logo novices who attempt to construct a triangle using 60 degrees rather than 120 degree. They conclude that instead of a way of increasing mathematical knowledge and problem solving that the reality may be that children spend too much time in low-level trial and error manipulation of a domain they do not fully understand.

2.2.6 The role of the teacher in the teaching of Logo

As mentioned earlier Logo is very much a reflection of many of the Piagetian ideals of Constructivism and Discovery Learning. However there has been much disagreement over the role of the teacher in the learning of Logo.

This was highlighted by Hawkins(1987)who, in a two year research program conducted at the Bank Street College's Center for Children and Technology, found that the tension between free exploration of Logo and structured learning sequences was never fully resolved. Hawkins noticed that there were different solutions at different times and for different circumstances. Other research has come out even more strongly in favour of more structured learning methods.

> *Discovery Learning which has been advocated by Papert as the Logo teaching method of choice appears to be unsuitable for promoting true Logo mastery…Efficient Logo teaching requires more highly structured methods than those usually employed in discovery learning. (Maddux 1989)*

According to Pea, Kurland, and Hawkins (1987)

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

Yelland (1995) sees the teacher's role as crucial. Although the teacher does not always initiate Logo activity, he or she supports and enhances learning. Good teachers do so by letting the children develop their own strategic questions and providing necessary information. Relevant and thought provoking questions can often stimulate learning far more effectively than the recitation of facts.

Hoyles and Sutherland (1987) produced 7 categories of skill which teachers need to develop in a Logo environment

1. *Organising the class*
2. *Encouraging Links between Logo and the outside world.*
3. *Provoking reflection on the process and structure of Logo problems and the transference of the reflection to problems in the outside world.*
4. *Opening up new ideas.*
5. *Presenting obstacles to confront perceived pupil misconceptions i.e. giving children tasks which will help them overcome syntactical and other anomalies inherent in the language of Logo*
6. *Allowing own goals and individual ways of working.*
7. *Encouraging experimentation.*

Walsh (1994) in a Literature Review investigating research which has focussed on the role of the teacher in learning Logo concludes that *the role of the teacher is critical in promoting children' Logo programming skills and in developing their cognitive or metacognitive learning. Logo instruction that balances carefully planned teacher-mediated lessons with student problem solving and planned, independent Logo exploration should be provided.*

2.3 Logo and Cooperative Groupings

Research into learning Logo specifically in cooperative learning situations is limited. Webb (1984) in a week long workshop of thirty five children working in 3-person homogenous groups found that verbal interaction in the group influenced the basic learning of commands and syntax but did not seem to influence learning how to generate graphics programs. However the relationships between group process variables and computer programming in the study did seem to indicate that small group work might be a "*viable setting for learning computer programming*".

Hoyles, Healy and Pozzi (1994) reported the findings of a very comprehensive three-year investigation into the factors which influence the success of groupwork with computers. Two of the three mathematics tasks set for the purpose of the study involved groups of six children using Logo. They concluded that the extent to which children can avail of the benefits of groupwork with computers depended on two conditions.

- The pupils must be sufficiently mature to manage , the task requirements and the resources
- The group must be unimpeded by antagonism

They found that where these two conditions were met that the group settings were more likely to be successful.

Knupfer (1993) investigated the effects of student ability grouping on geometry learning transfer after a semester of instruction within the Logo environment. The subjects included two classes of sixth grade children. The children were placed into homogenous and heterogeneous pairs. Knupfer found that Logo exercises can help children learn particular geometry concepts. However it was unclear whether it was the thought process or the visual aspect of Logo that promoted the transfer of geometry skills. In relation to the groupwork aspect of the study Knupfer concludes strongly that

> *Computer exercises should not be restricted to either targeted groups of high achievers or low achievers, but should be available to all ability levels in a cooperative learning situation. Furthermore cooperative learning situations should involve heterogeneous grouping of children.*

2.4 Summary

Having reviewed the Literature it seems reasonable to hypothesise the Logo, presented in a cooperative learning environment could provide certain benefits to children in their learning of mathematics. Logo provides opportunities for problem solving which is an essential part of the mathematics curriculum. Logo can provide opportunities for enrichment in much of the mathematics curriculum. However care must be taken, as Logo does not provide this enrichment across the board in mathematics. Claims in relation to the benefits of Logo in relation to some topic areas are unproven and possibly unrealistic.

The topic of geometry in particular would seem to lend itself most readily to the use of Logo. Logo's Turtle Geometry would appear to be a natural environment in which children can explore many of the essential elements of geometry such as length, angle, shape, rotation, symmetry etc. However care would seem to be needed in the handling of the concept of angle to avoid confusion between the internal angle and the external angle (which is also the angle through which the turtle turns).

The role of the teacher in Logo seems to be one lacking in consensus. However more recent research tends to recognise the importance of some form of intervention on the teacher's part (e.g. Maddux (1989), Pea, Kurland, and Hawkins (1987), Walsh (1994)).

In presenting Logo in a cooperative learning environment certain elements need be present to ensure proper cooperation occurs. Because children are working together in a group around one computer does not mean that they engaged in cooperatively. Often groups of children sitting working at a computer are involved in the "now its my turn" scenario where one person is actually interacting with a package and the others are waiting for their individual turn. The key elements of cooperation include positive interdependence, individual accountability, group rewards and group training. These elements are summed up fittingly in the words of Alexandre Dumas

> *All for one and one for all.*

3 Methodology and Action Research Approach

3.1 Purpose of Study

This study sets out to establish the potential benefits of Logo in a co-operative group setting for children that are mathematically weaker than the average. The study will focus on the area of Geometry and more particularly on angles and their significance in relation to the properties of regular polygons.

3.2 Rationale of Study

There have been limited studies on the use of Logo in a co-operative group learning situation. This is especially true in relation to a small group setting such as the remedial set-up as practised in Ireland, where children with difficulties particularly with English and less often with Mathematics, are withdrawn in small groups for special attention.

As cited in the literature review a significant majority of the research carried out on co-operative group learning situations recognises that co-operative learning promotes higher learning outcomes than individualised methods (Johnson & Johnson, 1989; Slavin 1984).

Logo is a language that has a chequered history. Many highly enthusiastic claims have been made for Logo's potential in education and particularly in the curricular area of mathematics and the area of problem solving in particular (e.g. Papert 1980; Yelland 1995). While these claims have been over exaggerated in some instances, the majority of research would seem to suggest that there is significant evidence to support the use of Logo as valuable tool in enhancing student cognition particularly in the area of mathematics and problem solving in particular.

Research into the use of Logo in a cooperative setting is limited. However it is likely that the advantages of learning Logo will transfer to the cooperative learning situations and vice versa perhaps enhancing the whole learning experience.

3.3 Aim / Objective of the Programme.

The aim of the programme is to encourage group and team cooperation in a Logo learning environment. It is hoped that the learning experience will lead to increased understanding of geometry with particular reference to angle and regular polygons.

3.4 Software Description

The software that will be used for the programme is the MSWLogo 6.2f version of Logo which is a Public Domain Logo which can be obtained free from Softronix (WWW5). George Mills at Softronix designed the GUI while the core is the UCBLogo core developed by Brian Harvey at Berkley.

3.4.1 Standard features:

- *Supports TCP/IP WinSock Networking.*
- *Supports Win16, Win32 and Win32s.*
- *Supports Text in all available fonts and sizes.*

- *Supports 1024 independent Turtles.*
- *Supports Bitmapped Turtles.*
- *Supports Cut, Paste and stretching bitmaps.*
- *Supports Clipboard Text and Bitmaps.*
- *Supports MIDI devices.*
- *Supports Direct I/O for Controlling External hardware.*
- *Supports Serial and Parallel Port communications.*
- *Supports Zooming.*
- *Supports Tail recursion (optimizes most recursive functions).*
- *Supports User error handling.*
- *Supports "Standard" Logo parsing.*
- *Supports Floodfill.*
- *Supports Save and restore images in .BMP format files.*
- *Supports 1, 4, 8, 16, 24 bits per pixels colors.*
- *Supports standard Windows Hypertext Help.*
- *Supports standard Windows Printing.*

- *Supports separate library and work area.*
- *Supports construction of Windows Dialog Boxes.*
- *Supports Event Driven programming (Mouse, KeyBoard, Timer).*
- *Supports MultiMedia Devices (.WAV sound files, CD-ROM control etc.)*
- *Supports Event Timers allowing multiprocessing.*
- *Supports 3D Perspective drawing.*
- *Supports Animated GIF generation.*

  (WWW5)

MSWLogo was chosen deliberately as the Logo package of choice, for the reason that it is freely available (in terms of cost). Too often it is assumed that worthwhile educational software must be bright, colourful and expensive. From experience this is often far from the case. Plenty of good shareware and freeware titles are available to teachers which can be inexpensive and just as educationally sound as some of the more expensive, professionally produced software titles. While not by any means dismissing these titles, teachers should be aware that they are not the only option. The shareware and freeware titles are often more of an option for cash strapped primary schools.

MSWLogo, while not as feature laden as some of the more expensive versions of Logo, still provides more than adequate functionality to explore the concepts of

Geometry, and angle and regular shapes in particular as required for this particular enquiry.

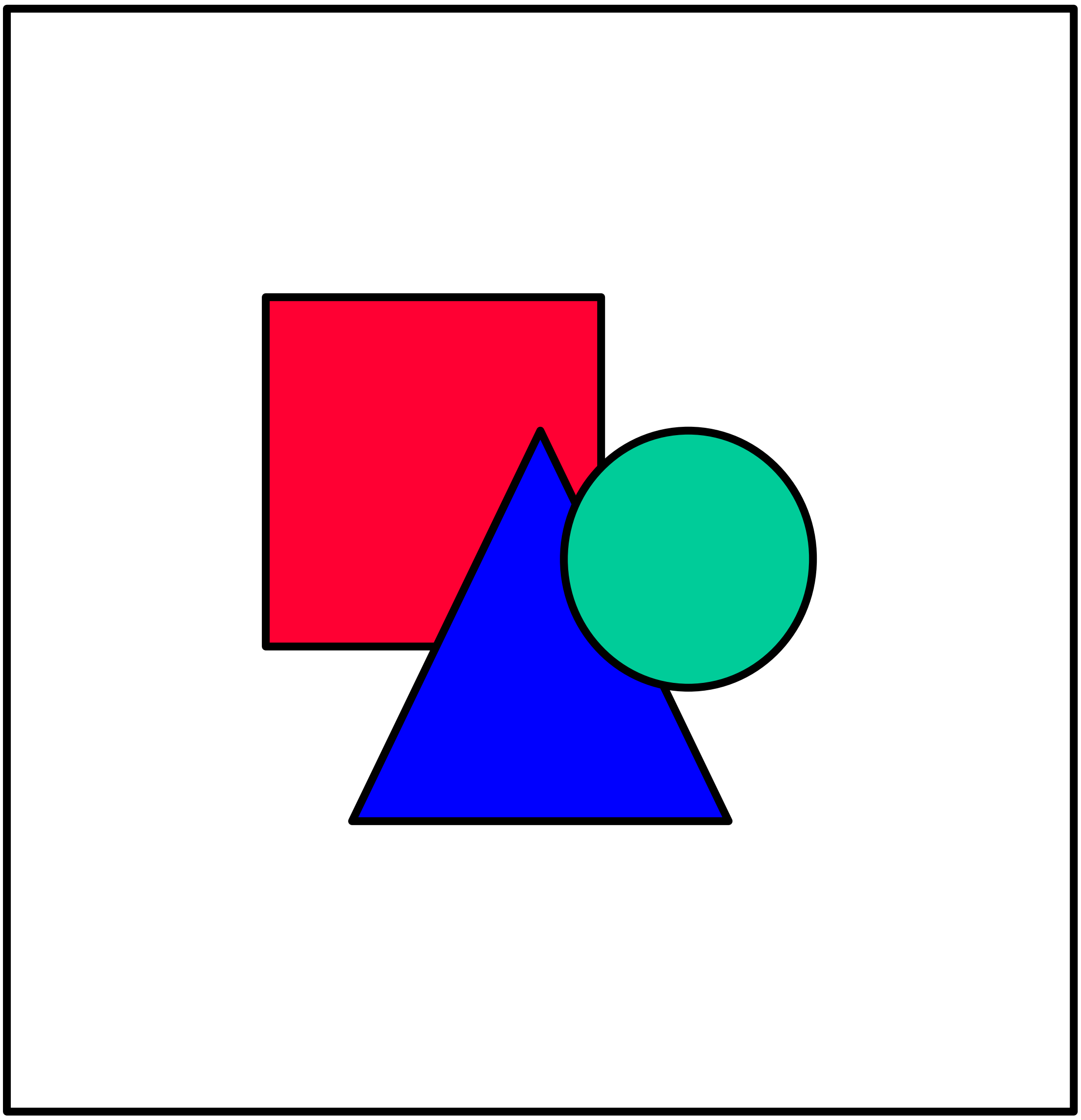

Figure 1

Figure 1 shows the interface to the MSWLogo software. The MSWLogo Screen is used as the main workspace in which any work is displayed. The following commands are available from the MSWLogo Screen.

File Menu

The File menu includes commands that enable you to operate on logo procedure files. Note that, as a side effect, any selection in this menu that has a directory in its dialog box will effectively change to that directory as the current working directory

- **File New Command**: This will clear all procedures currently loaded in memory. It's like starting with a "New" session.

- **File Load Command:** This allows you to load in procedures from disk into memory so that they can be executed or edited.

- **File Save As Command:** This is the same as File Save Command, but prompts your for a new file name.

- **File Edit Command:** This is how you edit procedures that have already been loaded (or developed) in memory. You will be prompted with all existing procedures (currently loaded within memory) and you can also enter a new one.

- **File Erase Command:** This is how you erase procedures that have already been loaded (or developed) in memory. You will be prompted with all existing procedures (currently loaded within memory).

File Exit Command: This is how you exit MSWLogo.

Editor

When you exit the editor, Logo loads the revised definitions and modifies the workspace accordingly. Multiple Edit sessions are supported. Be careful of having multiple edits going that includes the same definition. The last Editor Exited (and saved) is what takes precedence. Also if you delete procedures, property lists or names while in the Editor they will be erased from the environment you deleted them from at the time of exiting (and saving) the edit session

The format of the file you save things in, is known as, a Microsoft Windows Bitmap (.BMP). You can interchange these files with other applications such as Paint, Paint Shop Pro etc.

Note: that these files can be BIG and can take a while to read or write.

- **Bitmap Active Area Command:** This allows you to select the work area to be printed or saved. The primary purpose of this option is performance and space. You no longer need to wait for the software to build a full image. It takes less time and less memory to print and disk space to save a partial image. As a side effect you can adjust where your image ends up on the page by selecting different extents. You may at anytime click on reset to put the extents back to the full image. MSWLogo will remember what you set them to even after you exit.

- **Bitmap Print Setup Command:** This allows you to setup your printer before you print.

- **Bitmap Print Command**: This allows you to print your work on the printer.

Set Menu

The Set menu allows you to SET some of the characteristics of how LOGO behaves when drawing. The following are the main options available on this menu:

- **Set PenSize Command:** This command allows you to select the pen size in which the turtle will draw. You can also select the pen size with the Logo command SETPENSIZE and obtain it with the Logo command PENSIZE.

- **Set PenColor Command:** This command allows you to select the pen color. You can also select the pen color with the Logo command SETPENCOLOR and obtain it with the Logo command PENCOLOR.

Zoom Menu

The Zoom menu allows you set the ZOOM factor.

- **Zoom In Command:** This command allows you to double the zoom factor. You can also select the zoom factor with the Logo command ZOOM.

- **Zoom Out Command :** This command allows you to half the zoom factor. You can also select the zoom factor with the Logo command ZOOM.

- **Zoom Normal Command:** This command allows you to reset the zoom factor to 1.0. You can also select the zoom factor with the Logo command ZOOM.

The following are miscellaneous aspects of the MSWLogo programme which are important in terms of being proficient in it's use and that will most likely arise during the course of its use for a study such as the one outlined in this enquiry.

Edit Errors

If an error occurs when Logo "loads" in your edit you will be prompted to re-enter the Editor. This situation commonly occurs when a continuation "~" is missing within a list or missing a matching "]". When the editor reloads you will be placed at the start of the definition that caused the error. When this occurs make sure to check the commander window for a hint of what the problem was when loading.

Editing with Clipboard

Logo's Editor and many controls support the Clipboard. The Clipboard is where most Windows application store data during cut and paste operations. This means that when you cut text from an application, such as Notepad, it can be pasted into Logo's Editor (the reverse is also true). This means you can copy examples in this document directly to the editor.

The Input Box also supports the Clipboard. Only one line of text is supported between the Input Box and the Clipboard. Note that the Input Box does not have an Edit Menu like the Editor. You must use the "Short-Cut" keys for the desired actions (Cut CTRL-X, Copy CTRL-C, Paste CTRL-V).

The Output/Command-Recall List Box also supports the Clipboard. This means you can turn code you entered in the commander into procedure by copying the Commander Output to the clipboard and paste it into the editor. Or take text output you generated and paste it into another application.

Context Sensitive Help

Logo's Editor, Input Box and Output/Command-Recall List Box all support context sensitive Help. If you select a keyword (such as FORWARD) in these places (double-click works best in the editor) you can ask Logo to look up the keyword without going through the Help Menu followed by a Search and so on. You simply ask by clicking the right button on the mouse (or by hitting the F1 key), abbreviations are also supported. See also Context Sensitive Help to bring information back from the help system (like example code) for you to work with.

Hardware

The MSWLogo software can run on any machine with a minimum specification of a 286 with a minimum of 2 MB of Ram running Windows 3.0 in Standard Mode. This is another reason for choosing to look at the potential of MSWLogo. Many schools have outdated machines that cannot run the more modern, multimedia based educational software packages. The Computers that will be used for the programme vary from IBM 386 running at 20 MHz. with 4 MB of RAM to Gateway 2000 PII running at 233 MHz with 32 MB of RAM. The fact that MSWLogo can be used across each of these machines is of great importance to schools as it has the potential to provide a use for machines that are being forced into obsolescence by the newer multimedia software packages.

3.5 Logo and the Mathematics Curriculum

Many claims have been made in relation to benefits of using Logo in relation to improving pupils understanding of many aspects of mathematics. These studies have been usually carried out over a long period of time ranging from a term to a couple of years. Given the time restrictions of this research it would be impossible to expect any serious improvements in any mathematics area in general. For example Pea (1987) concluding after research into the cognitive benefits of Logo that lasted a year admitted that it might not have been of “sufficient duration”. Hence for this study it was decided to try and narrow the focus. Instead of investigating the broader issues of cognitive benefits or problem solving strategies, the focus will be on assessing the potential benefits of using Logo to enhance the learning experience of sixth class pupils understanding of Geometry and more particularly angles and regular polygons. The pupils were given a pre-test designed to assess their understanding of angle and shape before the treatment. They were then be given a very similar post-test after the treatment in an attempt to establish if there has been any significant improvement in the understanding of the pupils in relation to shape and angle. The Logo learning experience was also monitored for any evidence of improvement in understanding of the above.

3.6 Cooperative Learning Environment

The programme also investigates the potential of working in cooperative pairs while learning Logo programming. An effort was made to incorporate the essential key elements of cooperative learning as highlighted by Brush (1997) into the pupils learning experience. The only aspect that was not be incorporated is that of Group Training. It was felt that the pupils already have sufficient skills in working together as much of their learning is structured around working in groups. After consultation with their class teacher it was decided that the pupils already possessed sufficient skills in working together in groups, so as not to require extra training in this area. The following elements will be taken on board to create proper structures in which the pupils would be motivated to interact in a cooperative manner.

- *Positive Interdependence*- Efforts were made in this area to involve each member in the pairs and avoid a situation where an individual took over the learning situation and leading to the other partner possibly loosing interest and opting out.

- *Individual Accountability*- It was important that each individual realised that he or she would be individually tested on their learning so that the did not sit back and depend on their partner to do all the work.

- *Group Rewards* – While individual accountability is important to keep both pupils of the pair focussed, it was necessary to provide some group reward structures to ensure that there was cooperative interaction within the pair and not two individuals working separately in a group setting.

3.7 Action Research

The methodology that was be used in this investigation was based on the model known as Action Research. An understanding of what distinguishes action research from other research methods was derived from the action research literature (McNiff

1988; Lomax 1994; Laidlaw 1992; McNiff, Lomax and Whitehead 1996).
Briefly Action Research is "an intervention in practice to bring about improvement" (Lomax 1994). It does not involve control groups or artificially set up laboratory experiments but instead focuses on the practitioner making classroom enquiries in a real situation. It involves evaluating current practices that the practitioner may feel are ineffective and asking questions in relation to how to improve the situation. While this is or should be part of every practitioner's working routine, Action Research differs from this in that the type of enquiry is more formal and concerns issues relating to the fundamental practice of the practitioner. It is also put in the public domain and therefore open to serious challenge.

Action research is different to other research in certain aspects yet similar in other aspects. This is best summarised by McNiff, Lomax and Whitehead (1996)

> *Action research shares the following characteristics with other research:*
>
> - *It leads to knowledge*
> - *It provides evidence to support this knowledge*
> - *It makes explicit the process of enquiry through which knowledge emerges*
> - *It links new knowledge with existing knowledge*
>
> *Action research is different from other research because:*
>
> - *It requires action as an integral part of the research process itself*

- *It is focused by the researcher's professional values rather than methodological considerations*

- *It is necessarily insider research, in the sense practitioners researching their own professional actions.*

A misconception seems to have grown up around Action Research that equates it with solely qualitative research techniques. McNiff, Lomax and Whitehead (1996), however, state that Action researchers can employ both qualitative and quantitative research techniques. They make the point, though, that whichever technique is used, the proper guidelines developed for the technique must be followed, as Action research is "not an excuse to use an established research technique badly".

This Action Research enquiry followed a particular methodology of action planning outlined by McNiff, Lomax and Whitehead (1996). They suggests a set of key questions:

- *What is your research focus?*

- *Why have you chosen this issue as a focus?*

- *What kind of evidence can you produce to show what is happening?*

- *What can you do about what you find?*

- *What kind of evidence can you produce to show that what you are doing is having an impact?*

- *How can you evaluate that impact?*

- *How will you ensure that any judgements you might make are reasonably fair and accurate?*

- *What will you do then?*

These questions were used as a basis for an Action Planning strategy for the classroom enquiry. They were modified slightly to be more appropriate to this particular enquiry as suggested by the authors.

3.8 Action Research Planner

This plan was drawn up before the study took place and needs to be presented as was written to avoid confusion as to when they were written. As a plan which is future oriented it would be inappropriate to rewrite it in the past tense.

3.8.1 What is your research focus?

The focus is on improving my practice in relation to the way in which I teach mathematics to a sixth class group of weaker students. Two central issues arise from effort to improve my practice which stem from a realisation of my educational values. The first is the potential of Logo to enhance the understanding of angle and properties of regular polygons. The other concerns the environment in which this learning takes place or more specifically a cooperative learning environment. However considering the time –scale of this study it would be impossible to do justice to an investigation into two issues. Hence the concentration will be on the potential of Logo to enhance children’s understanding of angle and properties of regular polygons. However it must be mentioned that this learning took place in a cooperative learning environment. When appropriate any significant issues that arose from this environment will be mentioned in passing.

3.8.2 Why have you chosen this issue as a focus?

Two events occurred within a narrow time span to conspire to direct attention to using Logo in a cooperative learning environment. The first occurred when a colleague was specifically highlighting the benefits of cooperative groupwork and specifically stated that the computer could not be successfully used in this manner. This was the initial catalyst to investigate the possibility of using the computer in cooperative group learning settings.

The second event was less of an event than a personal realisation that much of the educational software being utilised by the children was of very limited value especially in terms of its scope and the length of time it can be used. This realisation was stimulated in part by colleagues continually asking for new software as the children had either finished the main challenges or had grown tired of using it. This in turn led to an investigation into more extensible software suitable for Primary School children. Logo with a “low floor, no ceiling” premise and the advantage of extensibility and no cost provided the ideal source for investigation.

Having formally conceptualised my educational values I realised that these values were not being lived out in practice. While the children often worked in groups, it was too readily assumed on my part that they were co-operating when in reality they were often working together ‘individually’. While I believe in the power of computers in general to play a significant part in the educational development of children, this role was not being fulfilled to my satisfaction. I felt that my personal knowledge of using computers had increased almost exponentially in the past two years. However the use of computers in my teaching practice needed to be extended beyond the more ‘adventure-game’ and ‘drill and practice’ software which was the most significant contribution to my use of computers with the children I teach.

3.8.3 What can you do about improving the situation?

A small-scale enquiry, involving six children that I withdraw from their mainstream classes for extra help in mathematics, will be instigated over a two-week period. There will be particular emphasis on providing activities that will enhance the cooperative experience and generate learning experiences that will hopefully lead to a better understanding of both Logo and certain mathematics concepts (angle and regular shape). Issues of teaching methodology and facilitation will be monitored continually and evaluated on a lesson by lesson basis. At the end of the first week these evaluations will be used to make improvements for the second week, where appropriate, thus feeding into a new Action Research Cycle. Hence I will be able to improve my facilitation of the learning through reflection on my own practice.

3.8.4 What kind of evidence can you produce to show that what you are doing is having an impact?

> *Data is not the same as evidence. You use data as evidence of particular interpretations and expectations of the action.*
>
> McNiff, Lomax and Whitehead (1996)

Hence during the Action Research Cycle records will be generated from direct observation and reviewing the video of each lesson which have monitored and evaluated the cycle. These records will be used to show the improvements that have taken place. This should lead to progression of ideas and solutions charting the changing understanding of the situation and a re-evaluation of values held at the start of the research.

3.8.5 How can you evaluate that impact?

The difficulty in evaluating the impact of change in any research is showing a “cause and effect” relationship. While it is virtually impossible to prove a “cause and effect relationship to 100 percent even in many scientific enquiries, it even more so when dealing with human science. Hence a rigorous approach to evaluating any improvements made must be adhered to.

According to McNiff, Lomax and Whitehead (1996) this happens by:

- *Gathering the data*
- *Identifying criteria for improvement*
- *Selecting pieces of data to act as evidence of improvement*
- *Matching that evidence with your initial research concern*
- *Presenting your work for others to judge whether you have brought about the stated improvement.*

The evidence collected will consist of videotapes of the sessions, daily evaluation reports, pre- and post-tests, and a post-questionnaire of the children's views on the learning experience.

3.8.6 How will you ensure that any judgements you might make are reasonably fair and accurate?

Two essential claims are aimed for at the end of the enquiry. Firstly improvement has actually occurred. Secondly the processes and significance of the improvement is understood. However it is not enough to just assert the claim. There must be some external form of validation.

McNiff (1988) sees three steps in the "*validity of a claim to knowledge*"

Self Validation

Peer Validation

Learner Validation

It is in the interaction of these three steps that any attempt at validation for any claims will be made. This provides a process of triangulation as depicted in the Figure 2.

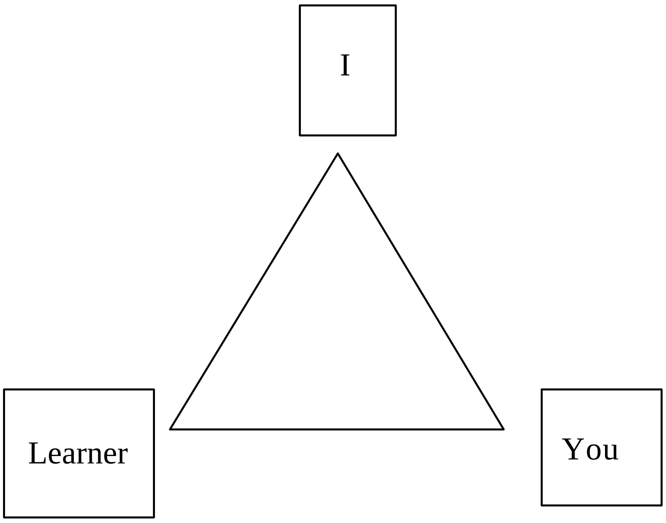

Figure 2

My Educational Values

A meeting with a colleague, my supervisor and a mathematics teacher currently researching at PhD. level helped to clarify the educational values I hold. In essence these are that

- Children learn best by doing.
- The value of peer interaction among children is often undervalued in education.
- Individual children should be able to take responsibility for their own learning,
- Computers provide much potential for education but do not provide "miracle cures" as some people predict or others expect.

These values needed clarification, as it is easy to loose sight of these and accept educational practices that are commonly practised as always being the correct ones. This group helped provide part of the on-going process of peer validation. A meeting with Deirdre Butler who completed an excellent and comprehensive study into Logo in relation to Problem Solving further enlightened my focus of enquiry. From initially reviewing using Logo as a means of improving my teaching of Mathematics, I realised that I would have to narrow this focus given the time scale of the enquiry. The methodology of enquiry (i.e. Action Research) was further enlightened after a Action Research Validation meeting. The method and rationale of the study was discussed and a question and answer session ensued which helped clarify certain points or flaws within the reasoning behind my enquiry.

3.9 Continuous Cyclical Development.

Action research was chosen as the methodology for this research, as it is a methodology that promotes the idea of research having a direct relevance to what actually happens in the classroom. It is possible to have what might be termed a ‘good knowledge’ of educational theory without actually using it in one’s own situation. It could then be argued that this superficial learning is not in fact knowledge at all.

The `living educational theory' as outlined by Whitehead (WWW6) is not an alternative or a subversive one but one which combines traditional theories with practice to form a new understanding and in doing so provides new theories which may have some generalisability to the profession as a whole.

Schön (WWW7) stresses the need for such research to be ‘I’ - based. McNiff, Lomax and Whitehead (1996) echo this sentiment but warns only “where you are where you are asserting your particular ownership of the statement being made”. Such research can construct a new theory of a unique case. Hence much of my action research report is written in the first person, as this is how it was carried out. I did the research. `I' was at the centre of my research question. I am concerned with the specifics of my research not, in the report itself, with generalities or indeed with relevance to other situations. I will however consider these points after the report.

The reasons for presenting this report are many. I am making public my action learning. I am presenting it as evidence of my own professional development. I would like fellow professionals to learn from it. In presenting my findings my intention is not to be prescriptive but to demonstrate some insights into the subject of educational dialogue. As teacher- researchers, by focusing enquiry on the children's learning and integrating the insights of existing theories into our enquiry we can make a significant contribution to educational knowledge.

> *'Do y instead of x and the pupils will learn more'. This is contrary to the truth ethic of research, for it omits the details of context and circumstance which give it meaning...Suppose that instead the researcher said to teacher ' Do y instead of x and your pupils may learn more'. This is no minor change. It is not just admission of frailty in the way that the research was conducted. It is a firm reminder that there are many variables which determine whether learning takes place. And it is an invitation to the teachers to enter into discourse about it - to read the evidence in support of this statement, to discuss it with anyone else who engages in x, to reflect on the issue, to test out in their own classroom the efficacy of y, and to report the outcomes to whatever group will listen. (Bassey 1998)*

It is not intended that huge generalisations will be made but that this study can be read by teachers that may choose to apply findings to their own situation if appropriate.

4 Implementation and Evaluation of the Enquiry

The previous chapter outlined the purpose and rationale of this enquiry. This chapter describes a practical course taught to Sixth Class Primary School Pupils covering the curricular area of Angles and Regular Shapes investigating the potential of Logo to provide a deeper understanding of theses concepts. In the literature many claims were made for Logo but equally many of these claims were refuted. Having examined the research studies in using Logo in general and more particularly in a cooperative group setting, there appears to be little consensus in relation to the potential of Logo.

This study will attempt to explore the potential of Logo, used in a cooperative Learning environment, to deepen the children's understanding of angle and properties of regular polygons.

4.1 The Context

The school in which the research was based is situated in a generally middle class area in a village approximately twenty miles north of Dublin. The school is over fifty years old but has undergone a major renovation within the previous ten years. Recent developments in the housing sector have led to a growth in population in the area. This was not envisaged at the time of the renewal, which means that space is at a premium with the Physical Education Hall being used as a classroom and the staff room converted to a resource room. The school does have a good reputation within the area, which is reflected in the number of children who are bussed from a nearby town, which itself has sufficient schools to absorb the numbers.

There are a variety of different specification computers available in the school. They range from an IBM PS1 286 to a 233MHz Pentium II processor based Gateway 2000 machine. There is no computer room and it is unlikely that there will be one for the foreseeable future as there is insufficient space for one. Hence the computers are on trolleys which float between classes according to a timetable. While the machines are utilised regularly, the software packages mostly used are more drill and practice type software and adventure games.

A group of six children Gráinne, Tom, Simon, Ruth, Siobhán, and Louise[1] were chosen. These children regularly attend for extra tuition in Mathematics. They would not be regarded as needing remedial help in the normal sense of the word. They just tend to fall slightly behind the rest of the class at times during the year. Normally the children would be given extra tuition using traditional means. For this enquiry the children were introduced to Logo as a means of using ICT to deepen the children understanding and perception of angle and the properties of regular polygons. The group was assessed initially using a non-standard test on angle and shape. (c.f. Appendix A).

[1] To provide anonymity these are not the children's real names.

Research into cooperative grouping indicates that heterogeneous grouping of mixed ability is preferable to homogenous groupings. However these children were of similar ability (c.f. Drumcondra Standardised Mathematics Test - Appendix B). Because of this and the fact that the children knew themselves much better than I did, they were given the freedom to choose a partner to work with. It was hoped that this would alleviate any conflicts or personality clashes that might have occurred if the groups had been randomly chosen.

The groups formed as follows:

Group 1: Gráinne and Ruth

Group 2: Siobhán and Louise

Group 3: Tom and Simon

4.2 Rationale for Test on Angles and Shape

The "Angles and Shape" test was devised from the guidelines outlined in Curaclam Na Bunscoile, (the Primary school Curriculum). Concepts in angles that should be developed for fifth and sixth class in Mathematics formed the basis for the central ideas behind the activities. The fifth and sixth class mathematics books "Maths Mastery 5 & 6", "Busy at Maths 5 & 6" and "Figure It Out 5 & 6" were utilised in the development of the test.

It was hoped originally to adapt the sections on geometry and angle from the standardised mathematics tests, the Sigma T and the Drumcondra Primary

Mathematics Test, to make the test more formal. However the sections on Geometry in general are extremely limited so the test was devised as mentioned instead.

Hence the test was devised by way of individual professional perceptions of what should constitute a test on a senior primary school pupils understanding of angle. This obviously detracts from its validity in comparison to a more formal test. A more formalised test would be more desirable, however one was not found specifically dealing with the topics required. The test should measure to some degree the extent of a pupils understanding, or lack of understanding of angle in general.

Question 1

This question is designed to evaluate the overall understandings of angle possessed by the children. The marking of this will be arbitrary to some extent but should provide valuable insight into the level of understanding of each individual student.

Question 2

This question is based on the idea of conservation of angle as outlined by Noss (1988).

Question 3

This question is designed to investigate if the student understands the difference between marked reflex angle and a marked acute angle which look similar in construct but in practical terms opposite in size.

Question 4

These problems are designed to evaluate the children's ability to estimate in degrees the size of the angles marked in red. The answers will be marked right or wrong depending on the intelligence of the guess (i.e. anything between 55^0 and 35^0 will be acceptable for the first part but anything other than 90^0 will not be acceptable for the second part etc.).

Question 5

This question is designed to test the children's knowledge of a right angle being 90^0 and a full turn being 360^0.

Question 6

This question is designed to evaluate the children's understanding of 180^0 as being a straight line and also the sum of the internal angles of a triangle. One aspect look at the property of opposite angles being equal.

Question 7

This question requires children to draw angles of specified sizes. The same system of marking will apply to this as did to question 4.

Question 8

Finally this question explores the children's concept of the properties of some regular polygons.

4.3 Description of the Programme

The programme as designed is intended to augment weaker children's understanding of angle by supplementing their classroom work with lessons in Logo. These Lessons were designed with particular emphasis on improving the children understanding of angle and properties of regular shapes.

General Aims

- To enhance the children perception of geometry.
- To provide a stimulating environment in which to achieve this enrichment.
- To utilise a cooperative learning environment to enhance the total learning experience.
- To promote cooperation between children.
- To create an enjoyable and productive learning experience for the children.

Specific Objectives

- To deepen the children's understanding of angle and regular polygons.
- To provide structures of Positive Interdependence, Individual Accountability and Group Rewards to enhance the cooperative learning situation.
- To provide the children with a reasonably substantial introduction to Logo.

- To provide the children with opportunities for taking more responsibility for their learning.

4.3.1 Teaching Methodology and Educational Values

The methodology used reflects in some ways my own educational values and results from more recent research into the role of the teacher in the learning of Logo. Maddux (1989) Pea, Kurland, and Hawkins (1987), as mentioned, have voiced concern about a solely discovery based methodology for the learning of Logo. Given the time constraints and lack of resources generally available to primary schools a more guided discovery learning approach may be more appropriate. This is in concurrence with one of the key principals on which the primary school curriculum is based according to the White Paper on Education published by An Roinn Oideachais (1995)

- *the central importance of activity and guided discovery learning and teaching methods.*

With this in mind, the first section of each lesson will be more teacher-oriented. An effort will be made to lead the children to basic knowledge required for each lesson, though if the children are slow to pick up on the concept a more direct form of instruction will be instigated.

The second part of each lesson involves providing the children with worksheets with challenges for them to work towards. In this section of the lesson the teacher will be very much a facilitator of the learning experience. The criteria for this facilitator role were based on the following criteria, which were drawn up before the implementation.

4.3.2 On Being A Facilitator

1. Facilitate self-correcting rather than to correct.

2. Guide and challenge rather than to lecture and to tell, which will foster 'guided discovery'.

3. Create a student-centred environment that fosters exploration

The following points are ideas that should be considered in the role of facilitator.

1. Allow exploration

The children need time to experiment with new ideas even if this experimentation is not directed toward any clear goal. It may be difficult to distinguish constructive exploration from simply playing around. Through observation, it will hopefully become clear when the exploration is no longer productive. At this point, a different activity can be suggested.

2. Suggest activities that are within the student's ability

A range of activities needs to be planned. Many of the ideas may be developed into projects. If a student has an idea for a project that is too advanced, carefully suggest a modification of the idea that is within their capability. This could be a delicate situation because the desire is there to make the idea challenging for the children. A project may be developed at a further time.

3. *Give ideas without always giving answers*.

This strategy requires good judgement. If you feel the children are overwhelmed by a confusing situation, it is important to give direct answers so that they can overcome their problems. In other situations, it is often helpful to give just enough information for the children to discover the solutions on their own.

Reminder: Making mistakes and correcting those mistakes (bugs and debugging) are fundamental to learning MSWLogo, and a good basis for acquiring problem solving skills.

4. *Introduce new concepts and techniques when the children are ready to use them*.

Be sensitive to the right timing of the introduction of a new concept or technique.

5. *Review concepts and techniques that have been learned*.

In a "learning by doing" approach, the children can often apply new concepts/techniques before understanding the process involved. Reviewing concepts and techniques after the children have used them in their work reinforces what has been learned for them as well as for the teacher.

6. *Discuss the process as well as the product*.

Encourage the groups to show the results of their work to each other, and also to discuss what was involved in doing it. In this manner, they will learn that a result can be achieved in several different ways. Hold regular "bug" sessions where the children are given the opportunity to talk about the kinds of problems they are facing while doing certain activities. Direct the discussion so children can brainstorm together to find solutions to these problems; making children think about what they have been doing will help them develop an awareness of their own thinking. This kind of discussion also develops a respect for the thinking of others.

4.4 Action Research Cycles

4.4.1 Cycle 1

The course consisted of ten one-hour lessons. Each lesson was evaluated on its own merit. The first Action Research cycle extended for the first week of the course and covered the first five lessons. It was intended to video a different group on alternate days to have a broader overview of the learning experience across the groups. This would give detailed insights into the thought processes of the children as they considered each challenge and give evidence of the significance of peer interaction in the learning process.

Introductory Session

Lesson 1. The purpose of this lesson was to introduce the basic commands of Logo to the children. Initially the children were given maps and time to explore walking out the instructions in the school playground. E.g. Go forward 10 steps. Turn 90^o to the right. Go forward 10 steps. Turn 90^o to the right. Go forward 10 steps. Turn 90^o to the right. Go forward 10 steps. Turn 90^o to the right. What shape did you walk out? Could you write down instructions to make a rectangle, etc. Back in the classroom a brief introduction described the concept of the Logo programming language. Then commands were demonstrated on the computer with the large monitor.

Worksheet 1. The children were then given worksheets designed to challenge the children to work towards solutions with their partner. Initially they were given graph paper to plan their solutions before moving to the computer to implement their plan.

Reflections on Lesson I. The children responded enthusiastically to their initial introduction to Logo. They completed the four challenges within the time frame allocated. The challenge that caused most reworking was Challenge 3 (cf. Figure 3).

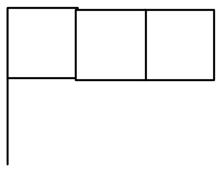

Figure 3

Each group decided to draw the pole first. They then went across to the end and tried to work back. Each group got into difficulty working back and found themselves finishing the three squares before reaching the flag pole (cf. Figure 4).

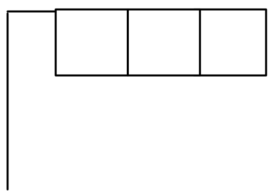

Figure 4

This led me to intervene indirectly in the learning situation. While not directly instructing the children, I suggested that maybe they should look for an alternative solution to the problem. Two groups then decided to draw the pole first and then draw the first square and then the second and finally the third. The other group decided it was better to start at the end of the flag and work back finishing with the flagpole. Each group completed the challenge much with none of the difficulties experienced in their initial plan.

The members of Group One were virtually inaudible on the video of the first session. They were obviously put off by its presence. Both members are by nature quiet. Despite encouragement to speak more clearly both members continued to whisper among themselves.

Lesson 2 – Abbreviated Commands and Creating Designs

Lesson 2. This lesson introduced the children to the abbreviated versions of the commands FORWARD, BACK, RIGHT and LEFT. It also gave the children time to further explore the basic commands. A brief discussion was held on the outcomes of Lesson one. The importance of pre-planning was discussed. While the children could see its importance, they still expressed a preference for sitting down and jumping straight in to solving the problem. However it was decided to pre-plan each challenge on paper before implementing a solution on the computer.

Worksheet 2. Worksheet 2 was designed to extend the challenges given in the first lesson and give the children ample practice on using the basic commands and the concept of 90-degree angles.

Reflections on Lesson 2. Initially the children planned their solutions away from the computers on paper. The children found planning difficult so they were given strategies to help in their planning (e.g. Try and minimise the number of times you move along a line already drawn, put distances in on the plan and make sure they add up etc.). Group one had a problem with solution, which turned out in essence to be similar to the Challenge 3 on Worksheet 1. When this was pointed out they were easily able to resolve the problem using their previous experience.

Challenge three (Figure 5) below proved the biggest obstacle for each of the groups.

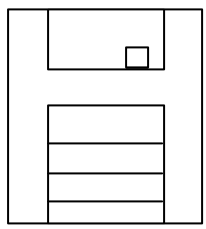

Figure 5

It is interesting to note that Group Two could not complete the problem even though their planning was more thorough and detailed than the other two groups. The problem was in itself a point of planning. Because the initial plans were not adequate, each group ended up in a situation best described by figure 6.

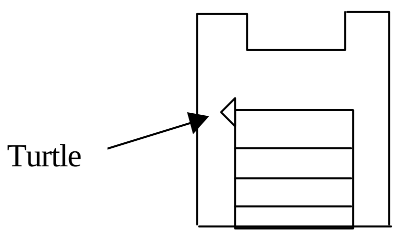

Figure 6

Note the position of the turtle. It is interesting that each group found themselves in this situation, as there was no collaboration between groups either during the planning or implementation stage. Further discussion using prompting questions led the children to see that instead of moving back over a substantial number of already drawn lines. Obviously this is not necessary if you use the PENUP and PENDOWN commands. However these were unknown to the children so they were working from the assumption that the only back to the top was to continue back along the lines already drawn.

The children were quick to pick up on the fact that if they turned 90 degrees in the wrong direction that by typing either LEFT 180 or RIGHT 180 would correct that. They quickly deduced that if, for example, they typed RT 18 instead of RT 90 that RT 72 would correct this. When group 2 mistakenly typed RT 909 it looked as though they were in trouble. However they quickly corrected the situation by typing in LT 819. The value of peer-peer dialogue in children's' learning can be seen from the reasoning that led to this correction.

Siobhán: *Oh no look what you did.*

Louis*e: Should we start again.*

Siobhán*: Wait, how could we get back to where we were?*

Louise*: Do the opposite of the last thing we did?*

Siobhán*: I know! LT 909. That will get us back.*

Louise*: Hold on. What if we went back..(she pauses takes out a sheet of paper and manually subtracts 909-90) ..that's it. We need to go back* 819^0.

Siobhán: *Are you sure?why?*

Louise*: Becaues if we go back* 90^0 *less than our mistake it will leave us turned the* 90^0 *we wanted in the first place.*

Siobhán: *Oh yeah go on try it*

Lesson 3 – Creating A Square using REPEAT

Lesson 3. This lesson introduced the children to a more advanced command, the REPEAT command. The commands used so far were initially revised. Initial discussion focussed on the labour saving nature of Logo. The use of abbreviations was discussed. Some samples of the students' previous work was displayed on the board and the disadvantage of having to retype the same lines repeatedly was alluded to. The REPEAT command was then introduced.

Worksheet 3. This was designed to give the children practice using the repeat command to draw squares of differing sizes. The children were also challenged to draw a rectangle using the repeat command.

Reflections on Lesson 3. The children understood the repeat command well in the context of a square. The children quickly completed challenge one. Challenge Two presented more of a difficulty. During planning the three groups did not see the problem of essentially three different sized squares. Each group presented planned solutions generally consisting of one square drawn using repeat and then a series of unstructured commands. The children were then asked to reflect that there are often many solutions to a problem in Logo and we should be continually searching for the best solution. The children were then asked to reappraise their initial solution to try and improve on it. At no time were the children told that the solutions they suggested were wrong. After reflection groups two and three could see that drawing three different sized squares provided a neater and quicker solution. Group one had difficulties coming up with an alternative solution. Rather than directly instructing the children on a better solution, Group 1 was given a chance to implement their initial solution, which they duly did. They were then informed that the other two groups completed the task with just three lines. Group two decided to look once more at the problem. The fact that the problem could be completed in three lines gave them enough of a clue to come up with the solution.

Lesson 4 – PENUP/PENDOWN and HIDETURTLE/SHOWTURTLE

Lesson 4. Lesson 3 was revised and the REPEAT command was further discussed. The children were then introduced to the PENUP/PENDOWN and HIDETURTLE/SHOWTURTLE commands. The advantages of each command were discussed and the children suggested situations where each would come in useful.

Worksheet 4. This worksheet was designed to give the children practice using the PENUP/PENDOWN and HIDETURTLE/SHOWTURTLE commands. The children were asked to avoid using curves for their initials, as they had not been introduced to them. Challenge 2 and 3 were intended to not only provide opportunities to use the four new commands they used but also to provide the children with further opportunities to use the repeat command.

Reflections on Lesson 4. The children found the PENUP/PENDOWN commands confusing. The concept in itself was not difficult but the children often forgot the pen was up and continued forward without drawing a line when they intended to. A greater effort was made to encourage the children to plan their solutions away from the computer. Group three was very reluctant to plan. Their planning was completed because it was required of them rather than the fact that the believed that it had any real advantage. This may be due to the inherent attraction to the computer for many children. Group three was the group consisting of two boys. Both were outwardly eager to finish each challenge before the other two groups.

Lesson 5 – Using the Editor

Lesson 5. The disadvantage of having to repeatedly type the same commands was discussed. The concept of a procedure was introduced to the children. The idea of procedures as building blocks was discussed. The children were shown how to save their work.

Worksheet 5. Worksheet Five was designed to give the children opportunities to use the editor to create procedures. It was hoped that the exercises would extend the children's use of the repeat command and further extend the children's knowledge of Logo in general.

Reflections on Lesson 5. This lesson caused the children problems. Because the children found the multi square challenge so difficult, they were put off the actual task of using the editor. Group one persisted in typing in the commands on the commander. A more structured approach may be needed to teach them how to use the editor properly. Detailed discussion of the advantages of reusing procedures is needed so the children can see clearly a purpose in writing a procedure. Group 3 typed in the commands for the door in the editor. When they executed the door procedure there were a lot of bugs in their plan. They wanted to give up and do it from the start typing in as they went along. They were asked what would they do if they were asked to design a house with the same door the next day or a row of houses with similar doors. Would they be content to have to retype the commands every time?

Tom: *Is it okay if we just type out the commands like we did yesterday?*

T: *That's fine but what if you need to draw a door tomorrow. Will you be happy to type out the commands again.*

Tom: *(Pause) Yes.*

T: *(addressing all the groups)Can anyone suggest what advantages are there to being able to write out the commands as one procedure and saving it?*

Siobhán*: You only need to do it once.*

T*: What do you mean?*

Siobhán*: well when you write it and save it, it's always there. When you need it you just have to type in the name you gave it.*

T: *Do you agree with that Tom*

Tom pauses again and shrugs.

T: *What if you had to draw a row of ten houses with the same door tomorrow. What way would you do the door then.*

Tom: *Oh yeah! I didn't think about it like that.*

This discussion helped to convince the children that it would be better to persevere with the editor in the long term even though they were finding it difficult to use. It became important, thus, that the children could switch easily and comfortably between the editor and the commander. Extra instructions had to be given to each group in this capacity.

4.4.2 Cycle 2

After looking back on the notes and video-recordings from the first five sessions, I am wiser in terms of the organisation of the sessions and the support that a facilitator must provide to improve the quality of the learning experience. I decided to video group two only, as the attention of the camcorder was affecting the cooperation of the other groups and that consequently, their performance in learning Logo was compromised.

Attendance at a course given by David Johnston on cooperative learning coincidentally given on the weekend between the two cycles provided new information and knowledge that was incorporated into the second cycle. This included an enhanced understanding, gleamed from watching the organisation of cooperative learning in practice during their workshop and from practical tips for the organisation of such sessions.

Lesson 6 – Triangles

Lesson 6. This lesson introduced the children to the triangle. Mindful of the 'triangle bug', as mentioned in the literature review, the introduction to this lesson was planned thoroughly. This was done in an effort that the actual misunderstanding described by Cope, Smith & Simmons (1992) of the internal and external angles in Logo could be used constructively to actually deepen the children's understanding of angle in general.

Worksheet 6. This worksheet was designed to give the children opportunities to write triangle procedures without and with using the repeat command. After the procedures are written the children are given opportunities to incorporate these into new procedures to draw objects containing triangles.

Reflections on Lesson 6. The children quickly came up with the correct procedure to draw an equilateral triangle. The children found the demonstration, using chalk on the blackboard to highlight the angle of the turn as opposed to the internal angle, very helpful[2] (c.f. figure 7)

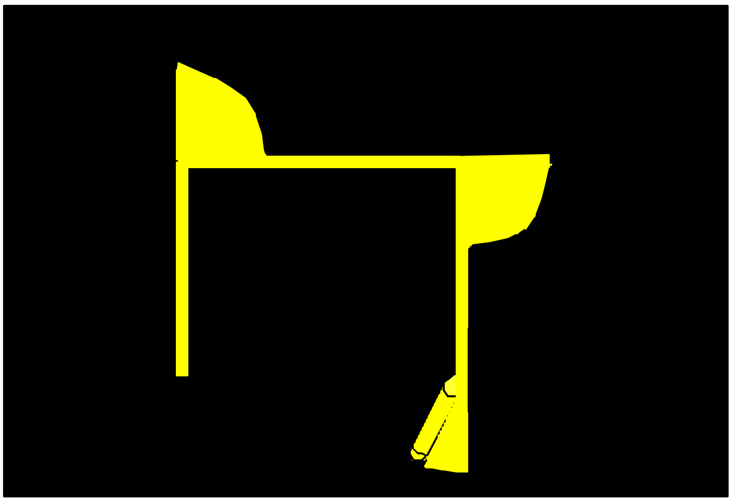

Figure 7

Each group had great difficulties with the Windmill challenge (c.f. figure 8).

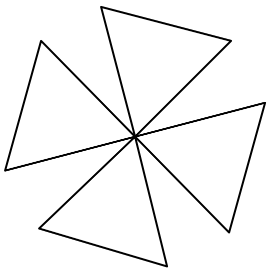

Figure 8

[2] This involved turning the chalk on the board in such a way as to leave a shading of the actual angle of the turn.

This stemmed from the way in which the triangle procedure was written in the first place. To get a triangle drawn as shown below the children either turned 90^0 right

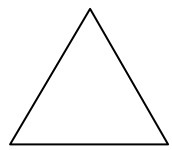

Figure 9

first and used REPEAT 3[fd 100 lt 120] or they turned 30^0 right first and then REPEAT 3[FD 100 RT 120]. Each group had difficulties because of the fact that they had incorporated this initial turn into the procedure. When the children went to write the windmill procedure they used the repeat procedure. This involved in a considerable investigation into the properties of an equilateral triangle and the concept of 360^0 in a full turn. They used this knowledge to deduce that the problem involved drawing a triangle and turning a certain angle and drawing another triangle. They discovered that the angle between each triangle would be 30^0. They then tried to incorporate this into a repeat procedure. This caused great difficulties because of the initial turn in the triangle procedures. At this point it became necessary for teacher intervention as the children became frustrated. Through a series of prompting questions[3] each group. While each group could figure out how much the turtle would have to move to be in position to draw the next triangle there was still problems

[3] This involved getting the children to look at where the turtle was facing at the end of their triangle procedure and figuring out how much it would have to turn to start the next triangle and so on.

because of the initial turns in their triangle procedure. At this stage group two had given up trying to use repeat and were using some very complex manoeuvring to draw the windmill. This was because they wrote their procedure using an initial right turn of 90^0, which made it even more difficult to use. The other groups used a turn of 30^0 that made using repeat easier. Both Groups one and three managed to write a windmill procedure involving repeating a triangle and a turn four times. Group two managed to complete a windmill shape that did not have the regular 30^0 spacing between each sail. It is slightly ironic that from a Logo perspective that Groups one and three managed to write much neater and effective coding for the windmill yet group two were engaged in much deeper and complicated reasoning around angles because of the more haphazard manner in which they produced a solution.

Lesson 7 – The Total Turtle Trip Theorem

Lesson 7. The purpose of this lesson was to introduce the children to the idea of the sum of the external angle of any closed shape is 360^0. This lesson was designed mindful of what Cope, Smith & Simmons (1992) found in relation to the misconceptions experienced among children in relation to the difference between the internal and external angles of a shape. While acknowledging this maybe a difficulty, an effort was made to lead the children to an understanding of these differences and hence deepening their understanding of angle. It was felt that this was more constructive than using this as a reason for not using Logo because it can lead to these misconceptions. It was hoped that by focusing on both internal and external angles during the lesson that children would be able to distinguish between the two types of angles and relate both to the way regular polygons are constructed.

Worksheet 7. Worksheet 7 was designed to give the children practice incorporating the fact that that the sum of the external angles of any closed shape is 360^0 into their procedures for writing squares and triangles. It was then hoped that the children could use this knowledge to write procedures to draw a pentagon, a hexagon and a octagon.

Reflections on Lesson 7. Similarly to the previous Lesson care was taken initially to distinguish between internal and external angles. The use of the chalk demonstration was again used to reinforce this concept. To further reinforce this, a table was drawn up of the external angles of a square, triangle, pentagon, hexagon and octagon from a chalk diagram of each shape. The children saw that if the shape had five sides the external angle was 360 divided by 5 etc.

Shape	Sides	External Angle	Total
Triangle	3	120	360
Square	4	90	360
Pentagon	5	72	360
Hexagon	6	60	360
Octagon	8	45	360

This followed on from the discussion in relation to the external and internal angles of the triangle. Then the children were asked if they knew the internal angle for each shape. The following table was drawn up.

Shape	Sides	Internal Angle	Total
Triangle	3	60	180
Square	4	90	360
Pentagon	5	108	540
Hexagon	6	120	720
Octagon	8	135	1080

A discussion was held in relation to the difference between the two tables. This led to a clearer understanding in the children of the differences. They saw that the internal angle was 180^0 minus the external angle and vice versa. While all this may seem like an overstatement of a very trivial concept it forms the essence of being able to use Logo to promote a deeper understanding of angle. It is not as trivial either as it may appear. Logo Ar Scoil, the excellent guide produced by the East Cork Teachers' Computer Group makes the following mistake:

> *The Total Turtle Trip Theorem (TTTTT), otherwise known as the Rule of 360^0 states that the sum of the internal angles (sic) in any closed shape is 360^0.*

While not in any way being critical of a very worthy book, the fact that this mistake was not spotted highlights in some small way that the issue can be confusing even for teachers at times.

With this grounding work done, the children undertook the challenges without difficulty. After the children were given time to experiment with writing procedures for different sized shapes. This led to group two discovering a procedure for a circle. This led to quite remarkable reaction both from group 2 and correspondingly the other two groups. The reaction from group 2 was very obviously pride driven for which the "self-discovery" aspect should not be understated.

Lesson 8 – The Circle

Lesson 8. This lesson revised the concept of multisided polygons and discussed with the children the procedure written by group two to draw a circle. The children could point out that it wasn't really a circle but a many sided polygon. The children were told that to draw a circle for the moment they should think of it as a 360-sided polygon.

Worksheet 8. Worksheet 8 introduced the structure to draw a 360-sided polygon. The students were encouraged to write a procedure to draw a circle as a 360-sided polygon. This was further extended to encourage the children to draw a semi-circle, a series of increasing circles, a question mark and a matchstick man.

Reflections on Lesson 8. The children initially had problems drawing the circle due mainly to the fact that they were putting in a forward move much too big. This caused the turtle to wrap around the screen producing some obscure designs. Each group was unaware yet obviously impressed with what was happening. After considerable time they had not managed to figure out what was happening. They were asked to think in words what they were actually telling the turtle to draw. This prompt led the children to realise that if they chose FORWARD 100 that they were drawing a shape with 360 sides with each side 100 steps in length. They realised that they would have to make the sides much smaller.

Lesson 9 – Sub-procedures

Lesson 9. This lesson was designed to introduce the children to the idea of procedures as being building blocks. The advantages of procedures in general were discussed initially. Then the idea of using sub-procedures was discussed in the light of examples of procedures written by the children already which had incorporated sub-procedures without formal knowledge of what a sub-procedure was.

Logo Worksheet 9. Worksheet 9 provided the children with opportunities to use the concept of using sub-procedures to make a procedure house. The house was chosen as it metaphorically represented the idea of building blocks.

Reflections on Lesson 9. While this lesson was intended to introduce the children to using procedures within procedures, they had already been using them in such a way in the previous three lessons quite naturally. However it was necessary to formalise this concept in the children's minds. While the building blocks concept had been discussed regularly over the course of the lessons the children, group one in particular still often tended to opt for typing the commands out. However over the course of this lesson they seemed to grasp the building block concept which was evident from their code for the house.

To House

WallsAndRoof

MoveToWin

Windows

MoveToDoor

End

I decided purely on personal professional judgement to introduce the idea of using variables during this lesson. Spur of the moment decisions such as this can sometimes be a bad idea, as the method of presentation has not been properly thought out. However in this instance it complemented the lesson as it stood. Rather than having to write procedures for the different sized squares, the children only had to write one. Because the children completed the challenge early they were asked to try to write a procedure to draw each of the following using variables: a triangle, a pentagon, a hexagon, a circle, a rectangle. Each group managed to complete this task without any major problems. The only difficulties were syntactic such a not leaving a space before the colon. A little discussion centred on the need to input two variables for the rectangle, which was the final challenge. Siobhán pointed out that “you just need to add another **:size** after the first one”. The children were then prompted to consider would it be a good idea to call both variables ‘size’. They agreed that it probably was not. They were then asked to consider appropriate names considering what they already know about rectangles. Louise said “length and breadth” which the other groups thought was a good idea so the variables took those names or abbreviations thereof.

Lesson 10 – Creating Designs using Repeat Loops

Lesson 10. This lesson was designed to introduce the children to the concept of rotation of regular polygons, how they retain their properties after rotation. The children used the repeat command to draw a regular polygon and then rotate it a certain number of degrees.

Worksheet 10. The corresponding worksheet gave the children practice in rotating the following shapes.

Triangles, Squares, Rectangles, Squares

Reflections on Lesson 10. This lesson was one of the more enjoyable lessons for the children. They each derived very enthusiastic pleasure from solving each challenge. The problems caused by including an unnecessary turn in writing the procedure for the four basic shapes was discussed initially. The Windmill Bug[4] was discussed. It was decided it would be too confusing to include an initial turn and that it would be better to write the procedure in a standard way so that it would be possible to quickly figure out what direction the turtle would end up facing after each basic shape. From there it would be easier to work out the required angle of rotation.

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[4] This bug was caused by including an initial turn before writing the REPEAT section of the code for a triangle in order to have it lying in a particular way.

One problem that arose that needed discussion was the over rotation of a shape (i.e. the number of times used to repeat the rotation meant that the completed design was often been overwritten) or similarly an under-rotation causing the design to be incomplete. The children were asked for ideas on a solution to avoid this. They could see it was a related to both the angle of rotation and the number of repeats. However they were having difficulties establishing a relationship between the two. Using plastic shapes the children were encouraged to map out the rotation of a square around a central point on paper. Firstly they were asked to make a design with three squares in one full rotation. From this they discovered they would need to turn the square 120^0 or 360/3. Then they were asked to make a design with 5 squares in one rotation. They then began to realise the connection between the number of times they rotated the square and the angle of rotation. When they went back to the computers they were able to solve the other challenges quite easily.

The enthusiasm of the children during this lesson deserves a mention. From a tentative start in Logo the children were becoming quite adept at using the basic commands, using repeat, writing procedures and incorporating sub-procedures into procedures. They seemed to get real joy out of solving the challenges. There was no problems motivating the children whatsoever. The motivation seemed to be inherent in the satisfaction of deriving a solution and appeared to be self-perpetuating as the children’s knowledge of the power of Logo increased.

Tom and Simon: *Yes!!*

(On completing the challenge requiring the rotation of a circle to design a pattern. The other groups look around. There is a very obvious sense of pride on the faces of Tom and Simon. The other children come over to have a look.)

Louise: *Cool, how did you did you do it?*

Simon: *We used repeat to draw a circle and then turn it*.

Gráinne: *How much did you turn it*?

Tom: *That a secret*.

Ruth: *Do it again*.

(Tom types the name of the procedure and the design redraws itself. The others seem genuinely impressed. The fact that the circles draw more slowly than the other meant that the children could actually see the design unfold).

Siobhán: *Come on I think I know what to do.*

(The other two groups go back their computers visibly motivated to complete the challenge themselves.)

4.5 Evaluation

To evaluate the success or otherwise of the course in Logo it is important to consider the validation requirements for an Action Research enquiry. To provide rigour to the claims it is important that any claims can be backed up in a thorough manner. The process of triangulation provides a rigorous means of achieving this. Hence information gathered has strived to provide this rigor. The information was gathered from the following

- Video tapes of the lessons
- A diary monitoring the main events of each lesson
- The pupils work saved on disk
- A Logo Test
- A questionnaire
- Informal interviews with their mainstream teacher[5]

During the lessons one group was videotaped while working on the computer. For the second week only group two was videotaped as the participation of the other two groups were being seriously undermined by the video camera. This did mean that it

[5] This is the teacher who has direct responsibility for the children, in whose class the children are enrolled and spend most of the school day in. This teacher has twenty years experience teaching at 6th and 5th class level and is obviously very familiar with the 6th class mathematics programme.

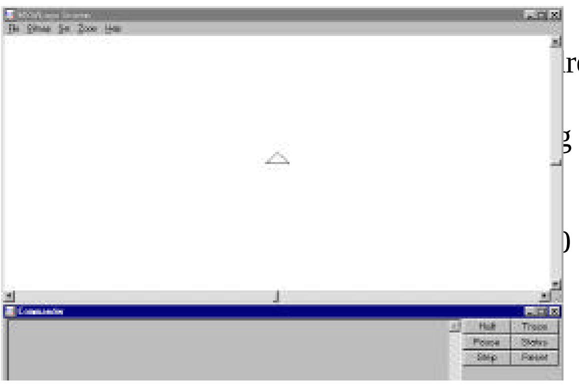
was possible to monitor the groups one and three more thoroughly. The outcomes, problems, issues, etc. which occurred in each lesson were documented in a diary during and immediately after each lesson. The main observations of the learning experiences focussed on the groups not being recorded each day (i.e. Groups one and three during the second week). Later the video recordings were analysed and any significant findings were documented.

The Logo test was given to the children after the course. The purpose was primarily to give incentives for the individual members of each group to work together. At the same time it would show to some degree the extent to which each individual child had progressed over the ten lessons in Logo.

The children were also given a questionnaire in an attempt to establish what the children thought of the experience of learning Logo and whether they say any relationship between Logo and mathematics.

The mainstream teacher of the children was interviewed informally prior to the Logo enquiry in relation to any difficulties he found that children experience in relation to understanding angles and regular polygons and their properties. Other informal interviews were held after the Logo enquiry to establish if there had been any noticeable carry over effect in relation to the children in either to their attitudes to mathematics or any aspects that could be directly attributed to the Logo enquiry.

4.5.1 The Logo Experience



was very much confined to using adventure games and "drill and practice" type software which is usually highly polished in terms of having colourful graphical interface and highly motivational game-oriented challenges. Compare the two screen shots (Figures 10).

Figure 10

Give most children a face value choice and it is not difficult to predict which software they would choose to use. Initially the response of the children was good but not terribly enthusiastic. They seemed to be pleased to be out of their mainstream class and using the computer. This was backed up by a comment on the questionnaire.

"I got off a lot of work too. That's why I enjoyed using Logo."

This comment is interesting, as it seems to suggest that this particular child didn't see Logo as work in the traditional sense of learning in school. This was despite the fact that they were involved in considerably complex learning situations, planning solutions, implementing these plans and debugging to eliminate any errors in their initial plan. This fact could mean that Logo could be a useful tool in the education of those ever increasing number of children who are very much demotivated by the more traditional classroom learning practices.

As the lessons progressed there was an almost tangible increase in the levels of involvement with Logo. This is difficult to describe in words and is a very subjective statement but I feel it needs stating. Having read much literature on research into children using Logo, I was sceptical about some of the claims regarding the children's reactions to discovering new aspects of Logo. However as the depth of the children's knowledge of Logo increased, so too did the enthusiasm of the children's reactions also increase. At this time of the year the sixth class children can get very cynical in relation to schoolwork. They are ready to leave Primary school and move on to Secondary school. Withdrawing sixth class children at this time of the year for extra help has in the past been a waste of time. It becomes too much of a battle to make it worthwhile. That considered, the enthusiasm of the children was more than welcome. Any claims that the enthusiasm was only fuelled by a desire to avoid their traditional classroom work must be considered in the following context. For the last three lessons no group finished the challenges in time and each group specifically asked, with no encouragement whatsoever, if they could finish their work during their break for lunch and playtime.

4.5.2 Logo, angles and properties of regular polygons.

The children's mainstream class teacher pointed out that children do have difficulties in relation to the understanding of what an angle is. This is borne out by research into the conservation of angle (Noss 1988) which shows children have difficulties understanding which of the following angles is bigger.

Figure 11

According to Ainby and Goldstein (1988), *This confusion arises because of the need to appreciate the dynamic nature of a turn, as well as the static concept of the two lines drawn on a page. It is difficult to get across this dynamic aspect of angle in print…*

While teachers use concrete real objects to help children understand angle, the fact that this confusion exists would suggest that there is a problem of transfer between the children understanding an angle in real terms and the formal representation. Logo possibly provides an intermediary experience between physical movements and formal measurements of angle. In the pre-test the children collectively only scored 4 out of a possible 12 marks on the conservation of angle test. However they managed 10 out of 12 on the Post-test. The definition of what constitutes an angle was consistently clearer across the six children. The biggest improvement in this was Ruth who gave no definition in the Pre-test. In the post test Ruth defined an angle as follows;

An angle is the amount of degrees turned when you turn something like the turtle on the computer or the door opening.

While maybe not a perfect definition it was a significant improvement on no attempt at all. It is also a very difficult concept to verbalise. It is possible that Ruth always had a basic understanding of angle but that only by working through the Logo sessions and discussing and planning with her partner that she came to be able to verbalise that understanding more clearly. Even if that is the case, that achievement in itself should not be dismissed.

The pre-test demonstrated a lack of knowledge in relation to the internal angles of either a pentagon, hexagon or octagon. Not one of the six children knew what the angle was or had any strategy to work it out. Three children made educated guesses based on the pictures of each polygon but the other three made very uninformed guesses considering their ability to estimate the angles in the previous questions was good. This seems to further suggest a lack understanding of what an angle really is. Their ability to estimate the size of angles probably stems from practice of guessing angles in that format (i.e. between two lines). However when placed in another context some children have difficulties. The post-test demonstrated that all of the children knew precisely the internal angle which suggests that the Logo lessons helped the children to internalise the relationship between the number of sides and the internal angle. This was to some extent surprising as it was expected that there might be confusion between the internal and external angle which Cope, Smith, & Simmons (1992) attributed to the angle of the Logo turn. The fact that this did not occur in this instance may be attributed to the manner in which the constructions of the polygons occur (i.e. using the chalkboard demonstration as previously described). From this the children could see clearly the angle of the turn was the external angle from the markings on the chalkboard. Drawing from their knowledge of 180^0 as being a straight line or half a full turn they could then use this information to easily work out the internal angle. The discovery that you could write a procedure for any sided polygon as,

```
REPEAT NumberOfSides[fd 100 360/ NumberOfSides]
```

further enhanced this understanding.

4.5.3 Cooperatively Learning Logo

To promote cooperation an effort was made to incorporate elements of positive interdependence, group rewards and individual accountability into the Logo Lessons. These efforts became more significant during the second cycle because of enhanced knowledge of methods of incorporating these elements into a lesson as mentioned earlier.

The children were told initially that they were going to have a test at the end of the Logo sessions to test how well they had grasped the concepts. A reward would be given to the best, combined score of one of the three groups (i.e. the sum of the two individual scores). This was intended to provide an incentive for the individual members of each group to cooperate. The fact that each individual was to be tested meant that there was individual accountability. This prevented one student in a group from opting out and leaving the work up to their partner. This could have occurred if their work was assessed by say a group assignment. To further encourage cooperation the children had to present a solution to each challenge that had been agreed upon by both members of the group. The children were told that one from the group would be randomly asked to explain a solution to a challenge. If they could not do so sufficiently they would loose a mark from their overall combined score. This worked extremely well in keeping the group focussed and encouraging cooperation (i.e. if one individual was not sure of the solution the other individual spent time explaining it).

The group dynamics were quite diverse considering there were only three groups. Group One consisted of Ruth and Gráinne. It was very difficult to monitor the dynamics of this group, as they were very 'secretive' in their work. Despite trying to encourage them to speak a little louder while being videotaped, it was impossible to pick up what they were saying. Even when not being videotaped they only whispered quietly between themselves. When approached and quizzed very informally in relation to how they were getting on, they were very reticent in their response. Their responses on the questionnaire to working together were mixed. Ruth could see the benefits to working with a partner, "*your partner will help you do your work when your teacher is not available*" yet was not fully convinced; "*if you don't know how to do a shape and your partner is doing it you won't learn it*". She decided that she would given the opportunity prefer to work on her own.

4.5.4 The Usability of the Software

The usability of the MSWLogo software package was evaluated according to the three essential criteria for usability as outlined by Dix (1993) which are learnability, flexibility and robustness

MSWLogo's interface was very intuitive and easily circumnavigated by the children. They were not complete novices to using a computer with the Microsoft Windows 95 operating system so they had little difficulties in opening up the software, loading and saving their work and generally manipulating the interface. Minor problems occurred in relation to the design of the commander and the main Logo screen. These are almost completely separate entities in terms of their screen placement. Neither can be docked in a permanent position on the screen. When the main screen was maximised (usually in error) it often hid much of the screen behind the commander. This caused confusion initially and could have been avoided if there was a more secure system of fixing the size of both the commander and the main screen. In general, however the package fell within the remit of being easily learnable by sixth class children with limited experience of using computers.

The package was quite flexible in terms of providing a multiplicity of ways of approaching different tasks. Commands could be directly typed into the commander. To save typing in similar commands directly, it was possible to either click on the line in the command window and this would input that line immediately into the command line in the commander. Alternatively the same thing could be achieved by moving the cursor up to the required command using the up and down arrow keys. The options provided on the set menu provided an alternative to typing in commands in relation to implementing certain common graphics features such as setting the pen colour, the pen size, the type of flood fill, type of font etc. However it lacked a certain degree of customisability. For example as mentioned earlier it was not possible to dock the two main components of the interface, the MSWLogo main screen and the commander which in turn affected the learnability of the software package. One aspect, however, that caused difficulties was saving work. The children were encouraged to save their workspace regularly in case of the software crashing. This actually only occurred once but a number of times the children lost work by accidentally clicking the close button (i.e. the x) on the main Logo screen window. This brought up the following dialogue box (c.f. figure 12):

Figure 12

Several times the children instinctively clicked on the OK button and lost their work. The following dialogue box could have avoided this:

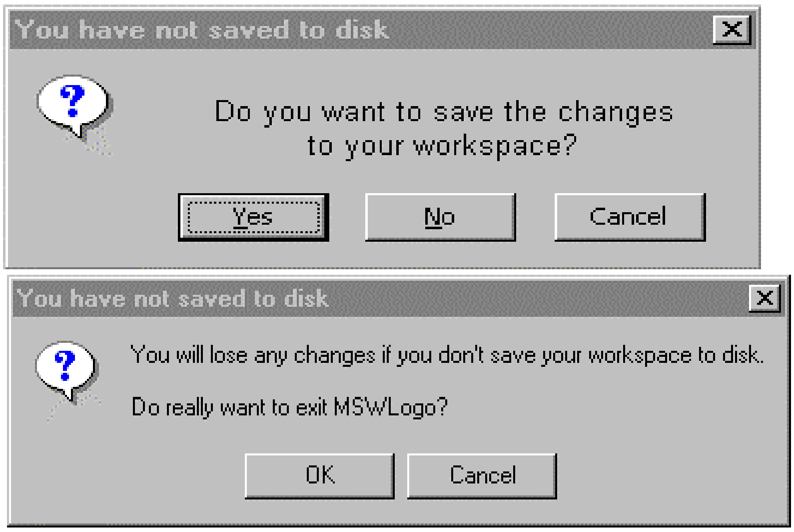


Figure 13

The package appears to be quite robust. It only crashed once in ten lessons use on three substantially different machines. The fact that this occurred on the machine with the lowest specification with the smallest amount of Random Access Memory may have been more than a coincidence. This occurred when the group three unwittingly wrote a recursive procedure, which went into a continuous loop. Even though the halt button was pressed to stop this, the program would not work properly. However it did not crash fully as significantly it allowed the children to save their work. From that perspective it provided a certain degree of recoverability.

Overall MSWLogo proved to be well within the range of ability for a sixth class group of students with a basic knowledge of using computers. Both members of group two had a slightly more advanced knowledge of using computers. This did not enhance their performance using Logo and significantly did not give them any advantage over the children with less experience. This could be advantageous from an educational sense as children who possibly don't have a computer at home need not feel inferior to those who do as would possibly occur for example using word processing or desktop publishing lessons. Hence these children can experience using computers from a relatively level playing field rather than feeling frustration at seeing how quickly children luckily enough to have computers advance during the aforementioned lesson types.

5 Conclusion

Curaclam Na Bunscoile[6] states in relation to geometry in the senior classes that

> *"(t)he work should involve investigating the properties of shapes and the relationships between them. The general approach might be to observe shapes in the environment, and to examine them in models made with concrete materials and in frameworks made with geostrips, drinking straws, etc.*

This research shows that Logo has potential in helping children understand the concept of an angle better and similarly provide a useful environment in which to explore the how this forms a crucial aspect of the relationship between regular polygons. Logo seems to provide a bridge between the concrete real world understanding of angle and shape that the approach mentioned above clearly gives children and the formal representation on paper of these concepts. A sophisticated knowledge of Logo is not required for this learning to take place. It was well within the ability of children who while not classified as requiring remediation in the normal educational sense, were struggling at times to keep up with the rest of the class in mathematics. Much learning actually occurred while trying to figure out solutions that were not overly well thought-out from a Logo programming perspective. Sometimes these inept solutions actually forced the children into thinking more deeply about the underlying geometrical context than well written neat and tidy

[6] The Irish Primary School Curriculum

procedures. This is important, as the successful use of Logo for enrichment may not be dependent on the quality of the children's ability to use Logo.

Many extravagant claims have been made in relation to its potential role in relation to children's education. However these claims have often been to its detriment. As Mary Cron(1983) a self-proclaimed Logo enthusiast points out,

> *"I believe the initial "true believer" syndrome that surrounded Logo was misleading and set expectations too high to touch ground in the typical classroom."*

There is no doubt that Logo has great potential as an educational package. This study shows the possible potential in relation to a particular section of the mathematics curriculum for a small group of children experiencing minor difficulties with mathematics in general. This may transfer to a remedial type setting and possibly to a whole class grouping for sixth class when divided into cooperative learning groups. The foundations for a course are laid out in the Lesson Notes (Appendix B) and the Worksheets (Appendix C). Suggested improvements over the initial course plan would be to include Lesson nine, the lesson on sub-procedures directly after Lesson 5, the lesson on procedures. A simple lesson on variables could be incorporated to give the children more power and flexibility in the final couple of lessons.

Logo probably should not be relied upon on its own to teach children about angle and relationships in regular polygons but should used in conjunction with traditional methods as an enrichment for deepening understanding rather than a replacement for standard practice.

The cooperative learning environment provided the children with a rich environment in which to explore the Logo programming language. Logo particularly lends itself to enabling children to work cooperatively at the computer. The relationships between the children were improved. They learned to be more tolerant and listen to their partner's advice. There was some competition between groups two and three. These groups at times were competing against each other to get their challenges working on time. However this was more in fun than in a challenging competitive manner. As the course developed this became less and less significant as the children increasingly wished to show their work with the other groups.

Winter(1989) highlights what he feels are the main principles for the conduct of Action Research; 'reflexivity', 'dialectics', 'collaborative resource', 'risk' and 'theory practice and transformation'. From a reflexivity perspective this thesis is based on modest claims drawn from judgements made from personal experience. These may or may not transfer to similar situations but the claims in themselves can be transformed into questions and a range of alternatives or modifications can be suggested contributing to a situation where previous particular interpretations have been taken for granted.

Dialectics starts with a notion of contradiction. Through this research I came to realise the contradiction in terms of my educational values which were not being lived out in practice. Through my action research project I came to find a way of accommodating these new ideas into my practice which has contributed to my professional knowledge and which may contribute in a similar way to my professional colleagues.

Working collaboratively in action research involves, taking other peoples viewpoints into consideration. Other peoples questioning of my statements and actions led to a more informed and focused insight on my part in relation to my reasoning around my research. I have outlined throughout this dissertation how various validation meetings with fellow action research colleagues contributed to this.

With Action Research you put yourself at risk through the process of investigation. Because you engage in a process of change of your practice you are in a way making a statement about your current practice that may not be positive. You admit perhaps to a lacking in your practice in an effort to improve that practice from a personal perspective yet hope that the manner in which you have improved your practice can be an inspiration to others and contribute to a living educational theory. This possibly involves more personal risk than a more positivist approach, which undertakes research on educational practices in general, rather than on an individuals personal practice.

The dichotomy between theory and practice is one that has enjoyed considerable attention in educational philosophy. Winter (1989) states that,

> *Theory and practice are not two distinct entities but two different and yet interdependent and complementary phases of the change process…theory being theory based in practice, is itself transformed by the transformation of practice. Theory and practice do not therefore, confront one another in mutual opposition: each is necessary to the other for continued vitality and development of both.*

In Action Research Methodology, research is based in practice. Theory being based in practice is itself transformed by the transformation of practice. Hence theory and practice need each other. They are mutually indispensable phases of a change process. This process is engendered in the notion of a living educational theory. Through dialogue I have identified my educational values and have discovered that some of these values were not being lived out in practice. Having gone through the process of this enquiry I have managed to successfully live out these values in my professional practice while at the same time improving a part of that practice.

> *If you can provide a validated account of how you have improved education through your action research, you have contributed to the creation of 'living theory' (*McNiff, Lomax and Whitehead *(1996)*

Hopefully this dissertation can at least in some small way contribute to a 'living educational theory'.

Perhaps the most satisfying aspect of this study on a personal note, was the way in which, my relationship with the children changed. Using more traditional means to deliver help to these children caused problems in relation to motivating the children especially towards the end of the last term and for sixth class children in particular. Increasingly I found myself being continually forced into an authoritarian role of keeping order and teaching by instruction. Because of the fact that the children were given more responsibility for their own learning and provided with in-built structures to motivate themselves it became totally unnecessary to take on an authoritarian role. As the course progressed a sense of shared experience created genuine empathy between these children that I had never experienced to such an extent in my teaching before. The dialogue between the children and I at the end of the course was inspiring. The Logo experience had a lot to contribute to this. The children had become accustomed to interacting with me in a very different manner. I was there to help present the basics of the functionality of Logo to the children. They were then responsible for what they did with that knowledge. I was there to facilitate their learning not to control it. When they had difficulties I tried to engage in discussion with the children and indirectly provide opportunities for the children to maybe look at the problem from a different perspective. I openly admitted to the children at times that I was not sure if some of their proposed plans would work. This seemed to enhance our relationship as they were less afraid to experiment and were correspondingly less afraid of being wrong. The words of Jerome Bruner describe eloquently the significance of this facet of education that is often over looked,

> *The shrewd guess, the fertile hypothesis, the courageous leap to a tentative conclusion - these are the most valuable coin of the thinker at work. But in most schools guessing is heavily penalised and is associated somehow with laziness.*

5.1 Recommendations and suggestions for future work

5.1.1 Recommendations

- Logo should not be relied on in isolation to teach children about angle and properties of regular polygons. It should be used in conjunction with normal classroom practice involving real world exploration linking this knowledge to the formal representations of the aforementioned concepts.

- Teaching Logo is more suited to senior primary school children. It can be a wonderful motivator, making the mathematics learning environment much more enjoyable for students who may not enjoy mathematics or who may have difficulties.

- To avoid confusion in describing and distinguishing between the internal and external angles of a shape the use of chalk on a blackboard as described in Footnote 2 and shown in figure 7 can be used to great effect to negating a problem documented in research (Cope, Smith & Simmons1992)

- The role of the teacher is crucial in the success of Logo. It seems clear that some teacher intervention is desirable to fully extend the children's learning experience particularly in a school-based learning of Logo. Caution is advised when intervening not to directly take control and inform the children immediately when they are in difficulty. It would be better to try and tease out a solution in dialogue with the children perhaps using knowledge the children already have and helping the children apply this knowledge in a new context.

5.1.2 Suggestions For Future Work

- Investigate the extent of the effects of peer to peer learning in cooperative groups learning Logo

- Investigate exactly what areas of the mathematics curriculum does Logo lend itself to and areas that Logo might prove to be detrimental to or should Logo be used independently of any specific mathematical goals.

- A larger scale investigation into the group dynamics involved in learning Logo in cooperative groups. What type of grouping is suited to this learning? How often should the groups change or should they change?

- Investigation into the potential of Logo used in a remedial setting with children who have specific difficulties with mathematics. Most research seems to focus on standard class groupings or gifted children. This balance needs to be addressed.

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7 Appendices

Appendix A. - Pre and Post Tests

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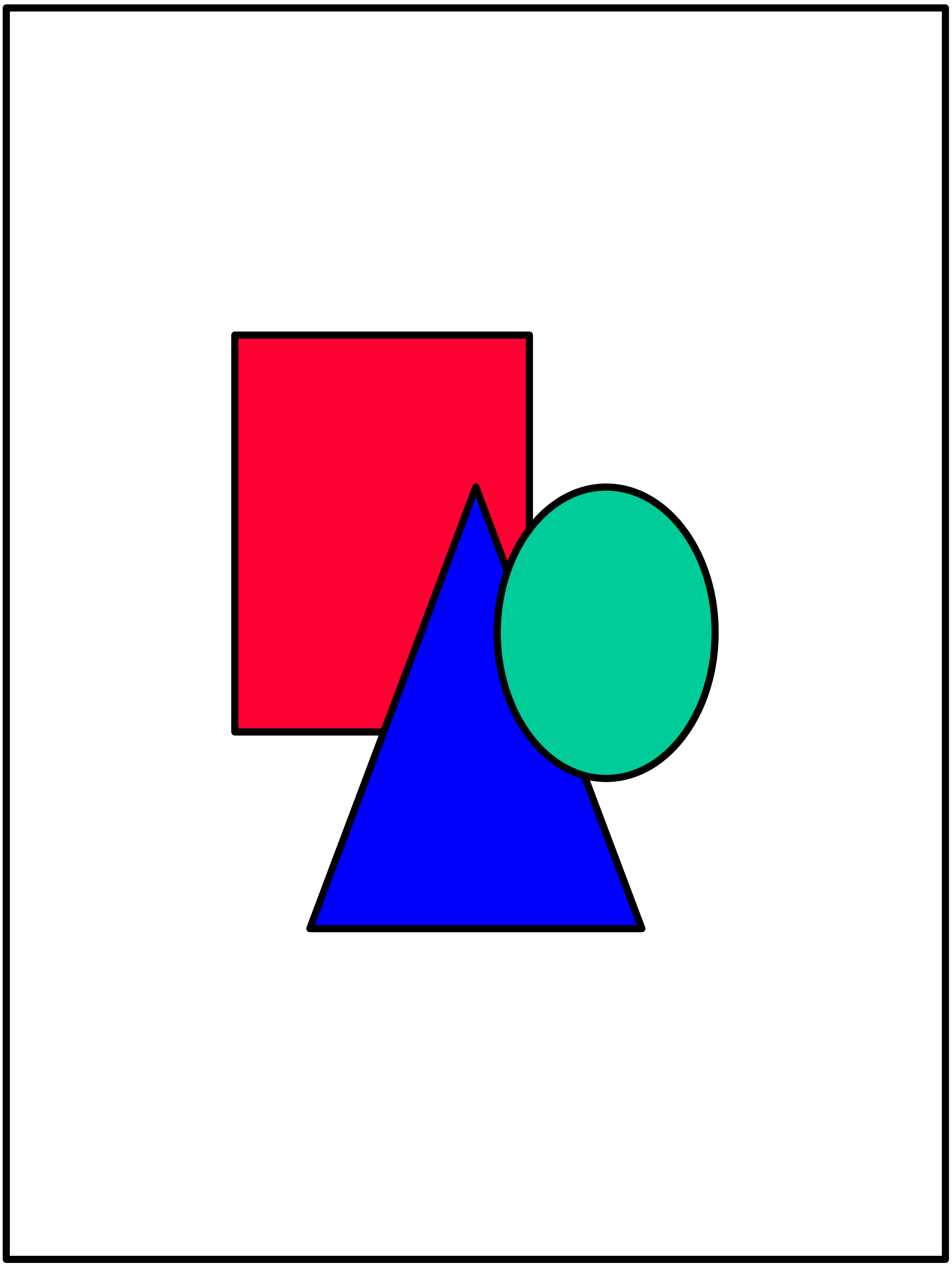
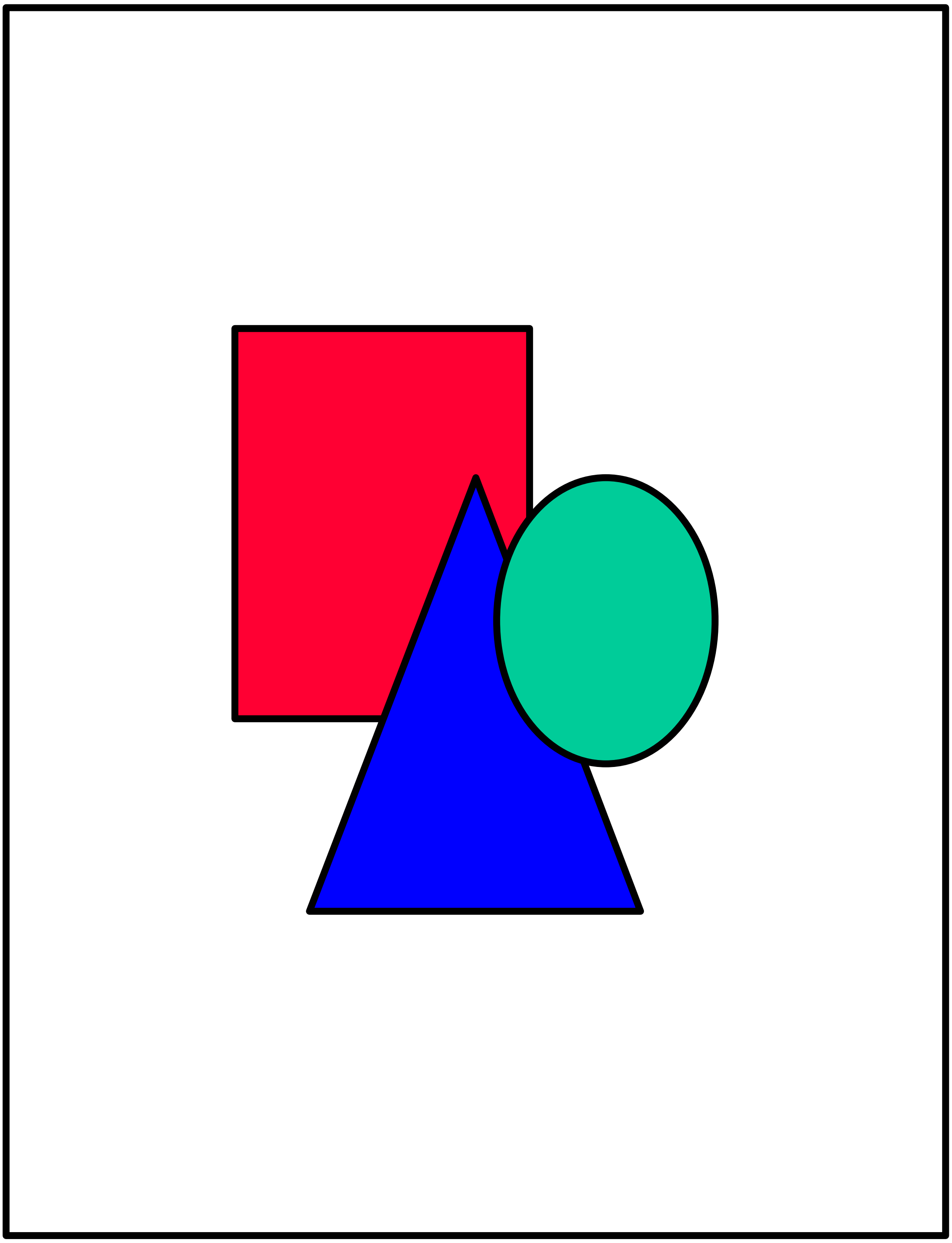
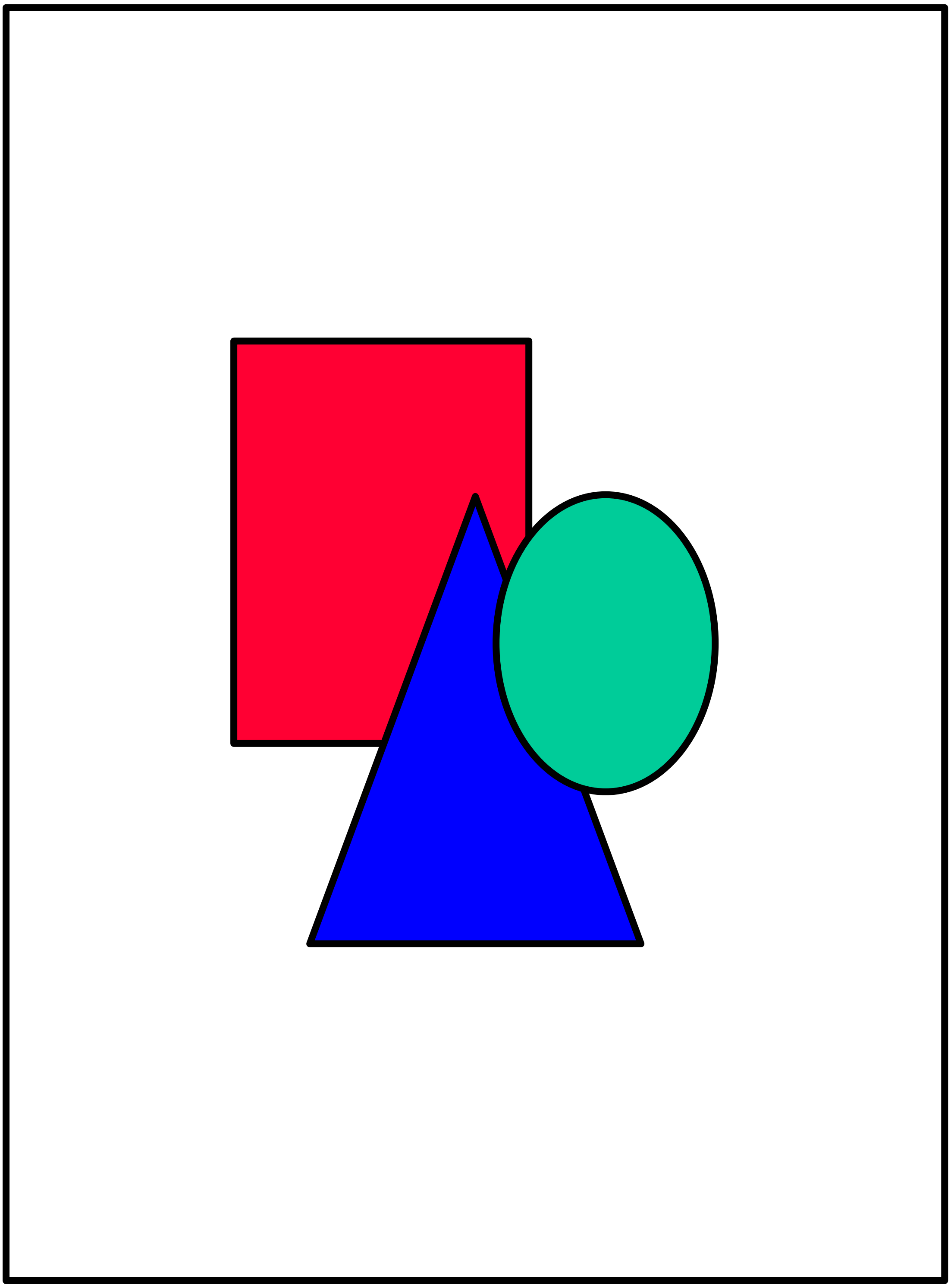
7.1 Appendix A – Pre and Post-tests

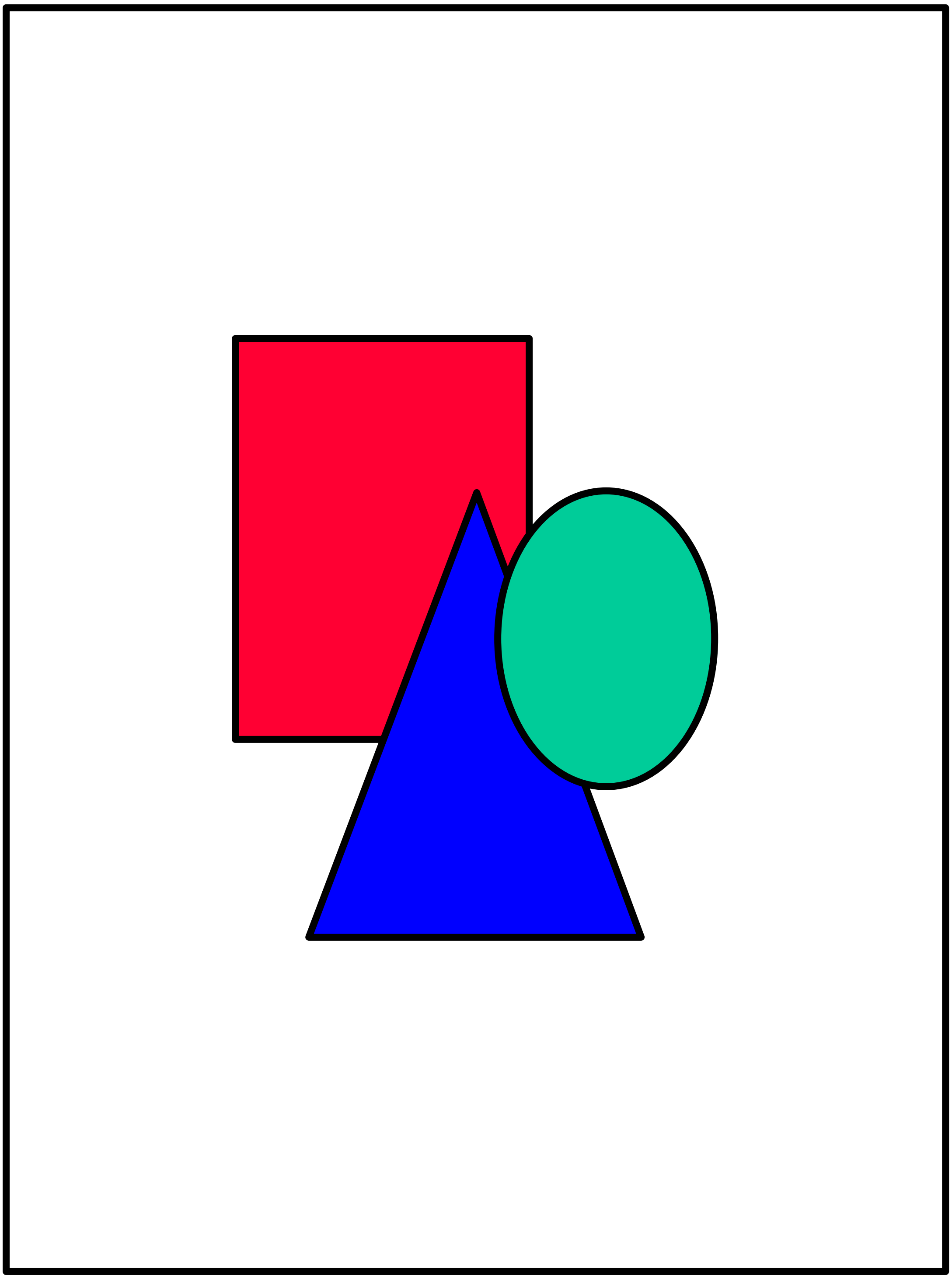
7.1.1 Pre-Test

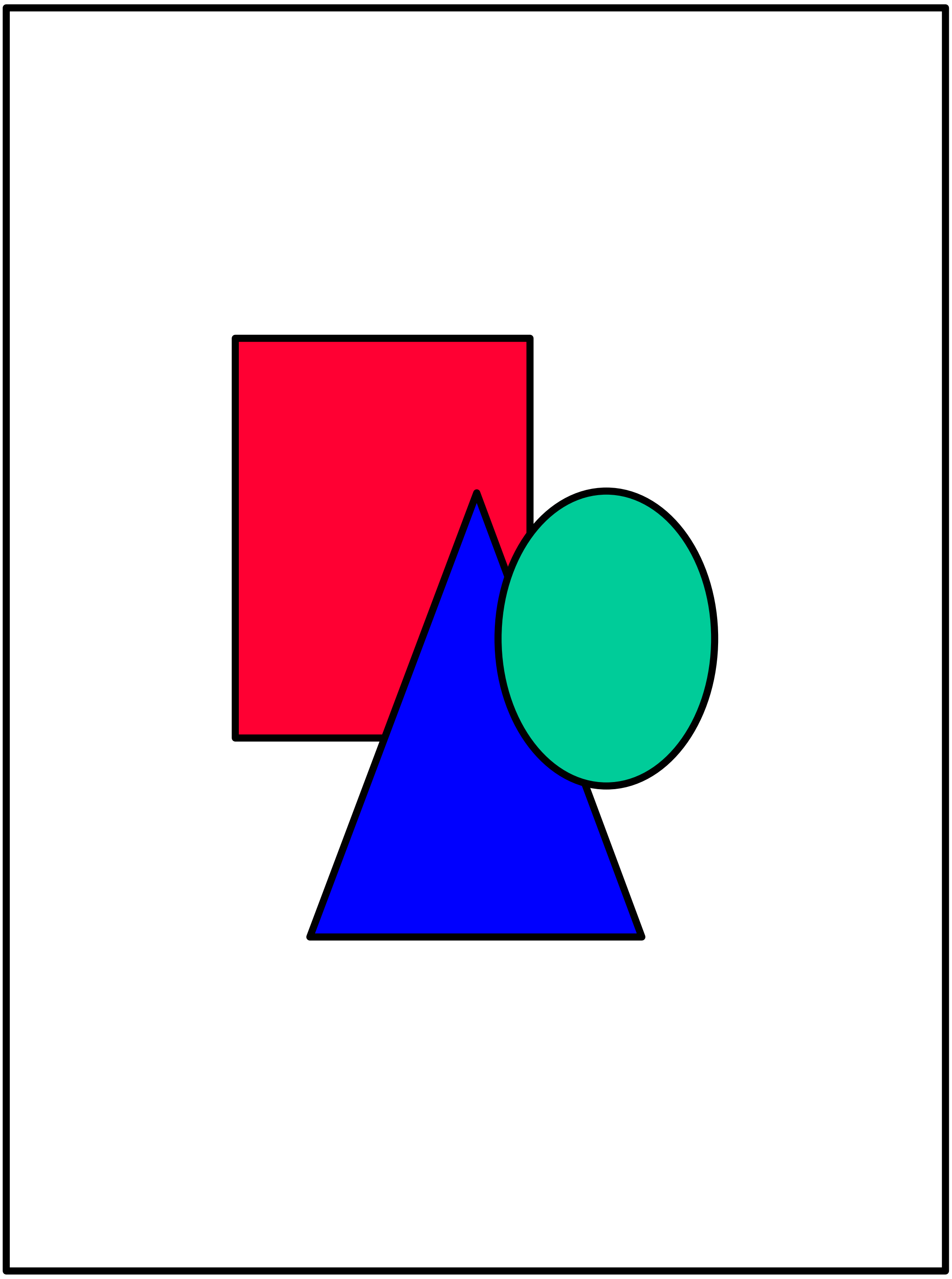


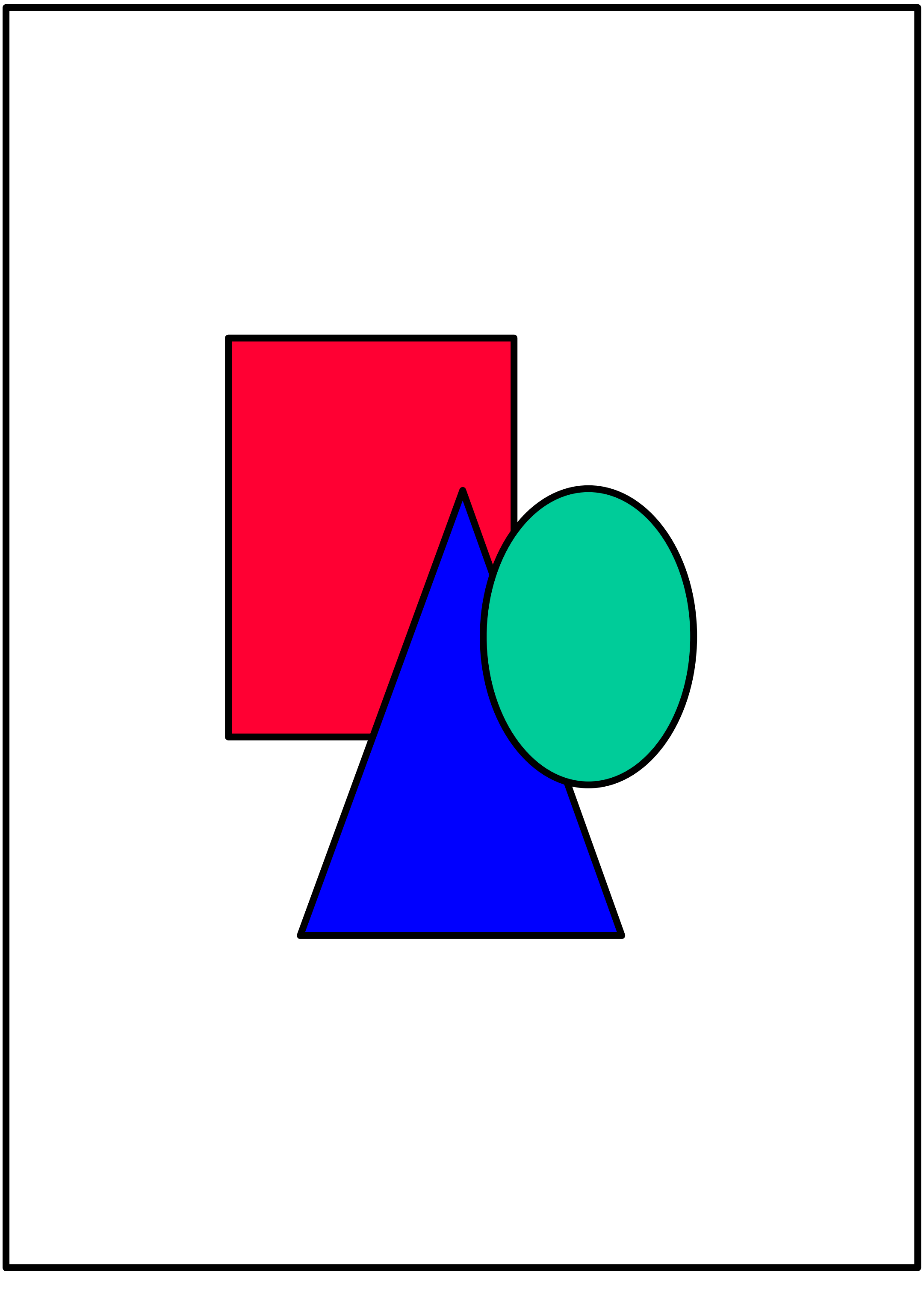




7.1.2 Post-test







Pre and Post Test Results

	Pre-test	Post-test
Ruth	34	43
Gráinne	38	48
Siobhán	35	46
Louise	32	44
Tom	34	47
Simon	37	46

Note: While the test results show a significant improvement the test not a standardised test. A proper standardised test would be more appropriate. The test did contribute to highlighting areas that the children had not grasped after learning about them in their main stream classes two weeks before hand. The children's understanding of these areas showed significant improvement after the Logo course.

7.2 Appendix B – Drumcondra Standardised Maths Test

Results

	Computation			Concepts			Problems			Total		
ID	RS	SS	PR	RS	SS	PR	RS	SS	PR	RS	SS	PR
1	29	112	78	32	111	77	24	105	63	85	111	76
2	25	104	59	33	113	81	26	110	76	84	110	75
3	34	131	98	33	113	81	32	139	99	99	128	97
4	29	112	78	34	115	84	22	101	52	85	111	76
5	25	104	59	33	113	81	28	117	87	86	111	78
6	33	125	95	39	132	98	31	131	98	103	137	99
7 *	26	105	64	25	101	53	26	110	76	77	105	62
8	29	112	78	35	117	87	26	110	76	90	115	84
9	32	121	92	35	117	87	31	131	98	98	126	96
10	29	112	78	35	117	87	29	120	91	93	118	89
11	28	109	73	32	111	77	27	113	81	87	112	80
12	30	114	83	32	111	77	26	110	76	88	113	81
13 *	26	105	64	27	104	60	18	93	32	71	101	53
14	35	140	99	39	132	98	32	139	99	106	148	99
15	31	118	88	38	127	96	25	108	70	94	120	91
16	25	104	59	39	132	98	32	139	99	96	123	93
17	27	107	68	37	123	94	31	131	98	95	121	92
18	35	140	99	35	117	87	29	120	91	99	128	97
19 *	25	104	59	32	111	77	21	95	38	78	105	64
20	27	107	68	39	132	98	32	139	99	98	126	96
21	29	112	78	36	120	90	29	120	91	93	118	89
22	31	118	88	37	123	94	29	120	91	97	124	95
23	34	131	98	38	127	96	31	131	98	103	137	99
24	33	125	95	32	111	77	25	108	70	90	115	84
25	30	114	83	40	140	99	31	131	98	101	130	98
26	30	114	83	29	107	67	27	113	81	86	111	78
27 *	30	114	83	27	104	60	21	95	38	78	105	64
28 *	19	94	33	24	100	49	24	105	64	67	99	47
29	28	109	73	33	113	81	29	120	91	90	115	84
30	35	140	99	38	127	96	30	125	95	103	137	99
31 *	21	97	42	28	105	63	16	89	24	68	98	44
32	25	104	59	37	123	94	24	105	64	86	111	78
33	26	105	64	40	140	99	29	120	91	94	120	91
34	31	118	88	35	117	87	26	110	76	92	117	87
35	30	114	83	35	117	87	29	120	91	94	120	91

Notes

1 **The scores of the children chosen are highlighted in blue.**

2 **RS** = Raw Score
SS = Standardised score
PR = Percentile

7.3 Appendix C – Lesson Plans

Lesson Plan 1 - Introductory Session

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left , right , back and forward commands on it

Lesson Plan

Time required: 30-40 minutes

Objective: To familiarise the students with the basic commands for MSWLogo

- Make sure the children are familiar with using the computer and keyboard. Use a sheet with a diagram of the computer keyboard on it to highlight the keys used most frequently with MSWLogo (FORWARD, BACK, RIGHT, LEFT).
- Have children sit in an area away from the computers while demonstrating the turtles four basic moves (FORWARD, BACK, RIGHT, LEFT). Each command must be typed in as follows. Examples: FORWARDD 50, RIGHT 90, FORWARD 100, LEFT 75, BACK 30. REMEMBER to emphasise the space between the command and the input number. Initially the children type one command and input number per line, pressing return after each one. Introduce students to the CLEARSCREEN (CS) command.

- After showing the children different distances and angles, have the children suggest numbers to see how the turtle moves. The children will see that the larger numbers make the turtle wrap around the screen. Now have children go to their own computers and explore the four basic commands.

- Allow the children plenty of time to "play" with the commands and input numbers. They need to become confident with this in order to be ready for the next lessons.

Optional Ideas:

- Graph paper: Have students draw a simple design using straight lines and 90 degree angles on graph paper first.

- Body geometry: Have students 'walk out' the design they want to create (ie. square, circle).

Lesson Plan 2 - Abbreviations and Creating Own Designs

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left , right , back and forward commands on it
- Charts with abbreviations of commands
- Charts with some designs involving straight lines and right angles such as the following: cross, window, car, disc

Lesson Plan

Time required: 30-40 minutes

Objectives:

- To allow students to 'play' and 'explore' with the basic commands and concept of 90 degree angles.
- To introduce the abbreviated versions of the commands
- To learn that by changing the input numbers, students will achieve unique designs. In doing so, students begin to learn to 'debug' (correct) the mistakes they have made.

- Introduce abbreviations to the children. Discuss logic of.

- Before having the students create their design on the computer, have them choose a design from the chart paper and draw it out on graph paper first. This will help the students to more clearly understand the right angles, and which direction they must turn the turtle.

- Let one square on the graph paper represent one 'turtle' step. E.g. FD 10 will use 10 squares.

- If the students are still having difficulty deciding which command to give the turtle, have them try body geometry to understand which way the turtle will move/ turn. For example to make a square: Have the students find their own space and tell them to walk forward 5 small steps, turn right 90 degrees facing the next wall. Do this 3 more times making a complete square. To make a circle have the students walk forward one step, turn right one step- emphasising it takes 360 steps to make a complete circle.

- Later on, allow the students time to create their designs.

- Continue with this lesson until the students are comfortable with creating their own design.

Optional Ideas:

- Any design using straight lines and right angles is suitable for this lesson

Lesson Plan 3 - Creating a Square

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left, right, back and forward commands on it
- copies for each child of the commands for creating a square; markers for each child to use to keep track of their place on the list of commands

Lesson Plan

Time Required: 30 - 40 minutes

Objectives:

- Students will learn about 90-degree angles and how to create a square.
- To learn about the repeat command.

- Make sure the children are familiar with using the computer and keyboard. This will ensure more success when using MSWLogo.
- Make sure the children are familiar with MSWLogo and the four basic moves the turtle makes. Review the four basic commands as well as the clearscreen (CS) command with the students. See Lesson 1 for previously covered concepts.

- Have children sit in an area away from the computers while you demonstrate the way a square is created. Each command must be typed in as follows: FD 40, RT 90, FD 40, RT 90, FD 40, RT 90, FD 40, RT 90. REMEMBER to emphasise the space between the command and the input number. The children type one command and input number per line, pressing return after each one. If the students are having difficulty understanding the rt 90 command, have them use body geometry to physically 'walk out' a square.

- It is important for the children to understand the process used in making a square before introducing the quicker method to them. Once the students understand the process involved in creating a square show them how to use the command repeat. To create a square with this command you would type in the following: REPEAT 4 [FD 40 RT 90].

- After the students have created a square following your instructions, allow them plenty of time to 'play' at creating different sized squares by changing the input number on the FD command. Introduce making a square using the LT 90 command rather than the RT 90 command.

Optional Ideas:

- Make a square within a square

- Make a square beside another square

- Make a window(s) using squares

- Combine a square with straight lines to make a flag, a ladder, glasses, etc.

Lesson Plan 4 - Pen Up/ Pen Down and Hide/Show

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left , right , back and forward commands on it

Lesson Plan

Time required: 30-40 minutes

Objectives:

- Students will become familiar with the pen up and pen down commands.
- To provide students with new commands which will allow them to explore more freely when using the MSWLogo program.

- Pen up and pen down is a little confusing at first for the children and requires practice
- Demonstrate to the students how to use PENUP (PU) to move the turtle to a new location without drawing a line. For example, PU FD 50. The turtle will move forward 50 without leaving a line. Now put the PENDOWN (PD) and begin drawing with the various commands.

- The students 'play' and explore on their own with what these two new commands will allow them to create.
- Continue with this lesson until the students are comfortable with the pen up/ pen down commands.
- Repeat process for HIDE and SHOW

Optional Ideas:

- Make a highway
- Try drawing a signpost
- Anything that requires the turtle to be moved without leaving a line

Lesson Plan 5 - Using the Editor

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall

Lesson Plan

Time required: 30 minutes

Objective: Students will learn how to create their own procedures and save them on disk.

- This lesson can be introduced at any time throughout the lessons.
- Have children sit in an area away from the computers while demonstrating this lesson.
- Demonstrate that by typing square Logo does not understand.
- Demonstrate using the edit command emphasising the use of single quotations and space between edit and the quotation marks.
- Create a new design with the students. When ready to save, demonstrate the method of saving e.g. File → Save As.. using the .lgo extension.
- When students choose File-Open, they will notice the name of their saved page. Students may select this page at any time to revise or use in making other designs/pictures.
- Discuss the advantages of procedures and being able to save them.

Optional Ideas

- Creating procedures for the shapes already drawn
- Mini-lesson on Disk Care

Lesson Plan 6 - Creating a Triangle

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left, right, back and forward commands on it
- copies for each child of the commands for creating a triangle; markers for each child to use to keep track of their place on the list of commands OR write the commands on the board/ chart

Lesson Plan

Time required: 30 - 40 minutes

Objectives:

- Students will learn how to make a triangle.
- Students will explore different angles.

- Children are very interested in changing the square into another shape and will ask how to make a triangle early in the use of MSWLogo.
- Make sure the children are familiar with MSWLogo and the CLEARSCREEN (CS) command with the students.

- Have children sit in an area away from the computers while asking the students how they think a triangle is created. Accept a number of different answers from the students while you demonstrate each of their responses. When the class is ready, show them the correct way (if it has not already been discovered) to create a triangle. Each command must be typed in as follows: RT 120 FD 30 RT 120 FD 30 RT 120 FD 30.

- REMEMBER to emphasise the space between the command and the input number. It is best that the children type one command and input number per line, pressing return after each one.

- There is a quicker way for the children to make a triangle, but it is important for the children to understand the process used in making a triangle before introducing the quicker method to them. Once the students understand the process involved in creating a triangle show them how to use the command repeat. To create a triangle with this command type in the following: REPEAT 3 [FD 30 RT 120].

- After the students have created a triangle following your instructions, allow them plenty of time to 'play' at creating different sized triangles by changing the input number on the FD command. Introduce making a triangle using the LT command rather than the RT command.

Optional Ideas:

- Make a triangle within a triangle

- Make a triangle beside another triangle; perhaps a mountain range
- Make a house using a square and a triangle
- Combine a triangle with other shapes/ lines to create a design
- Have students create a yield sign with the word yield inside (very challenging at this time)

Lesson Plan 7- The Total Turtle Theorem

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left , right , back and forward commands on it
- copies for each child of the diagram depicting External and internal Angles

Lesson Plan

Time required: 30-40 minutes

Objectives:

- The students will become aware of how useful the repeat command is in creating designs quickly.

- Students will explore different angles and be aware that the sum of the external angles of a closed shape is 360

- Make sure the children are familiar with MSWLogo and the CLEAR SCREEN (CS) and REPEAT commands.
- Have children sit in an area away from the computers while reviewing and demonstrating the basic commands for making a triangle and discuss how repeat works again.
- Discuss the difference between internal angles and external angles.
- Discuss in relation to Logo paying particular attention to the physical rotation of the turtle at each corner of a shape.
- Introduce way to draw Square and Triangle using the knowledge that the turtle turns a total of 360.
- Challenge students to further this by drawing pentagons, hexagons etc.

Optional Ideas:

- Get students to physically walk out the turns involved
- Draw up a table highlighting the total sum of the internal and external angles for different shapes.

Lesson Plan 8 – The Circle

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left, right, back and forward commands on it
- copies for each child of the commands for creating a circle; markers for each child to use to keep track of their place on the list of commands OR write the commands on the board/ chart

Lesson Plan

Time required: 30 - 40 minutes

Objectives:

- Students will learn how to make a circle.

- Children are very interested in changing the square into another shape and will often ask how to make a circle early in the use of MSWLogo.
- Make sure the children are familiar with MSWLogo and the CLEARSCREEN (CS) command with the students.
- Have children sit in an area away from the computers while asking the students how they think a circle is created. Accept a number of different answers from the

students while you demonstrate each of their responses. When the class is ready, show them the correct way (if it has not already been discovered) to create a circle.

- After the students have created a circle following your instructions, allow them plenty of time to 'play' at creating different sized circles by changing the input number on the FD command. Introduce making a circle using the LT command rather than the RT command.

Optional Ideas:

- Make a circle within a circle
- Make a circle beside another circle;
- Make a man using a circle
- Combine a circle with other shapes/ lines to create a design
- Have students create a stop sign with the word stop inside

Lesson Plan 9 – Subprocedures

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having left, right, back and forward commands on it

Lesson Plan

Time required: 30 - 40 minutes

Objectives:

- Students will learn how to make a concept of procedures as building blocks.

- Recall the advantages of being able to write procedures.
- Discuss idea of building blocks
- Pose Two Square Problem and discuss solutions. Point pupils in the direction of decomposing the problem into smaller sub-problems
- Demonstrate possible solutions
- Discuss the House challenge. Ask the children what would lend itself to a sub-procedure. Would you need separate sub-procedures for each windows etc.
- Children plan design on paper first.

Optional Ideas:

- Using the house to create a street.
- Breaking tasks into smaller instructions.

  i.e. do make tea

  boil kettle

  make tea

  pour tea

- Discuss possible sub-procedures within each.

Lesson Plan 10- Creating Designs using Repeat

Materials Needed:

- charts with commonly used MSWLogo commands ready and set up on the wall
- page with turtle having LEFT , RIGHT , BACK and FORWARD commands on it

Lesson Plan

Time required: 30-40 minutes

Objectives:

- The students will become aware of how useful the repeat command is in creating designs quickly.
- Students will explore different angles.

- Make sure the children are familiar with MSWLogo and the CLEAR SCREEN (CS) or clear graphics (cg) and repeat commands.
- Have children sit in an area away from the computers while reviewing and demonstrating the basic commands for making a square and discuss how repeat works again.

- After making the square (e.g. REPEAT 4 [FD 40 RT 90]) turn the turtle 45 degrees by typing RT 45; then type in REPEAT 4 [FD 40 RT 90]. You will notice the square is at a different angle. Repeat this procedure a few more times. CLEAR SCREEN (CS).

- Let the students give different input numbers (two or three examples should be enough)

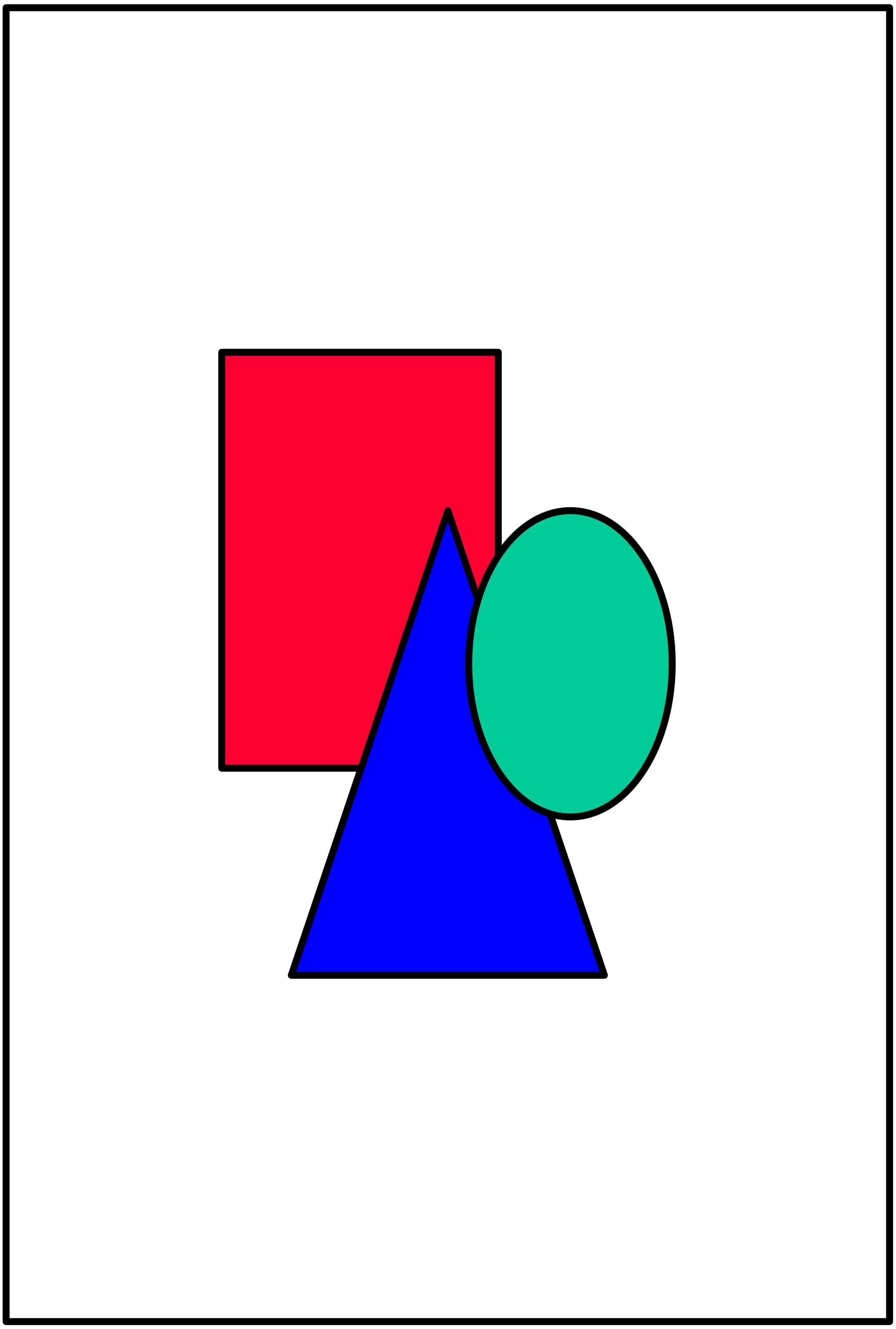
- Now let the students create their own designs by changing the input numbers. Introduce making a rotating square design using LT 90 command rather than the RT 90 command.

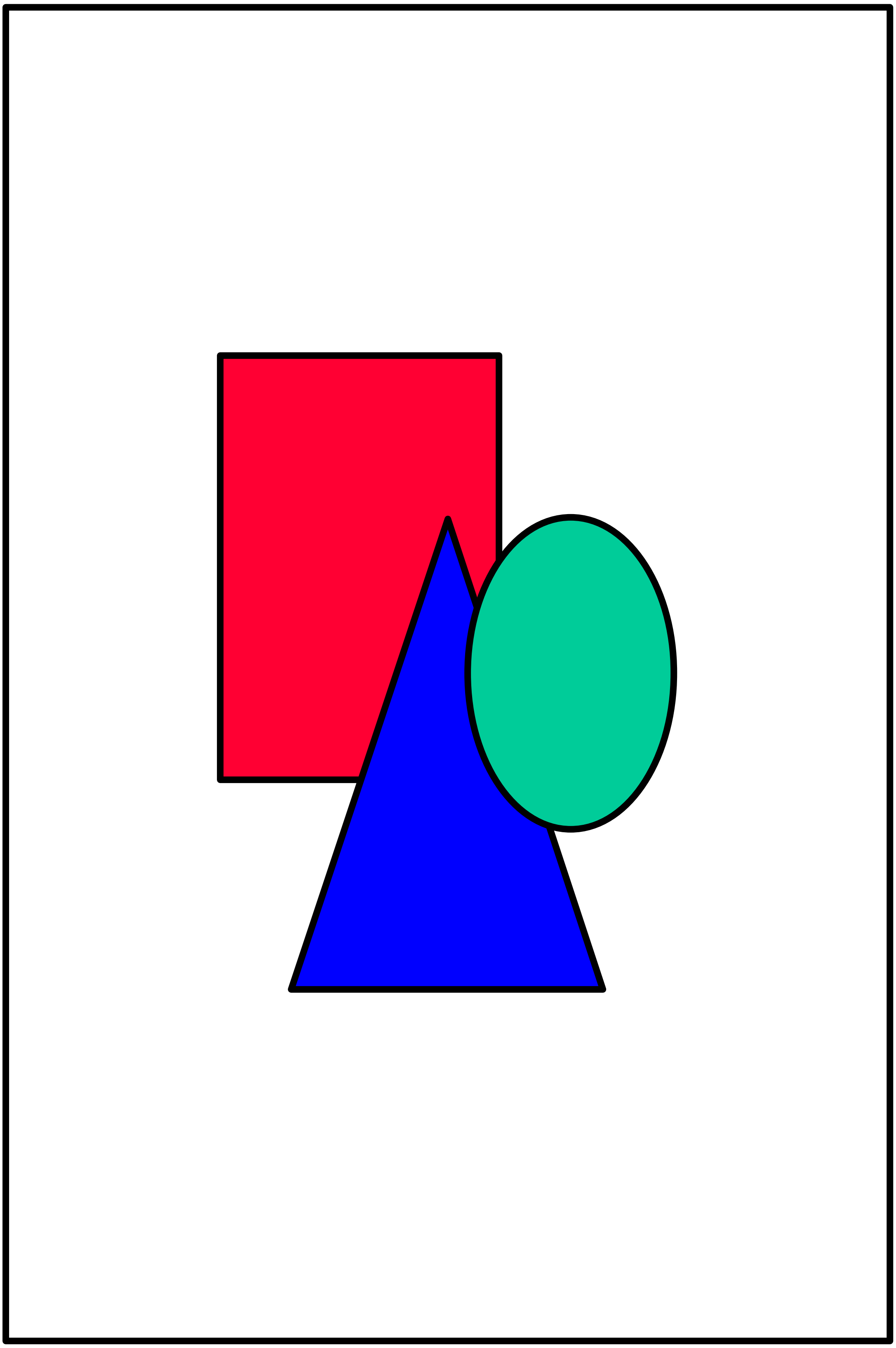
- Allow the children explore designs and patterns rotation other shapes.

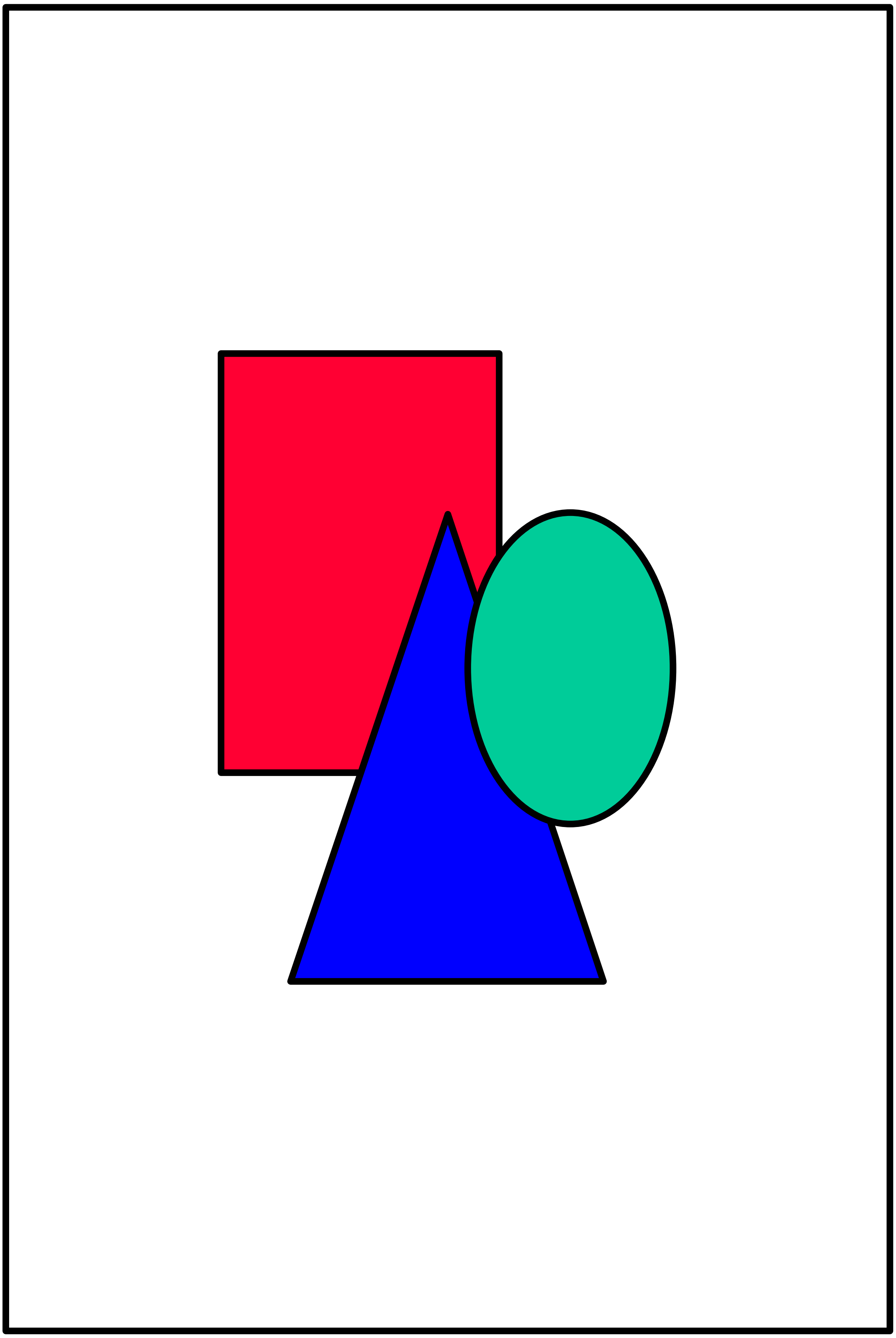
Optional Ideas:

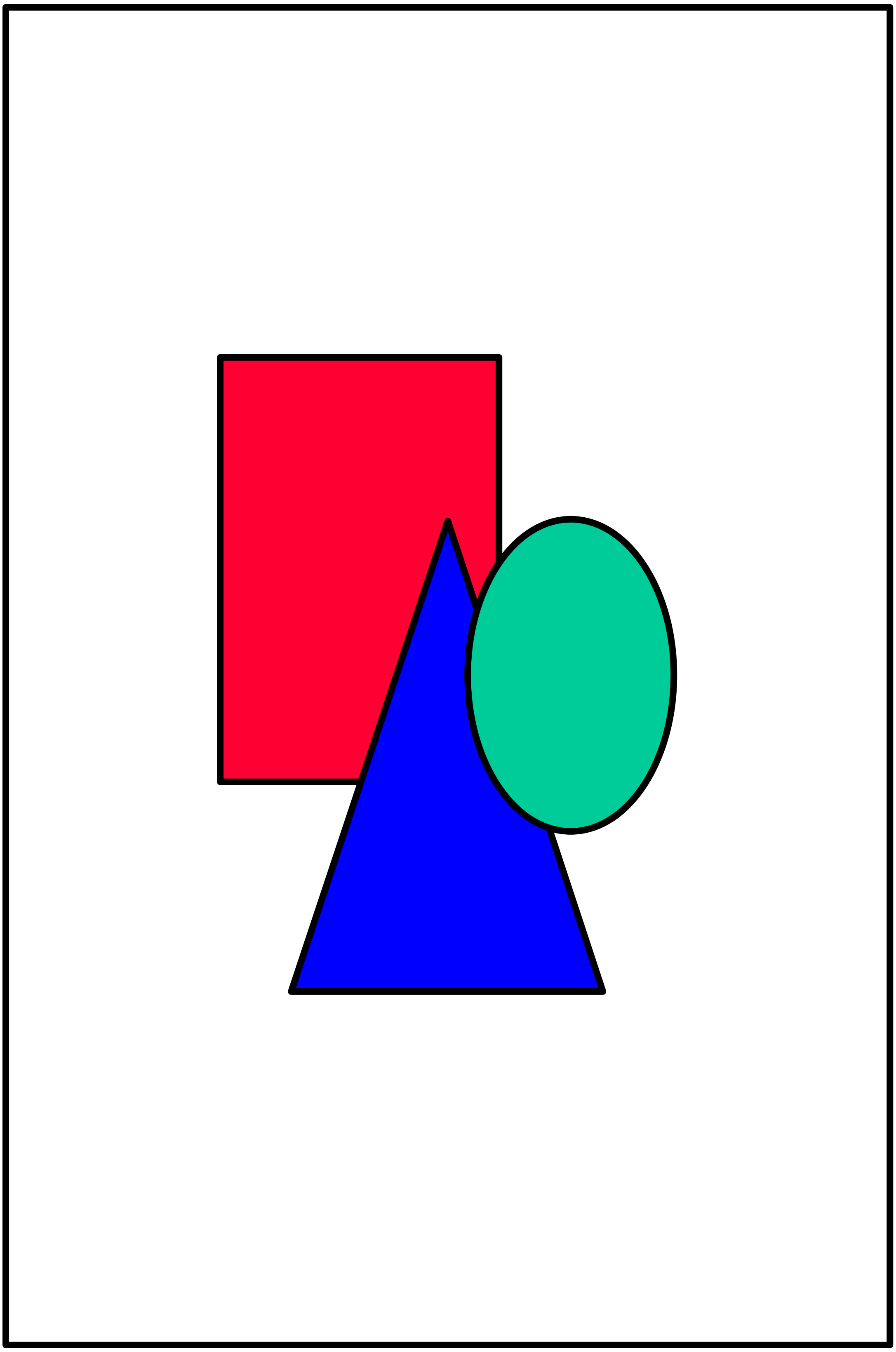
- Create multiple rotating designs by PEN UP (PU) the turtle, move to a new location, PEN DOWN (PD) and type in the name of the procedure again.

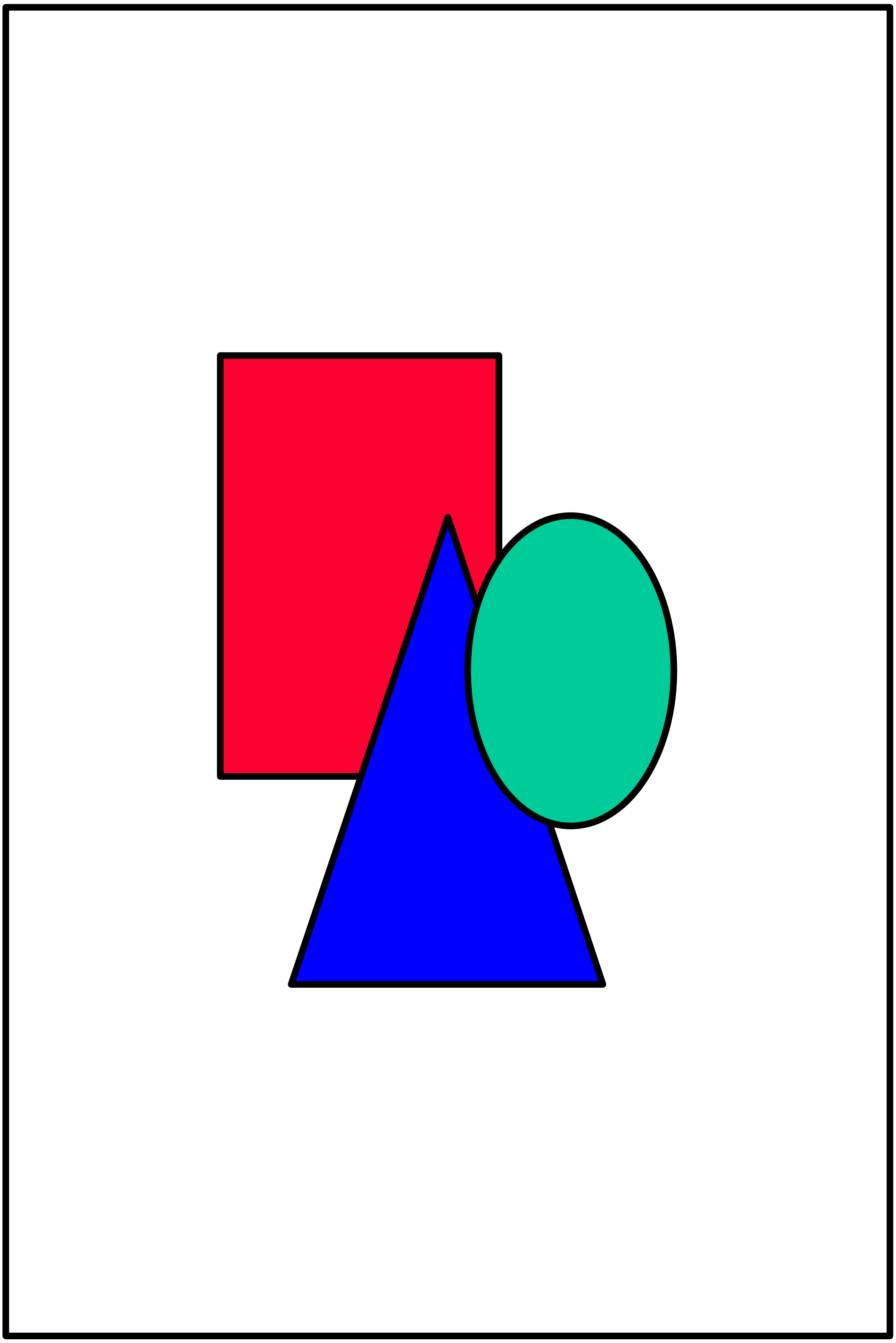
7.4 Appendix D – Logo Worksheets

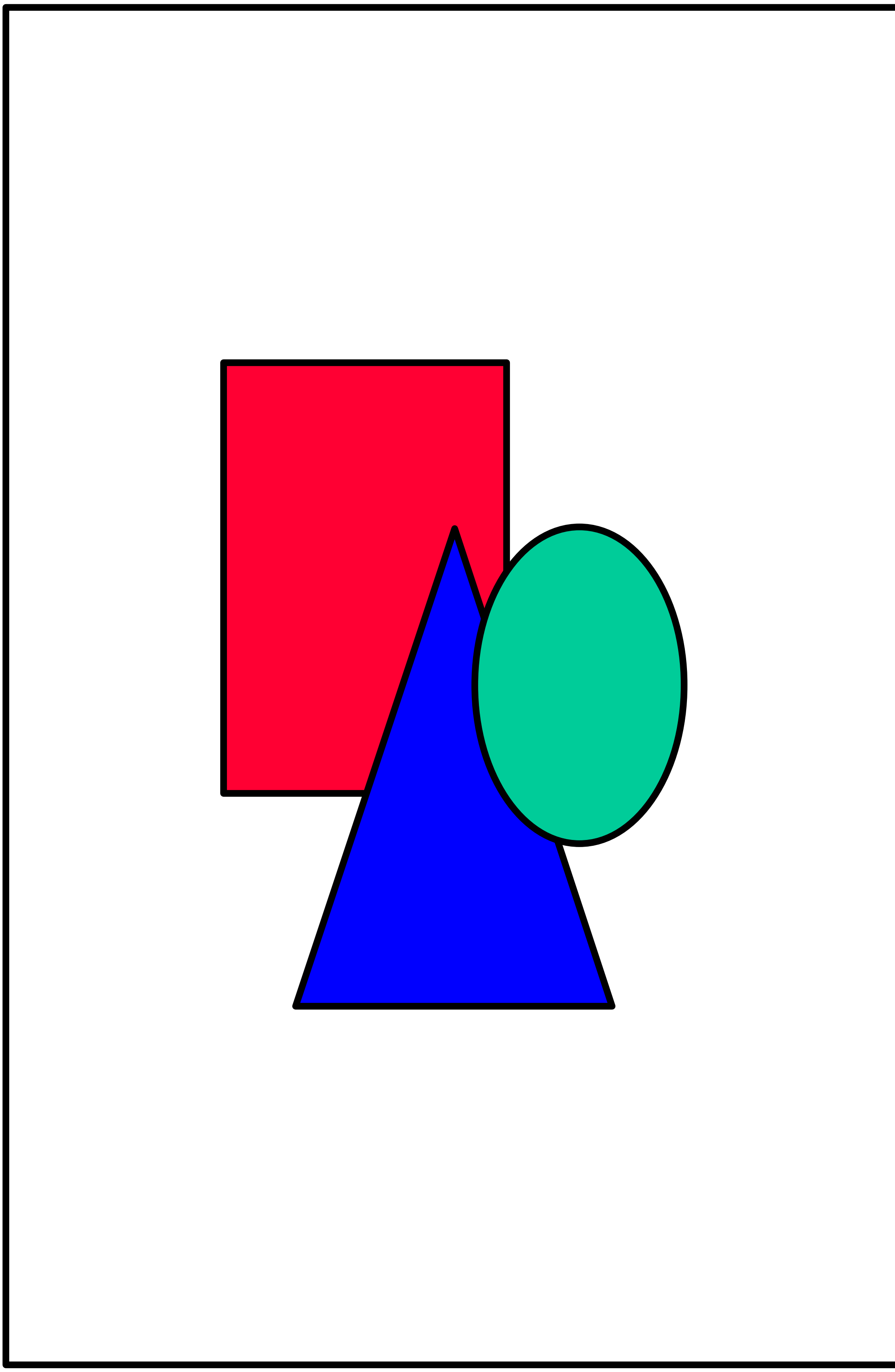


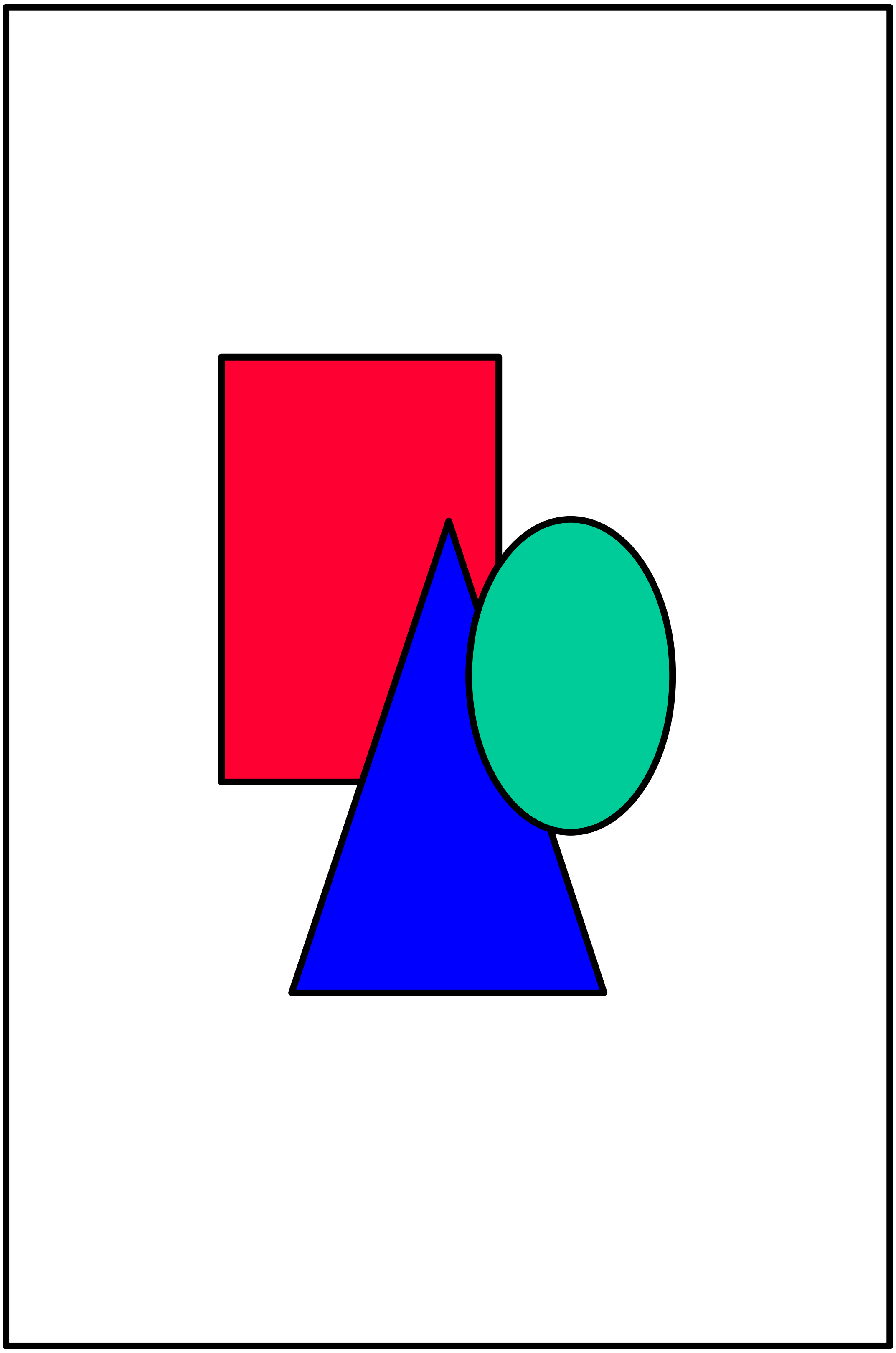












Logo Worksheet 8

The Circle

One way to draw a circle is to imagine it as a 360 sided polygon.

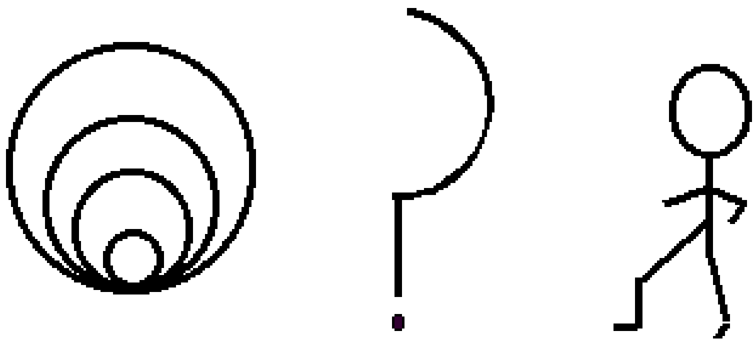
Recall!!
To draw a 8 sides polygon we used REPEAT 8[FD 100 RT 360/8]

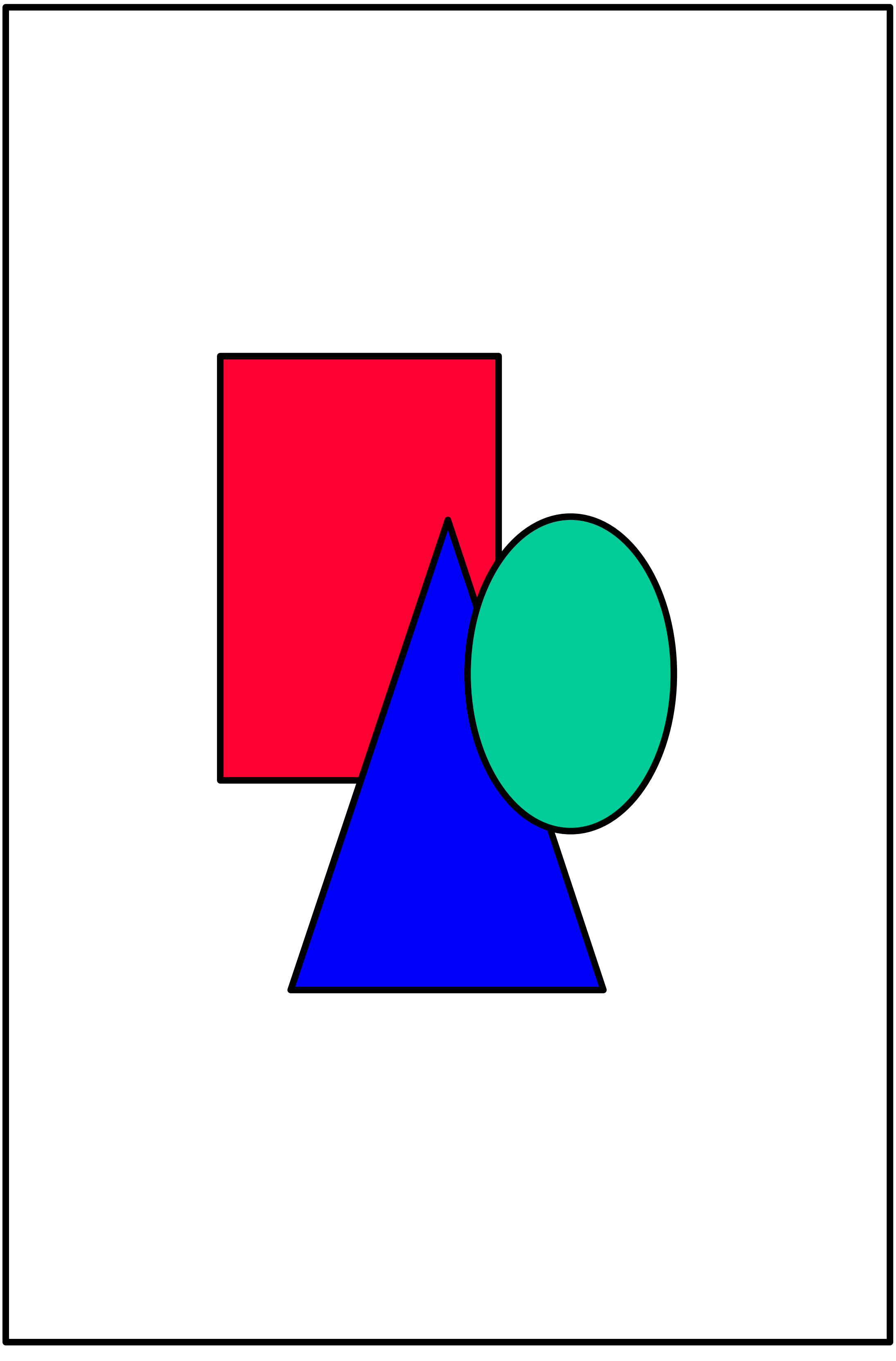
To draw a 360 sided polygon we can use REPEAT ___ [FD 1 RT 360/ ___]

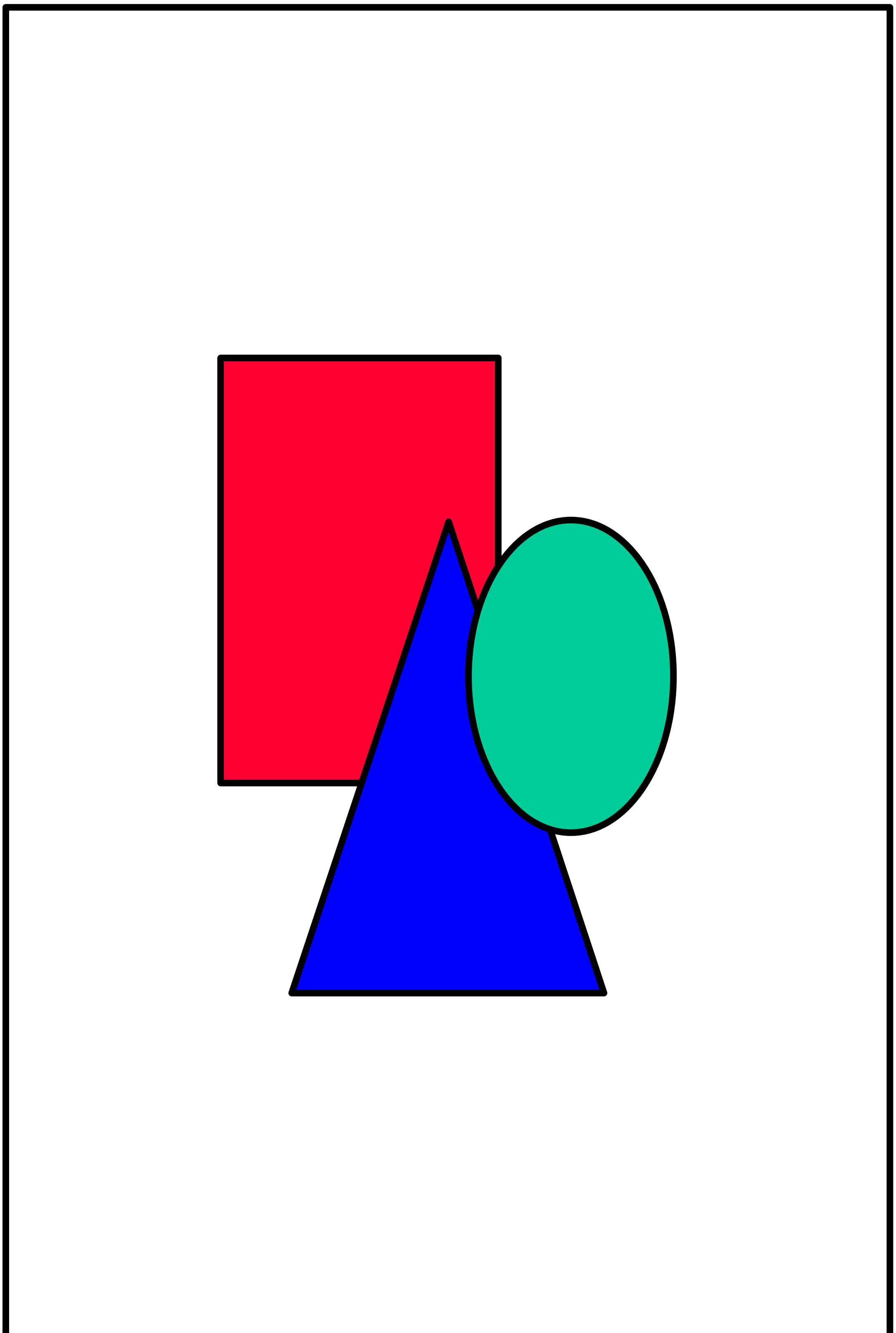
Challenge 1:
Fill in the spaces above and use it to write a procedure to draw a circle.

Challenge 2: Given a full circle is 360, write a procedure to draw the following half circle

Challenge 3:
Draw the following designs.







7.5 Appendix E – Description of the Computers used.

Computer Number 1.

Gateway 2000 G6 233 MHz Pentium II Processor with MMX

32 MB RAM

17” SVGA Monitor

4.2 GB Hard Drive

Windows 95 Standalone Machine

Computer Number 2.

Gateway 2000 P5 133 MHz Pentium Processor

32 MB RAM

15” SVGA Monitor

2.1 GB Hard Drive

Windows 95 Standalone Machine

Computer Number 3.

Gateway 2000 486 DX2-66 MHz Processor

8 MB RAM

14” SVGA Monitor

540 MB Hard Drive

Windows 95 Standalone Machine

7.6 Appendix F – Questionnaire

1. Did you enjoy using Logo or not? Give reasons for your answer.

   ____

   ____

2. Do you think Logo is a good way to learn about angle and shape? Give reasons for your answer.

   ____

   ____

3. Did you find it helpful to have a partner to work with? Give reasons for your answer

   ____

   ____

4. Would you prefer to work on your own or with a partner? Why?

   ____

   ____

5. Did you experience any difficulties working with a partner? If so give details.

   ____

   ____

6. Did you find Logo easy or difficult to use?

____

____

7. What are the best points about Logo in you opinion?

____

____

8. What are the worst points, if any about using Logo?

____

____

9. What advantages does Logo have over other educational packages you have used? (eg. Word processing, Educational Games, Desktop publishing etc.)

____

____

10. What disadvantages does Logo have over other educational packages you have used? (E.g. Word processing, Educational Games, Desktop publishing etc.)

____

____

7.7 Appendix G- Logo Test

1. Open a logo file called test_ _.lgo (fill in your initials instead of the blanks i.e. if your name is John Smith the file will be called testjs.lgo)

2. Write procedures to draw

a square

a rectangle

a triangle

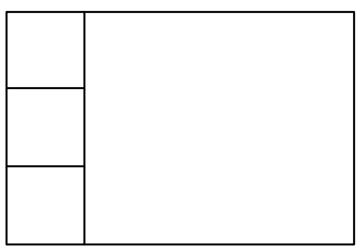
a pentagon

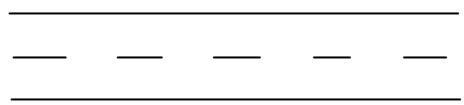
a hexagon

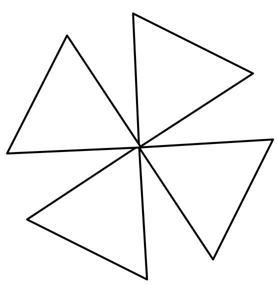
an octagon

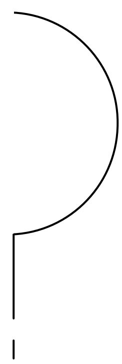
a circle

3. Write procedures to draw the following.









Logo Solutions

Gráinne

```
to tri :size
repeat 3[fd  :size rt 120]
end

to sq :size
repeat 4[fd :size rt 90]
end

to rec
repeat 2[fd 90 rt 90 fd 300 rt 90]
end

to pent :size
repeat 5[fd :size rt 360/5]
end

to hex :size
repeat 6[fd :size rt 360/6]
end

to oct :size
repeat 8[fd :size  rt 360/8]
end

to circ :size
repeat 360[fd :size rt 360/360]
end

to wind
rec
repeat 3[sq 30]
end

to road
rt 90
fd 200
rt 90
pu
fd 100
pd
rt 90
fd 200
rt 90
```

```
fd 50
rt 90
repeat 4[pu fd 50 pd fd 50]
end
to 4star
repeat 4[tri 30 rt 90]
end

to qmark
rt 90
repeat 180[fd 1 rt 180/180]
lt 90
fd 50
pu
fd 10
pd
fd 5
end
```

Ruth

```
to tri :size
repeat 3[fd :size rt 360/3]
end
```

```
to sq :size
repeat 4[fd :size rt 90]
end

to rec
repeat 2[fd 50 rt 90 fd 100 rt 90]
end

to pen
repeat 5[fd 30 rt 180/5]
end

to win
repeat 4[fd 30 rt 90]
fd 30
repeat 4[fd 30 rt 90]
fd 30
repeat 4[fd 30 rt 90]
fd 30
rt 90
fd 200
rt 90
fd 90
```

```
rt 90
fd 200
end

to road
fd 100
pu
rt 90
fd 50
rt 90
pd
fd 100
rt 90
pu
fd 25
rt 90
repeat 5[pd fd 20 pd fd 20]
end

to tricros
tri 50
end

to questionmark
repeat 360[fd 1 rt 180/360]
lt 90
fd 100
pu
fd 30
pd
fd 20
hp
end
```

Louise

```
to tri :size
repeat 3[fd :size lt 360/3]
end

to sq :size
repeat 4[fd :size rt 360/4]
end

to rec :len :width
repeat 2[fd :len rt 360/4 fd :width rt 360/4]
end
```

```
to pent :size
repeat 5[fd :size rt 360/5]
end

to hex :size
repeat 6[fd :size rt 360/6]
end

to oct :size
repeat 8[fd :size rt 360/8]
end

to win
rec 150 50
repeat 5[sq 50 lt 90]
repeat 5[sq 50 lt 90]
repeat 5[sq 50]
end

to road
rt 90
fd 150
rt 90
pu
fd 50
pd
rt 90
repeat 10[fd 10 pu fd 5 pd]
lt 90
pu
fd 50
pd
lt 90
fd 150
end

to triangles
tri 60
lt 120
pu
fd 30
pd
tri 60
rt 180
end

to questionmark
rt 120
circ 180/360
lt 90
```

```
fd 100

pu

fd 10

pd

fd 5

end
```

Siobhán

```
to tri :size

repeat 3[fd :size rt 360/3]

end


to sq :size

repeat 4[fd :size rt 360/4]

end


to rec :lenght :width

repeat 2[fd :lenght rt 90 fd :width rt 90]

end


to pent :size

repeat 5[fd :size rt 360/5]

end

to hex :size

repeat 6[fd :size rt 360/6]

end


to oct :size

repeat 8[fd :size rt 360/8]

end


to cir :size

repeat 360[fd :size rt 360/360]

end


to win

repeat 3[sq 30 fd 30]

rt 90 fd 30

rec 120 90

end


to road

rt 90

fd 200

rt 90

pu fd 100 pd

rt 90 fd 200

pu rt 90 fd 50 rt 90
```

```
repeat 5[fd 20 pu fd 20 pd]
end

to settri
repeat 4[tri 60 rt 60]
end
to quest
repeat 360[fd .5 rt 180/360]
end

to questm
repeat 360[fd .5 rt 180/360]
rt 180 fd 100
pu fd 20 pd  fd 20
end
```

Simon

```
to triangle
repeat 3[fd 100 rt 120]
end

to square :size
repeat 4[fd :size rt 90]
end

to rec
fd 50
rt 90
fd 20
rt 90
fd 50
rt 90
fd 20
end

to pentagon
repeat 5[fd 10 rt 360/5]
end

to hexagon
repeat 6 [fd 50  rt 360/6 ]
end

to octagon
repeat 8 [fd 40 rt 360/8]
end

to shape1
repeat 4[fd 150 rt 90]
square 50
```

```
fd 50
square 50
fd 50
square 50
end

to road
fd 200
rt 90
pu
fd 50
rt 90
pd
fd 200
rt 90
pu
fd 25
rt 90
pd
repeat 4[fd 25 pu fd 25 pd fd 25]
end

to star
repeat 4[triangle rt 90]
end

to quiestion
repeat 180 [fd 0.5 rt 180/360]
end
```

Tom

```
to tri
repeat 3 [fd 100 rt 120]
end

to squ :size
repeat 4[fd :size rt 90]
end

to rec
repeat 2[fd 50 rt 90 fd 100 rt 90]
end

to pen
repeat 5 [fd 50 rt 360/5]
end

to hex
repeat 6 [fd 50 rt 360/6]
end
```

```
to oct
repeat 8[fd 50 rt 360/8]
end

to circle
repeat 360 [fd 0.1 rt 360/360]
end

to 3squrec
repeat 5[fd 33 rt 90]
repeat 3[lt 90 fd 33 rt 90]
fd 33 rt 90
fd 33 rt 90
fd 33 lt 180
repeat 4 [fd 33 rt 90]
fd 33 rt 90
fd 99 lt 90
fd 100 lt 90
fd 132 lt 90
fd 100
end
```

```
to road
rt 90 fd 200 rt 90 pu fd 25 rt 90 pd
repeat 4[fd 25 pu fd 25 pd]
 lt 90 pu fd 25 lt 90 pd fd 200
end

to 4tri
repeat 4 [tri rt 90]
end

to question
rt 90
repeat 90 [fd 1 rt 360/180]
lt 90 fd 50
pu fd 30 pd
circle
end
```