INTRODUCTION

PURPOSE OF THE STUDY

Although the volume of research relating to the use of the Logo computer language, developed by Seymour Papert (1980) and others continues to increase, attempts to verify Papert's (1980) claims for learning with and through Logo are clouded by a variety of debates about the research designs and methodologies that have been used by the various researchers including Papert himself. There is little reliable data on the effects of Logo and little empirical evidence focussing on possible interactions between children's use of Logo and their different cognitive styles of information processing and conceptual tempo.

Against this background of uncertainty about the merits of the use of quantitative and qualitative data for research into the use of the Logo language, this study set out:

1) to explore and evaluate any emerging differences perceived in the metacognitive development of young children learning in a Logo environment. The specific focus of investigation was conceptual tempo as expressed by reflectivity/impulsivity which was examined through the use of the Matching Familiar Figures Test;

2) to investigate any development of conservation abilities of young children learning in a Logo environment, beyond the development ordinarily anticipated for children aged five to six years;

3) to assess the spatial development of young children learning in a Logo environment and to compare this with the development of their peers in a non-Logo environment;

The study sought to clarify any developments noted in these areas through the use of a model of individual differences, namely that of the Russian neuropsychologist A.R. Luria (1973).

In addition to the three main areas of investigation, three other areas were also monitored. The development of the children's literacy and numeracy skills were investigated to check for any relationship between their development and the use of Logo. The children's problem-solving skills in the arithmetic domain were also checked for any unanticipated development that might have been attributable to the use of the Logo language.

The study also sought to monitor the social development and interactions of the children who were using Logo so as to check the role of social activity in environments where children were using Logo.

The study involved the collection of data for statistical analysis from ninety eight children during their first and second years of formal schooling. Thirty two of these children were placed in a specially set up Logo environment and behavioural observations were made of how these children responded to this environment over a period of some fifteen months. Where it was appropriate, pre- and post-testing was carried out for all children in the areas where potential differences were anticipated.

CHAPTER 1

WHAT IS LOGO?

"The true meaning of a term is to be found by observing what a man does with it, not what he says about it." (Bridgeman, P.W., p. 8).

The answer to the question "What is Logo?" is made clearer as more and more people, especially children, are observed working with it. However because of the uniqueness of Logo, and because some knowledge of its generic nature is needed to make sense of such observations, this chapter will look at what Seymour Papert and others, have to say about Logo. With the singular exception of Papert, the inventor of Logo, all other writers when making statements about the nature of Logo, are only able to articulate what it is after they have had the experience of using it.

Historical Development

In 1964, after spending five years working with Jean Piaget, Seymour Papert (1980) left Geneva and went to the Massachusetts Institute of Technology (MIT) where he became involved in the Artificial Intelligence Laboratory and in particular sought to answer the question: "How can we make machines that think?"

Papert in his work with Piaget by whom he had been greatly influenced, had been focussing on the nature of children's thinking and how they became thinkers. He saw the marriage of machines and developmental psychology as providing him with the opportunity to explore a new dimension of the world of children's thought processes. The setting up of a children's learning environment at MIT was the beginning of what has now been termed a new "computer culture".

Prior to the official formation of this environment Papert began work on a new computer language - one which was powerful in its programming characteristics, but also accessible to non-mathematicians and in particular to children. Papert (1980) says:

> The name LOGO was chosen for the new language to suggest the fact that it is primarily symbolic and only secondarily quantitative.
> (Papert, 1980, p.210).

Despite its so-called "simplicity", Logo is a very powerful computer language and requires considerable computer memory. Therefore prior to 1980, all Logo work was done on large computers. Now there are prototypes of Logo available for almost every type of microcomputer that is used in an educational environment.

Although the Logo language encompasses much more than Turtle Geometry, it is best known and most easily recognized by the presence of "The Turtle". The original Logo language had no graphics facility. However in 1968-1969, when one of the first Logo projects was being carried out at a Junior High School in Lexington Massachusetts, Papert decided it was time to try to place Logo within the reach of elementary and pre-school children. He therefore proposed the Turtle as a facilitator of this - one which he envisaged would be of interest to all ages. The subsequent development of the Turtle, like the Logo language, has gone through many developmental phases and is still evolving. Solomon (1980) describes it this way:

> The name is derived from Grey Walter's cybernetic invention, the tortoise. The first turtle existed in the

> physical world looking very much like a big yellow cannister- type vacuum cleaner on large wheels with a pen in the middle of its underbelly; this was 1970. This turtle was followed very quickly by a "graphics" turtle which lives on a TV screen and resembles a triangle. Recently the graphics turtle has been given new companions, sprites. Sprites are like turtles in many ways. Their behaviour is governed by commands which change their position and heading. Sprites differ from turtles. They are invisible; they do not have a specific shape, but can assume any that the programmer wishes to give them....
> (Solomon, 1980, p. 81.).

The evolution of the Turtle is probably still not complete, just as the exploitation of the Logo language is still continuing, particularly through the work being done by Andrea di Sessa (1984) and the development of the "Boxer" package.

The Nature of Logo

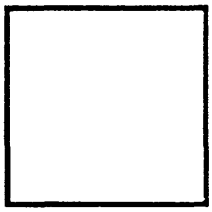
Logo is a procedural language. This means that Logo programs are created by joining a number of commands into clusters which are called procedures and then using these procedures themselves as elements in the building of more procedures so that quite high levels of complexity can be reached if desired. The main domain of the language in educational environments is turtle geometry, and commands are used to move and rotate the turtle around the screen.
For example:

To draw a square, the procedure SQUARE can be built up from the following commands:

```
TO SQUARE
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
END
```

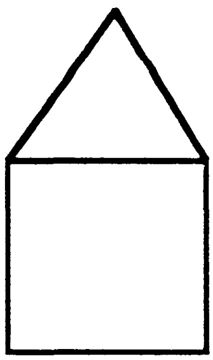
This could also be written as:

```
TO SQUARE
REPEAT 4 ( FORWARD 50 RIGHT 90)
END
```



Having defined SQUARE and then a TRIANGLE in a similar manner, these two procedures could be used to create another procedure HOUSE.

```
TO HOUSE
SQUARE
TRIANGLE
END
```



In this way a procedure can become a sub-procedure of another procedure, that procedure become a sub-procedure, and so on. In addition a procedure can call on itself within the same procedure. This is called recursion, and is one of the most powerful features of the Logo language.

Harvey (1984) says:

> It's hard to explain in a simple way why recursion is important. The idea behind recursion, though, has profound mathematical importance. By allowing a complicated problem to be described in terms of simpler versions of itself, recursion allows very large problems to be stated in a very compact form.
> (Harvey, 1984, p. 25.)

It is because of features such as recursion that Logo is perceived as a building block in the child's world. Adams (1985) says that a child "building" a computer program to effect a process, develops a complete understanding of the process described. Yet any child who builds computational models will invariably make mistakes, and the investigation of these mistakes (bugs) leads to the creation of new hypotheses, the testing of strategies, and then the provision of explanations for the unanticipated results.

Papert (1980) claims that there are no English words for the powerful ideas programmers refer to as "bugs" and the activity of "debugging". Debugging is an activity, but it involves both the use of skills and the cultivation of certain attitudes. Bass (1985) says:

> In using the debugging strategy, one must take the attitude that errors are going to occur and that nothing can be expected to work on the first try. One does not judge by standards of a 'right way' and a 'wrong way'. Rather one asks the question, How can I fix it? In debugging, one must first understand how something came to be that way. Only then can it be modified to fit the way we want it to be.
> (Bass, 1985, p.110.)

Logo is highly suitable for educative purposes because it is a computer language with a simple starting level which makes it easily accessible to children. Each command in the language can be made to produce a visible response, allowing the user to engage in "debugging". Finally, unlike most other computer languages, Logo allows the users to control the level of complexity as they "build" their own language (Wills, 1980, p.28).

The Philosophy of the Logo Environment

Jean Piaget must stand as one of the most influential child psychologists of all time. Certainly his influence is reflected in most school systems of the Western world. Papert (1980) acknowledges the debt of all educators to Piaget, but goes on to tell of his own personal frustration coming from Piaget's inability to describe what conditions were necessary for children to keep acquiring more knowledge.

Papert describes his own interpretations of Piaget as unorthodox. Yet other Piagetian followers have also been uneasy about how the functioning as well as the structure of intelligence should be described. It could be that the radical changes in the faces of the society in which children exist, coupled with the effects either positive or negative, of their constant exposure to such technologies as television, video games and computers, produce profiles of the development of children's intelligence that are quite different from those of the children who were the subjects of so much of Piaget's research. Piaget himself had admitted that different cultures and practices of education could affect the rate of development of intelligence.

Central to Piaget's viewpoint on development is the notion of intellectual structures. For Piaget there are certain preconditions that must exist before learning can take place. For new facts or concepts to be learnt the structures that will need to be employed in the learning must already exist in the mind of the learner or must be constructed through equilibration processes that are internally controlled (Piaget, 1970). This theory led to the formulation of the four stages of development which in Piagetian theory, are assumed to be stage-related rather than age-related, although age ranges have been assigned to the stages.

Papert's prime concern is to develop the intellectual structures that will support learning. He says:

> Piaget writes about the order in which the child develops different intellectual abilities. I give more weight than he does to the influence of the materials a particular culture provides in determining that order.....Piaget distinguishes between "concrete" thinking and "formal" thinking .... I do not fully accept Piaget's distinction....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 for addressing what Piaget and many others see as the obstacle which is overcome in the passage from child to adult thinking.
> (Papert, 1980, p.20-21).

Papert also declares openly that he views Piaget's stage theory as being conservative and in an effort to emphasize the degree of this conservatism classes it as a "reactionary" stance in its emphasis on what children cannot do! Yet, Papert's true admiration for Piaget comes through when he says that he is striving to release the more revolutionary Piaget, the one whose epistemological ideas could expand the known bounds of the human mind. Papert believed that the computer could now make this possible (Papert, 1980, p. 157).

Boden (1979) claims that from the earliest beginnings of "cybernetics" theory, Piaget showed his interest and pre-disposition towards these developments, although Piaget showed towards the end of his life that he did not hold such systems in high regard. However Boden (1979) rightly points out that Piaget's view of cybernetics was the classical one which embraced algebraic concepts and was qualitative rather than quantitative in nature. Such a model cannot adequately describe the procedural aspects of knowledge.

What Papert values most deeply in Piaget's work and what is integral to the philosophy upon which Logo is based is his genetic epistemology or developmental theory of knowledge. Central to Piaget's theory are the concepts of equilibration, assimilation and accommodation. Fishbein (1984) describes these:

> Each of us constructs a world view by applying our schemas - the mental tools for acquiring knowledge - in our interactions with the environment. Each time we apply our schemas, we are said to assimilate or fit interactions to them. In that each interaction is different from all preceding ones, we must modify or accommodate our schemas in order to make them fit. Thus, with repetition the schemas progressively change in such a way that more of our interactions, can be interpreted (made sense out of), and our interpretations become more complex. (Fishbein, 1984, p.391).

For Piaget the acquisition of knowledge is the structuring of behaviour as interchange between organism and environment, and the acquisition of knowledge of any particular phenomena is intimately linked to the phenomena itself. There is an interplay between what has already been assimilated in the existing structure and what must be accommodated from the environment.

Papert has taken Piaget's epistemological view and exploited it so as to include the development of intellectual structures other than those that develop with the passing of time and interaction in the "ordinary" environment. He then tries to design the learning environments to promote such development. He describes both of these in terms of the Turtle, which he calls a "transitional object" that exists in the child's environment and makes contact with the child's ideas which do not yet exist in a developed form (Papert, 1980, p.161).

It is Papert's "powerful ideas" theory which enables him to propose that a child may be able to experience an ideal or concept in such a powerful way in a single domain as to lead to some formalization of it which allows it to be then applied to other domains of experience. This differs significantly from the Piagetian "stage" which necessitates the child dealing with problems in all domains, before any abstraction of the concepts can take place. Lawler (1985) states:

> when a pre-operational child conserves number and recognizes - for the very first time- that it is possible to know with deductive certainty, the knowledge of number is a concrete exemplar by comparison with which all other problem -solving is ad hoc and unsure. If the child is then personally impelled to seek 'conservations' of something in her other domains of experience, the knowledge of number for her is both a powerful idea and also an ideal. The speed or delay with which she can invent new conservations is an artifact of her overcoming accidental checks to the spread of an epistemologically powerful idea.
> (Lawler, 1985, p.73-74).

A detailed following of the findings Lawler (1985) made in his observations of everything his six-year old daughter Miriam did in a six-month period, reveal that many of the powerful ideas at which she arrived including the process of learning to add, did not occur as the result of her acquiring and following uniformly logical procedures but rather when she articulated her powerful ideas, as she brought a number of her previous experiences together in a totally individual and idiosyncratic way.

Papert is adamant that so many of the experiences that children need to make "sense" of the world, to formalize their thinking, are not accessible to them in the everyday world. It is here that he sees that a computer may provide the power to experiment with their concepts, and that some of the resultant experiences may provide for formal thinking to take place. Lawler's study of his daughter Miriam produced such as result (Lawler, 1985).

Papert (1980) sums up such findings when after trying to examine why children have such a time gap (usually about 5 years) between the development of conservation and combinational skills, declares that it is related to the fact that in our culture, children have numerous and varied opportunities to experience number and hence conservation, whereas although our culture provides opportunities to practice systematic procedures, it is rarely able to provide materials for thinking about and talking about these procedures.

> But things may be different in the computer-rich cultures of the future. If computers as programming become a part of the daily life of children, the conservation-combinational gap will surely close and could conceivably be reversed: Children may learn to be systematic before they learn to be quantitative.
> (Papert, 1980, p.176).

Although Jean Piaget will remain a dominant figure in contemporary developmental psychology and the questions he raised will remain central ones, many psychologists, particularly Americans such as Brainerd (1978) and Keating (1980) are now arguing that his theories actually exceeded his grasp. Perhaps Seymour Papert could be attributed the role of trying to grasp the Piagetian theories and actually putting them to work in our environment to create the conditions for "Piagetian learning" to take place. Papert has taken one of the "riches" of our present culture - the computer- and shown how it might be used to create environments where children particularly, are empowered to think about the nature of things and their own thinking. It is in doing this that he takes his departure from Piaget (Papert, 1980, p.7) and it is perhaps the source of Papert's only real deviance from Piaget's thought. Yet it is this idea which may give Logo the potential to enable children to think and to learn in ways that previously have not been thought possible.

Powerful Ideas: Learning with Logo

Papert was highly motivated by his belief that children will learn best when they are encouraged to draw upon their own intuition and put to use what they already know in developing new ideas. Lawler (1985) in drawing parallels between Papert and Piaget, says that Papert has a major committment to the understanding of powerful ideas. He says that this quest has generated the questions of what an idea might be, how ideas function, how ideas relate to one another and what it could mean for an idea to be powerful (Lawler, 1985, p.72).

Papert proposes that if a child explores his/her environment or discovers and understands how something works, or why something is the way it is, the power of such ideas can be indexed by the degree to which it serves to help the child understand other problem situations by analogy.

The great potential of environments where powerful ideas are created is that so much can be discovered within them. In the discovery process one uses what is known to do something new, perhaps something that has never been done before or not even thought of. Having ventured into the "discovery", it is understood because of what is already known. In the Logo environment discovery of this kind is not limited to a few people; everyone can make original contributions, original discoveries. Indeed Papert's whole vision of computers

> emerges as many images each linked to one another through an underlying philosophy of creating conditions

> for people and computers to form relationships with one another which enhance people's sense of themselves and their own self worth, and thus putting them in touch with their own abilities to learn and develop.
> (Solomon, 1980, p. 80).

The place in which these powerful ideas are developed, Papert has called "microworlds". There is a need for many microworlds, each with its own set of assumptions and constraints. Lawler (1985b) defines microworlds as programs designed to provide streamlined experiences that are play worlds whose agents and processes children can get to know and understand.

Papert (1980) believes that within a microworld, children are able to explore the properties of the concepts embedded in it without being disturbed by "extraneous questions" and that in this exploration they transfer "knowledge" from their personal lives to the formal domain of investigation. The power of the computer provides a power and complexity previously not available to children in their own environments, and powerful tools permit powerful thoughts.

One of the earliest users of Papert's microworld concept in the teaching of physics was Andrea di Sessa, a former scientist at the MIT Artificial Intelligence Laboratory. Di Sessa has been captured by the Piagetian "genetic epistemology" approach to learning and his committment to the development of microworlds is amplified by his statement that the choice of appropriate representation of a situation is usually the most critical step in understanding (Di Sessa, 1984, p.17).

The essence of the value of microworlds and computer cultures lies in the belief that if children are given tools powerful enough to "conceptualize" the world, their world, these "tools" will draw forth from them, knowledge and thinking, and thinking about thinking, in a way that has not previously been possible - not because the children did not have the ability to know and think but because the culture did not provide the objects to think with, or had obstacles that could not be overcome. Now the only limits are within the child himself. Minsky (1986) says:

> Programs...make things come to be, where nothing ever was before. Some people find a new experience in this, a feeling of freedom, a power to do anything you want. Not just a lot - but anything. I don't mean like having a faster-than-light spaceship, or a time machine. I mean like giving a child enough kindergarten blocks to build a full-sized city without ever running out of them. You still have to decide what to do with the blocks. But there aren't any outside obstacles. The only limits are within yourself. (Minsky, 1986, Preface).

Skills and Powerful Ideas

What is it that children can learn as they engage in using powerful ideas? To reduce the Logo experience to a set of skills to be acquired is probably unjust both to the computer language and the children who use it. Yet observations of both the nature of the language itself and the children who use it, seem to suggest that some major skill areas can be identified. Discussion of the research to validate whether these skills are actually acquired by children who use Logo is found in Chapter 2.

Skills which could obviously be outcomes of the use of Logo are the development of strategies for breaking "problems" into manageable components, the acquistion of planning strategies for the achievement of designated goals, the use of "debugging" which leads to the development of a more positive attitude to errors, the development of reflective thinking about one's own thinking and thought processes, the skills of "getting to know" a domain of knowledge and developing a personal style for doing this, the development of an understanding at a depth no other person can know because of the very nature of the experience, and finally the development of very positive attitudes towards learning and the acquisition of knowledge.

Planning and Problem Solving

Logo, because it is a structured programming language allows any program to be broken into smaller procedures and commands of which it is comprised. The benefits of such a language are highlighted by Bass (1985) when he says that:

> Through structured programming, it may be possible to build a large intellectual system without ever making a step that cannot be comprehended. And building with a hierarchical structure makes it possible to grasp the system as a whole; that is, to see the system as viewed from the top. (Bass, 1985, p.110).

This sub-division into smaller manageable tasks affords children the opportunity to engage in highly developed activities of planning and problem-solving. Most of the theories of human problem-solving acknowledge that the mind calls on what it knows to solve what is emerging as a "problem". The development of skills for analysis of Logo procedures and subprocedures facilitate the process of recognition of what is known. This can be verified by the numerous incidents recounted by Papert (1980), Lawler (1985), Solomon (1980) and Turkle (1984) which show children working with Logo, who in the process of working with one procedure find that it can be added to another procedure and another, to create a whole new image or representation. This is in accord with the Piagetian concept of constructivism, where the mind upon meeting a new situation, pieces together the new solution from fragments of earlier models and specific failure-provided guidance.

Pre-Requisites for Logo Programming

Despite the accessibility of the Logo language to young children, there are a number of skills which have come to be recognized as pre-requisite to its use. Kull (1985) identified these broadly as: a degree of familiarity with the keyboard, the notion of directionality, which she explains as being "strategies for correcting errors in turning right vs. left" (p.14), knowledge of the different available Logo screens, that is text, full and split screens, being able to develop a plan, and some comprehension of what the connection is between the programming code and the drawing that appears on the screen. She further found that not only was it really necessary for the children to plan a drawing of what they wanted to happen on the screen, but that they also needed to be able to assign the Logo commands that were needed to execute the steps of their drawings, for successful planning to occur. Otherwise, children spent time making drawings that were too complex for their programming skills, and outside the scope of their knowledge of Logo. However, in another instance, Kull (1986) points out that some children could "see" the graphical solution to their "problem", before they began to actually solve it. She says:

> They actually "drew out" the desired picture on the screen with their fingers before typing in the turtle commands to execute the drawing. When prompted, many declared their general overall strategy aloud: "I have to make him go up to here, turn this way, then go over to here and down." The solution was then refined as the problem-solver actually began the command moves.
> (Kull, 1986, p.117).

Munro-Mavrias (1983) and Rieber (1983) also both found that there was a definite correlation between conserving ability and the use of Logo. Both also point out that according to Piaget's developmental theory, the pre-operational child does not have this ability to conserve length, and observe fixed and rigid shapes - these skill deficits, along with the others that will be alluded to in Chapter 2, are somehow overcome when the young child *actually* uses Logo.

Conclusions

The development of the Logo language was clearly a development that was based on Piagetian thinking, but one which attempted to go beyond some of the "limitations" that are often associated with the work of Piaget. Papert proclaimed that children's use of the computer afforded them the opportunity to make the formal, concrete. Giving children such a tool opened up possibilities previously not available to them (Papert, 1980), and so Chapter 2 attempts to qualify and quantify the research to date on the use of Logo, particularly with young children.

CHAPTER 2

LOGO - THE REPORTED RESEARCH

Papert's Claims

Papert (1980) claims that there are two major premises that have shaped his own research on the use of computers with children. He says that children can learn to use a computer in such a masterful way that this learning can change the way they approach the learning of everything else (p.8). Later (p.27), he further describes these concepts in his use of Logo, by saying that children can learn physics or mathematics or linguistics in a "natural fashion", comparable to the way that the child learns to speak. However, Papert (1980) makes it clear that his focus is not really on the technology alone, but more importantly, on the mind, and on intellectual movements. He sees the computer as the *carrier* of "seeds", and in the event of these seeds taking root in the child's mind, technological support may not even be needed. Clements and Gullo (1984) see these conditions as enabling young children to master concepts and ideas which previously were thought too abstract for their developmental level. Papert (1980), himself, describes the use of the computer as being

> unique in providing us with the means of 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 separating concrete and formal. Knowledge that was accessible only through formal processes can now be approached concretely.
> (Papert, 1980, p.21).

Rieber (1983) says that Papert sees himself as an "educational utopian". Papert (1980) is very critical of the educational structures as they exist, and for the most part, of the ways that computers are used within them. In fact, he (1984) says that educators use computers in trivial and puny ways that undermine their image. He adds that most children do not get the opportunity to become "familiar with the computer as a powerful entity they can control."

So, what does Papert claim that learning to program with Logo, will do for a child? Krasnor and Mitterer (1984) say that, based on Papert's claims the use of Logo can facilitate the learning of powerful ideas in such a way that they can go beyond the immediate environment and be applied in other problem-solving situations.

Vaidya and McKeeby (1984-5) give their interpretation of Papert's claims thus

> It is expected that children who use LOGO will be able to write procedures which "learn" from experience and which embody simple problem-solving techniques. In writing procedures which think, learn and solve problems, children will think about learning, thinking and problem-solving. That is, they will become conscious of the meanings of these concepts and perhaps thereby become better thinkers, learners and problem-solvers.
> (Vaidya and McKeeby, 1984-5, p.34).

Rieber (1983) takes Papert's (1980) claim that children may learn to engage in systematic thinking before quantitative thinking, as being one of his most powerful, and it is on that claim that he (Rieber) bases his own personal research.

Papert (1980) himself, says that he has seen all types of children - gifted, emotionally, cognitively and physically disabled - learn to program with Logo, and that contrary to adult expectation, it has been very easy for them to learn to do this. He sees that even the simplest use of Turtle geometry provides new avenues for thinking about one's own thinking because in programming the Turtle, one is forced to reflect on one's own actions, in order to make the Turtle do what the user wants it to do. As children begin to program the computer in more complex ways, they are engaged in reflecting more complexly, on their own thinking. He says elsewhere (p.21) that the "real magic" in all of this, comes from the fact that this exercise gives children the knowledge that contains the elements that they need to become formal thinkers.

Research Designs

The attempts to verify Papert's claims are clouded by a variety of debates about the research designs and methodologies that have been used by the various researchers, including Papert himself. The substantial body of research eminating from M.I.T., tends to be anecdotal in nature, and Krasnor and Mitterer (1984) point out that Papert (1980) has consistently claimed that "traditional experimental research methodologies" are not appropriate for documenting what happens when children use Logo. Such claims are made because he believes that the individual learning patterns of children are obscured by the use of group-based designs and statistical analyses and that any standardization of Logo teaching procedures detracts from the individualized, flexible approach that should characterize the Logo experience.

In the first major school project, the Brookline Logo Project, that Papert and his associates undertook, the Final Report shows that data sources for the Evaluation included records of the children's interaction with the computer (dribble files), teachers' anecdotal records, printouts of students' procedures, reported observations from graduate students, MIT staff, pre and post student interview reports, comments made by parents at meetings, and an independent study done the year after the Project by Cynthia Solomon (Papert et al., 1979).

Yet another and completely different approach has been taken by Sherry Turkle (1984) who uses a completely ethnographical style of inquiry. This style has its roots in anthropology and sociology, rather than in mathematical statistics. There is no question that such an approach is systematic in nature, but it is also very interpretative, and it is this aspect which the empiricists take objection to. However, in fairness to Turkle, it should be conceded that she did not set out to "prove" as much as to "inquire" and "try to understand".

She says:

> I began my work with children through participant observation, watching them and playing with them. Their conversations gave clues about what they thought and felt. Pursuit of what they thought led me to supplement participant observation with a Piagetian-like method of investigation...Pursuit of what they felt led me to use a more clinical style of interviewing and psychological tests such as Rorschach, the TAT, and tests to measure locus of control. (Turkle, 1984, p. 320.)

The "results" of Turkle's (1984) work are of interest, and contribute to the body of knowledge concerning children's use of Logo, but they do not contribute to any development of the quantitative aspects of research.

Yet another approach has been taken by Robert Lawler (1985). The work which Lawler (1985a) calls The Intimate Study, focuses on the development of the thinking of his six year old daughter, Miriam, and the particular outcomes of her use of Logo. Lawler mechanically recorded almost every word and action of the child during a six month period, with "the value of an approach" being that he "could capture unscheduled learning" (p.19).

Lawler (1985b) further explains it as an "effort to explore the processes underlying the development of learned, every-day knowledge" (p.3). So, although he does uncover some interesting aspects about Logo, the generality of such discoveries can only be surmized, although the extraordinary effects of it on one child's thinking have to be acknowledged, and account taken of them.

Perhaps, the opinion expressed by Kull (1985) and subsequently followed in her own research, is worthy of some exploration. She says:

> In a new area of research, there is room for many research questions and a mix of methodologies ..... One reseach method is to use the more traditional model...:Formulate one or more hypotheses based on claims or theories or anecdotal reports and test them using an experimental or quasi-experimental design. The second method...is exploratory, observational, ethnographic and controversial.
> (Kull, 1985, p.4-5.)

She justifies her own use of this second method by saying that it was really impossible to formulate hypotheses as such, because there was insufficient empirical evidence available on which to base any hypotheses.

Of the more traditional methodologies that have been used, the following designs have been reported in research findings. Mohamed (1985) says that a "test-retest experimental-control group design" was used, and that the resulting data was analyzed by "inferential statistics to determine the differences" (p. iii-iv). Pea (1984) states that, contrary to the qualitative approaches taken by Papert, his research, and that of his colleagues, was quantitative in nature, although the instruments used were especially designed to probe the skills under scrutiny. Munro-Mavrias (1983), in her work with Kindergarten children reports a systematic test-retest situation, with the data being analyzed by regression analysis. Likewise, Clements and Gullo (1984) used a pre-test, treatment, post-test design, using analysis of variance and post hoc analyses (Scheffe) to describe what had occurred. Rieber (1983) also used a pretest/post-test design with the statistical analyses being done via independent and dependent *t* tests. Chambers (1986) used hierarchical R^2 analysis by sets, a multiple regression technique, to assess the effect of Logo on a large sample of children who had varying amounts of Logo experience in their previous two school years.

Therefore, it seems reasonable to say that, as yet, no standard approach to the assessment of the effect of Logo on children who use it, has been established.

Young Children and Logo

Practically every activity in which the pre-operational child engages, contributes to the development of this child, and therefore children must be able to spend time on activities if they are to learn. David Elkind (1981) stresses the importance of the stage of childhood and warns against hurrying children into adulthood.

Rieber (1983) however, states quite clearly that he does not see any notion of Papert's to be in conflict with this viewpoint. Papert sees the computer as only a *part* of a child's culture, although he hastens to add that it is potentially a more powerful part than most others, and one which enables them to do things that they are otherwise unable to do.

Yet, despite these claims, Clements and Gullo (1984) found that their work with 6 year-olds with Logo, produced no significant effects on general cognitive development, although there was evidence for effect on cognitive style.

A number of works *do*, however, suggest that some change in cognitive development has been brought about through the use of Logo. Hines (1982), working with five-year olds, found significant Logo effect on the children's ability to identify numbers, number quantity, and letters, and she also found a significant effect upon the development of their spatial concepts. Rieber (1983) showed that second-grade children that were supposedly not ready for the learning of geometric concepts, showed that they did transfer some of their Logo geometric ideas to paper and pencil geometry tests, and of interest to Rieber (1983), is the fact that this happened despite most children not being complete conservers of length and volume. Vaidya (1983) showed that Logo could be used with pre-school children to stimulate creative thought, enabling them to express new ideas and thoughts. Some of the examples given by her, show evidence of cognitive development beyond the ordinary expectation for a four-year old. This story was created after the child had drawn a whale through Logo's doodle mode.

> Whale (Jameel:age 4)
> Once upon a time a whale lived in a little house. He couldn't fit in it because he was so big. He went to his friend's house and got sick. And they played checkers and the whale ate all of it. After the whale ate all the checkers then he ate me and my friend up. And he got better because people is his medicine. And then his mommy said, "I told you not to eat nobody up."
> (Vaidya, 1983, p.26.)

However, in all of these reports, one must be cognizant of the fact that all the researchers make reference to the degree of difficulty involved in measuring any of these developments with children of this age. Rieber

(1983), noted that there were no "reliable dependent measures of basic geometry concepts for young children" (p.18.)

Finally, Munro-Mavrias (1983) found that in her work with Kindergarten children, age, gender and spatial-motor ability did not account for any significant variance in ability of the children to use Logo effectively. She *did* find, however, that conservation ability was a significant factor. This is in direct contrast to the findings of Rieber (1983). So one might conclude that the fact that Rieber's (1983) subjects were approximately two years older than Munro-Mavrias' (1983), means that complete inability to conserve is of significance, whilst only *some* inefficiencies in conservation abilities, are not of significance.

Divergent Thinking and General Metacognitive Abilities

What is it about the Logo language or the Logo environment that leads researchers to even investigate the fact that users of Logo might engage in more divergent thinking, or have enhanced metacognitive abilities? Streibel (1983) provides some answer when he suggests that Logo provides a learning experience in which

> 1) objects are treated as events and described in terms of the processes which bring them about,
> 2) events are eventually arranged into a hierarchy of subevents,
> 3) events at any level are described in clear, natural and explicit terms,
> 4) errors at any level of the description are easily found and corrected.
> (Streibel, 1983, p.477).

He goes on to point out that Logo "provides a very good environment for learning how to learn" (p.482). He says that he has often observed young children taking the lead in exploring a program idea. He states that in these circumstances, teachers should not interfere but should positively help the children to "gain an increasing control over the learning process." (p. 482). This he calls, learning how to learn.

Clements (1985) points to the characteristics of Logo that he sees as potentially being able to develop the metacognitive abilities of the children who use it. He says that children using Logo develop ideas for their own projects, and then take these goals and turn them into machine-executable code. This makes the Logo environment very effective in facilitating decisions about the nature of problems and the selection of mental representations for them. He also says that the use of "debugging" techniques should lead to increased ability in the monitoring of one's own comprehension of the "problem".

One may reasonably ask whether such claims can be made for young children? Cliatt, Shaw and Sherwood (1981) say that young children *can* learn to think divergently, and that the use of such abilities should be an essential part of their development, and should therefore merit as much attention as the development of the more traditional basic skill areas. They defined divergent thinking as "the generation of many appropriate responses to a question" (p.1061), and showed by their research with Kindergarten children that when given the opportunity, these children could pose questions, produce valid ideas, and realize dramatic increases in these skills when repeatedly exposed to divergent-thinking situations.

The research of Clements and Gullo (1984) appeared to show that Logo provided a situation for the development of these type of skills. Their work with six-year olds showed improvement in their divergent thinking skills and in the development of their metacognitive abilities. The control group used were other six-year olds who were using Computer- Assisted Instruction programs, but were not using Logo at all. They say:

> analyses revealed significant pre- to post-test differences on the Torrance Tests of Creative Thinking for the Logo group on fluency originality as well as on the overall divergent thinking score, while no significant differences were found for the CAI group...............The Logo group significantly outperformed the CAI group on both metacognition tasks. The ability to monitor one's own thinking and realize when one does not understand may also be positively affected by computer programming environments in which problems and solution processes are brought to an explicit level of awareness and in which consequent modification of problem solutions is emphasized. Through consistent feedback in the form of a visual representation of the procedures and sequences of their own thinking processes, children may have learned how to monitor those processes.
> (Clements and Gullo, 1984, p. 1056).

Church and Wright (1986), in observing young children using Logo, said that the very act of watching children work in such an open and playful environment as the Logo one, enables an observer to assess the thought processes and estimate the capacity for divergent thinking as well as convergent thinking. They gave anecodotal evidence showing five-year olds engaging in divergent thinking, while using Logo. Their evidence is similar to that also put forward by Papert et al. (1979) and Lawler (1981).

Reflectivity/Impulsivity and Cognitive Style

Reference has already been made above to the work of Lawler (1985). In one of his initial reports of the study of his daughter (1981), he concludes by focussing on individual differences and differences in experiences, and how he sees that these must affect the conclusions that can be made about one person's learning. He makes the point that a skill can be mastered in more than one way, although the number of ways is always constrained by the varieties of experiences that the learner has had. Finally, he says that the preferred path is the one that the learner follows after making some judgements about the worth of the experiences that have been comprehended. Lawler (1981) says that "in this sense, the learner's values determine the optimal path, the individual difference is everything (p.29). Such conclusions highlight the fact that it is extremely difficult to *generalize* about the cognitive styles of the *individual*.

Papert et al. (1979) said that their study has produced new examples of the diversity of intellectual styles, and the interaction of Logo with these. Using the dribble file technique, a capacity for collecting *all* the commands, both correct and incorrect that the child uses - they showed how two students who ended up with almost identical products, had come to them via very different processes, which showed that there was "no sense in which they just did the same thing." (p.1.17). The examples of convergence of different processes has enabled Papert and his associates to refine their classification of intellectual styles. Of interest also, is the fact that Mohamed (1985) reports that Rampy's (1983) research implies that the style of Logo programming that a child actually uses seems to have no identifiable relationship to the user's cognitive style- that is, that Logo appeals, in some way, to all children regardless of cognitive styles.

Mohamed (1985) also reports that Young (1982) found that all of the second grade children who had been classified as impulsive, according to the Matching Familiar Figures Test, were successful in their writing of Logo programs, and that there was, based on post-test scores, a shift towards the reflective classification, for these students. Mohamed's (1985) own research showed that students who used the "debugging" techniques *were* analyzing their programs and reflecting on their own ways of thinking, and he saw this as a possible training technique for the development of higher thinking processes. Clements and Gullo (1984) in their work with Logo and CAI groups of six-year olds, tested explicitly for differences in reflectivity/impulsivity. The Matching Familiar Figures Test was used, and they report:

> Comparisons of pre- to post-test scores on the MFFT revealed significant differences for the Logo group on error and latency, while no significant differences were found for the CAI group. For the Logo group, the latency time increased and the number of errors decreased. It might be argued that the Logo treatment affected the number of errors directly, through the development of visual discrimination ability in the context of graphic programming. However, the CAI group also worked with programs that specifically taught visual discrimination, yet no pre- to post-test difference in the number of errors was found. The increase in latency time for the Logo group probably accounted for the decrease in errors on the MFFT, because children took more time to compare the pictures before choosing. The nature of programming in Logo necessitates thoughtful advanced planning, reflection on one's thinking, and explicit analysis of errors in "debugging", all of which may have accounted for the increase in latency time.
> (Clements and Gullo, 1984, p.1056).

Logo and Spatial Abilities

Anyone using Logo Turtle graphics soon becomes aware that a central focus of this application is plane geometry, and therefore one would assume that it is necessary for a child to have some familiarity with, and even be able to draw some of the basic geometric shapes (Munro-Mavrias, 1983, p.3).

Noss (1984), in examining the processes (or modes, as he calls them) in which children seem to engage, whilst learning programming, found that significant learning took place in each of the modes, which he broadly categorizes as: -making sense of the new idea, exploring it, and solving problems. Clements (1985) states that Noss's observations support a "developmental model of spatial reference understanding in Logo", which was proposed by Roberts (1984), in which he identifies three distinct levels.

The first is when children can distinguish right from left, but cannot successfully give directions to the Turtle for turning right and left. The second is when they can direct the Turtle to turn right and left but only when it corresponds to their own right and left. Finally, children reach a stage where they can always give orientations to the Turtle correctly and Roberts (1984) suggests that at this stage, children mentally imagine the rotations of the self.

A number of studies have investigated the relationship between Logo and spatial ability. Munro-Mavrias (1983) in her work with Kindergarten children found that spatial motor-ability "did not account for significant variance in ability to program the computer" (p.8). However, she acknowledged that the small sample (26) she used, may not have been a true indicator. Also in this study, there was no use of a control group.

Mohamed (1985), working with upper primary grade students, found that there was a significant difference ($p < .0005$ and $p < .004$), in favour of the experimental group on the post- testing of the Spatial Subtest of the Developing Cognitive Abilities Test. This test emphasizes spatial visualization ability and the results were substantiated by observational data. Clements and Gullo (1984) report that their experimental group of 6-year olds significantly outperformed the control group on the test of describing directions, a skill that is directly related to the use of Turtle graphics. This example showed that the use of Turtle graphics was an effective means of providing practice for young children in visual perspective taking.

Rieber (1983) tested his Grade 2 experimental group on their learning of geometric concepts. He says:

> Although the increase of the mean on the post-test is not staggering by a teacher's point of view (from 11.4 to 14.8), it does show a statistical difference which makes it important. It must be remembered that the subjects of this study were young children in the second grade. This increase in an age group which, as already mentioned, is supposedly not developmentally ready for such concepts deserves much attention.
> (Rieber, 1983, p.30).

Of interest too is Rieber's (1983) findings that the majority of the children in the experimental group did not demonstrate ability to conserve length and volume, qualities which could be considered pre-requisites for acquiring geometric concepts in Logo, and yet despite this, the children achieved significant results.

Fishbein et al. (1972) explored children's understanding of spatial relationships and co-ordination of perspectives through a series of experiments with subjects aged between three and nine years. They came to the conclusion that both the social and cognitive developmental factors contributed to a child's ability to co-ordinate perspectives. They have expressed the social factors as a series of "rules", rather than "stages" - "you see what I see; if you aren't in my place, you don't see what I see; if I were in your place I would see what you see" (p.31).

They found, on the other hand, that the cognitive factors pertained to the projective internal relationships between objects, and that children solved the problems by ignoring the redundant information contained in some internal relationships, and locating only the relevant cues.

Also relating the role of social activity on spatial development, Emler and Valiant (1982) refer to the research of Doise and Mugny (1979) who reported that pairs of children working on spatial representation made more progress than children working alone on these tasks. They believed that it was the conflict that produced the developmental change. Such theories are of relevance to children working with Logo in pairs.

Gregg (1978) explored children's spatial abilities through the medium of Logo, in order to answer the more general question of "What are the processes and stages of a child's mapping of symbols onto events?" (p.276). The subjects were all four and five years old and were given three sets of problems, the results of which surprised the researcher, who had been anticipating that children of this age would not be able to work as well from the 180 degree position as from the 0 degree position. The reverse was true, defying the Piagetian concept of egocentrism. The second problem confirmed the original finding, but the third problem, relating to the setting of Headings, posed difficulties that sent the researchers to the literature on left-right reversals and mirror image discrimination, which offered little help for the task of process description. Gregg's (1978) work finally led to the identification of five stages in the acquisition of understanding of the "turtle task".

Gregg (1978), in his elaboration of the Stages, states that the achievement of Stage V, which is when the child fully understands how to turn the turtle in terms of direction of rotation, is rather more substantial than one would first realize, and that dealing with multidimensional tasks requires skills similar to those required for Piagetian conservation-of-volume tasks - problems supposedly too difficult for pre-operational children. He concluded that young children, contrary to expectation, *could* form exocentric representations, but were unable to attach spatial labels to the commands for moving the turtle. However, upon being helped with this, the children were able to proceed with the tasks, simply proving that the source of difficulty in spatial tasks was not the one that the literature had led the researchers to anticipate.

Gregg (1978) also provided an information processing analysis of the sequence of steps required for the child to solve a "turtle task". these are:

> 1. Notice the present location of the turtle.
> 2. Find out where the turtle should go (its goal).
> 3. Test if the current location of the turtle is different from the goal.
> 4. Test whether the turtle is facing the goal.
> 5. Find the button with value X, i.e., where X is the name of the direction the turtle must turn in to face the goal.
> 6. Assign a spatial name to an object (e.g. to a button or the goal location.
>
> (Gregg, 1978, p. 286).

Problem-Solving, Domain Transfer and Logo

Papert's (1980) description in terms of Piaget's theory of genetic epistemology, of the process of programming a computer, leads to the description of the learner as a problem-solver. This does not mean that programming in itself is problem-solving, but that the tasks that the learner engages in whilst programming, are components of what have been identified as problem-solving processes. One such description is given by Hofmann (1986) who says:

> Programming in its purest form is the creation of a solution or set of solutions to a given problem .... In order to understand a problem, the problem solver must have the freedom or control to manipulate the problem parameters. Once the parameters are manipulated, it becomes clear to the problem solver that some solutions fail, often for different reasons. Thus, the problem solver becomes a learner, learning not only THAT some solutions fail but also WHY some solutions fail. Computer programming provides the ideal environment within which such problem-solving skills may be developed and studied by children.
> (Hofmann, 1986, p.99).

Munro-Mavrias (1983) points out that preoperational children would have difficulty generating problem solving strategies, because they cannot reverse the direction of their thought, an hypothesis based on the work of Almy (1966). As children move towards concrete operations, however, they can begin to engage in reversibility applications, and develop strategies for working backwards to where they went wrong, in order to change this. This is of importance, because reversibility is the most commonly used principle in strategies for "debugging" in programming.

Krasnor and Mitterer (1984) point out that ability to solve problems through programming, may well be dependent on the Piagetian developmental level of the problem solver. Based on this, they suggest that younger children would understand and benefit from debugging and the adaptive response to errors of Logo, since it is less likely that these skills are dependent on the problem solver being able to engage in formal operational thought.

Nickerson (1985) using the term "thinking skills" rather than problem-solving, for "cognitively demanding tasks" gives a conjectural list of these skills, which he considers to also be elements of computer programming. The list in which he describes each one in full, includes:

> Planning....
> Anticipating....
> Problem decomposition....
> Hypothesis generation and testing....
> The concept of an algorithmic procedure....
> The concept of a heuristic procedure....
> The idea of a parameterized procedure....
> The idea of a procedural hierarchy....
> The importance of the precise use of language....
> The importance of thoroughness in procedure specification....
> The importance of avoiding unnecessary complexity....
> The fact that there are many ways to represent the same procedure....
> The notion of leverage....
> The idea of indirect reference....

> The difference between syntactic and conceptual errors....
> The difference between functionality and elegance....
> (Nickerson, 1985, p. 43-47)

Clements (1985) states that observation of children using the Logo language, indicates that there are two broad categories of programming styles, relating to how children solve problems. These two classifications are "top-down programmers" who prefer to plan in advance, looking at the "big picture" and "bottom-up programmers" who plan as they go, discovering what works as they go.

Pea (1982) describes planning as an involved mode of "symbolic action that consists of consciously preconceiving a sequence of actions that will be sufficient for achieveing a goal" (p.6). His research into children's perspectives on planning showed that children had quite well refined views of the activities they considered appropriate to planning, as well as clear concepts of the consequences of not planning. Despite this, when asked to list the occasions where they saw planning as being necessary, they did not include the problem-solving settings that were given them in the classroom. Streibel (1983) points out that he sees Logo primarily fostering the development of a top-down problem-solving strategy, because the use of Logo firstly encourages the formulation of problems in a modular and hierarchical form. However, the work of Church and Wright (1986) and of Kull (1985) perhaps suggests that this view may be a little too limiting to the real potentials of Logo for the development of problem-solving skills and so one wonders whether the development of top-down or bottom-up problem solving skills, is really the issue, and whether it is simply that Logo seems to provide an environment where children solve what are problems *to them*.

Kull (1985), reporting her work with six year olds, says that the "problems" to be solved by these children were graphics problems - which the children called drawings. She noted the development of hypothesizing abilities, as children talked about "what the turtle would do if.....", and then the subsequent development of planning skills. She described the children as mostly planning several steps ahead, tracing their drawings with their fingers, before typing in the commands. More complex problems were actually tried on the screen with the "penup" command, and she saw this as a real means of hypothesis testing.

Church and Wright (1986) state that perhaps the real reason why Logo motivates children to search for problem solutions is because

> the challenges are not being taught and there is no expectation of a "right" answer. A refreshing phrasing of a cognitive objective was made by Eleanor Duckworth, who suggested that a first cognitive objective be "the having of wonderful ideas" (cited in Kamii & DeVries, 1978). Children work long and hard at the problems and questions that they invent. And teachers who use these principles of teaching are frequently astonished at the difficult problems children set for themselves, problems they would never think of suggesting (p.45).
> (Church and Wright, 1986, p.142).

Research investigations in the area of general problem- solving have been going on since the first uses of Logo with children. The work of Papert and Solomon (1970), Feurzeig (1972), Folk (1972), Statz (1973), Papert et al. (1979), Howe (1980), Lawler (1980), Seidman (1981), and Watt (1982) are some of these and all show that Logo is appealing to children with a variety of abilities, and that "it is a beneficial experience for children in the area of general problem-solving.

Clements (1985) gives quite a comprehensive summary of reported research, in relation to problem-solving and the use of Logo. Like Mohamed (1985), he also quotes the work of Statz (1973) and Seidman (1981), stating that Statz (1973) found that the Logo group performed significantly better than their non-Logo using peers, on a permutation and classification word puzzle task, and that while evidence for transfer of general problem-solving abilities was hard to establish, there was transfer to a recursion task, to a degree that was statistically significant. Clements (1985) further found that teachers have also reported on the increase in systematic problem-solving skills by students using Logo. Such observations are supported by the work of Schwartz et al. (1984), Brown and Rood (1984), White and Collins (1983) Gorman and Bourne (1983), Young (1982) and Hines (1983). Clements also refers to his own work with Gullo (Clements and Gullo, 1984), where they found evidence for Logo users, of such things as: higher scores on the Cognitive Abilities Test, better performance on a test of rule learning, a shift towards more reflective thinking, increased performance on Piagetian conservation tasks, superior performance on a test of describing directions, improved classification ability, and better performance on seriation tasks. However, Clements (1985) rightly points out that in some of these projects, the circumstances under which the research was carried out, leaves the results inconclusive, and in some cases, somewhat questionable. These circumstances included the lack of use of control groups, no provision for control of factors other than Logo, that may have contributed to the results, and the use of extremely small samples of subjects. As stated elsewhere (p. 21), the lack of systematic research into the effects of Logo on its users, continues to be a stumbling block for potential users of the language.

In any discussion of the acquisition of problem-solving skills, the question that is always subsequently asked, is the question relating to transfer of these skills. Research into the relationship between the use of Logo and problem- solving has proved to be no exception. Papert et al. (1979) describe their investigation of transfer as "a tentative measure of transfer " (p.1.18). They go on therefore to say:

> What should we measure? It is clearly not sufficient to test knowledge of discrete "facts" such as "a square angle is called ninety". We want to measure the use of the knowledge in a context where the student has to apply it less literally. On the other hand, we do not want to confuse the issue of the student's knowledge about angles with problem solving methods in other domains. (Papert et al., 1979, p.1.18-1.19).

They give examples of geometric tasks that were given to the subjects of the study, students with less Logo experience than the research subjects, and students who had no computer experience. Papert et al. (1979) report that the research subjects came out ahead of the students with some computer experience by about the same score difference as these students were ahead of the non-computer using students. They declare that the evidence suggests genuine change, but are less declarative about the nature of what was changed.

However, Krasnor and Mitterer(1984), make a quick resume of the factors which are commonly recognized as influencing transfer of learning, and then try to match these conditions with the powerful ideas involved in Logo. They see the process of debugging in Logo, and the possibility of this process engendering positive attitudes towards "bugs", as being a "skill" that would seem potentially transferable. However, they feel that the degree of transfer is dependent on explicit instruction in the general applicability, and also on a deal of practice in different contexts, conditions which Krasnor and Mitterer (1984) feel will not always be fulfilled. Furthermore they see that the similarity between Logo tasks and other tasks to which the Logo learning may transfer, is in fact too abstract for most students to take up.

Clements (1985), however, takes a broader perspective on the transfer issues and states that they have not been settled. Granting that the attainment of transfer is not easy to accomplish, he reminds the reader that without transfer, education's most significant goals cannot be attained. Clements (1985) does not believe that there has been the appropriate research to either confirm or disprove whether the learning of Logo has potential transferability to other areas of learning or not.

Of the research that has been reported, Chambers (1986) states categorically that whilst Logo enhanced what could be described as general thinking skills in some students, it did not enhance their performance on other similar tasks. Rieber (1983) on the other hand, shows that his second grade subjects appeared to tranfer at least some of the knowledge gained through their use of Logo, to paper and pencil tests developed for the study.

Conclusions

This review gives a general indication of the research done with Logo to date, and also of the difficulties that are encountered by those who undertake research in this area. However, it also indicates a lack of focus in the experimental studies, on how individual children respond to Logo. There is a need, therefore, for a systematic examination of behavioural change within a Logo environment in relation to a relevant model of individual differences. The present study addresses this need by the selection of a model based on the work of Luria which is described in Chapter 7.

CHAPTER 3

COMPUTERS, SOCIAL INTERACTION AND PROBLEM SOLVING

Social psychology, by definition a study of human interaction, has, over a period of time, been curiously removed from a focus on the small group in its natural environment to laboratory type situations where control and measurement have been more easily monitored. Despite this, much of the research in the literature investigates the social processing of information to solve problems. Now in this decade, the computer has been singled out as an object which has the potential to influence the social interactions of the children who seem to be attracted to a group problem-solving approach using the computer medium. The review will address the theories and issues involved with this development. An examination of a particular form of problem-solving, that of arithmetic word problems, is also made, because of the need to concretize an expression of problem-solving in the study.

A Rationale for the Social Dimensions of Problem-Solving

From the moment of birth, children takes their place within a particular milieu. Their utter reliance upon others for knowledge of how to do things and why things happen in a particular manner, are so obvious that there has been a tendency to underestimate, or even forget, that it is within the social contexts that children find knowledge both being presented to them and being created by them. Damon (1981) points out that there is no difference in the processes of acquiring social knowledge and other types of knowledge, because as Chandler (1977) has argued "all cognition is intrinsically social in origin and in function."

Day et al. (1985) make four points in relation to the role that the social world plays in the cognitive growth of the child.

> First, cognitive abilities are socially transmitted. Adults and older peers pass on the knowledge and skills required in their culture to children. Second, cognitive abilities are socially constrained. Children employ skills in social interactions that they cannot use when working in isolation. Third, nascent cognitive abilities are socially nutured....In other words, they (adults) find ways to reduce the cognitive workload for children. Fourth, independent use of new cognitive abilities is socially encouraged. (Day et al., 1985, p.33-34).

It is worth noting that this view is consistent with Vygotsky's (1978) theory of the genesis of higher mental functions, a theory that will be considered later.

It is possible to say therefore, that the child's knowledge is continually guided by the social context which Damon (1981) calls the "co-construction" of knowledge by the child. He says this is true of both social and physical knowledge:

> Mathematical logic is as much a social cultural construction as is friendship or justice. Each child does not reinvent the number system from scratch when learning to count, add and multiply: Rather, the child constructs a mathematical knowledge from the information provided him through social as well as nonsocial interactions. (Damon, 1981, p.163).

Day et al. (1985) develop these ideas, indicating that the social interactions of children elicit an "intelligent" response in them. They point out that intelligence can be perceived not simply in the minds of the individuals, but as residing within the social interaction itself. In their view then, children can learn intelligent behaviour when it is modelled socially in response to settings they understand.

Social Conflict and Learning

The research of Smedslund (1966) cited by Murray (1972), develops the notion of the acquistion of intelligence as a function of interactions between the individuals and those about them and furthermore, states that "the occurrence of communication conflicts is a necessary condition for intellectual decentration", with evidence for this being given from instances relating to the acquisition of operational thought by children. This hypothesis is consistent with Piaget's (1969) view of the role of social interaction in the transition from egocentrism to operational thought.

Murray working with Botvin, (Botvin and Murray, 1975) says that conflicts may be a necessary *and* sufficient condition for intellectual development. This would add validity to the work of Brison (1966) who in working with conservation experiments showed that children learnt to conserve, even in the absence of any systematic instructional effort, because of the effectiveness of social interaction. Renshaw & Garton (1984) point out that children use speech in response to a social audience, to describe critical and important elements rather than peripheral details.

Doise & Mugny (1979) have based all their research on the assumption that "social interactions that engender cognitive conflict are potentially effective for cognitive change." Damon (1981) explains a very interesting development of Doise's (Doise et al., 1975) this way:

> Even more interesting were the results from a similarly presented conservation-of-quantity task '...subjects who did not possess certain cognitive operations... acquire these operations after having actualized them in a social co-ordination task.'
> (Doise et al., 1975, p.367).

> It seems that children in social interaction must restructure their cognitive performances in order to coordinate them with others. Moreover, this act of restructuring may have some direct influence on the organization of each participating child's thinking. This suggests a model of development with social interaction as an instrinsic feature, rather than as an additional external factor.
> (Damon, 1981, p.165).

Davis, Laughlin and Komorita (1976) report that a series of studies done by Laughlin (1965, 1972) and Laughlin et al. (1968), and McGlynn (1972) and McGlynn and Schick (1973), have shown that cooperative pairs are superior to individuals in concept attainment for a variety of conceptual rules, task difficulty conditions and interaction formats.

In summary then, there seems to be little room to argue against the importance of the role of social activity and even social conflict in a child's cognitive development. Vygotsky (1978) says:

> what children can do with the assistance of others might be in some sense even more indicative of their mental development than what they can do alone.
> (Vygotsky, 1978, p.85).

Moreover, Botvin and Murray (1975) have shown that what children learnt about conservation in social conflict situations, was not a "simple non-reflective imitation of the conservers' performance", because the children with newly acquired knowledge and skills could display reasoning patterns which were totally dissimilar to those of their more knowledgeable peers.

The Person/Knowledge Requirements of Social Situations

For the "success" of a social learning situation, particularly a problem-solving activity, there is usually a necessity for the presence of a "more capable peer." This person then assumes the role of planning, monitoring and regulating some aspects of the task at hand - in other words, this person assumes a "metacognitive" role, a dimension which needs separate investigation outside the context of this review.

However, Renshaw and Garton (1984) make the point that the success of these activities is dependent on all participants having "similar situation definitions", the establishment of which will be addressed further on.

A related, but different element of the social situation is the role assigned to 'scripted' knowledge, that is, cultural knowledge that the child has already acquired. Day et al (1985) reiterate the fact that if the participants of dialogue and social interaction can assume shared scripted knowledge, the effects on the interaction can be profound. This is particularly true for young children where scripts play such a significant role in cognitive development. The works of Lucariello (1983) and Lucariello and Nelson (1982) show that for children as young as two years of age, scripted knowledge permits reference to things not present in their immediate surroundings. Moreover, French and Nelson (1982) found that children aged between three years and five years, using descriptions of generalized event representations, showed cognitive abilities well above those generally attributed to children of this age. This is of importance in relation to problem-solving because, if young children with shared knowledge can participate in sophisticated social interactions, which presumably result in further development of these skills, then one might assume that at least some measure of these skills might be transferable to contexts where shared knowledge is not immediately available, but rather, must be established.

However, one must be mindful that the communication skills of young children are, of necessity limited, and Beaudichon (1981) suggests that the demands for information processing and the nature of the task itself must also interact with the children's ability to communicate meaningfully with each other, or with any other conversationalists.

Muller and Perlmutter (1985) suggest that:

> computers can provide a focus for children to work together... (and) there is the interesting possibility that the nature of computer tasks and their information processing demands may stimulate social problem-solving. (Muller & Perlmutter, 1985, p.184).

Learning in Socially-Based Classrooms

Hawkins (1983) also distinguishes between the claims made in regard to cognitive issues and social issues in classrooms where collaborative learning appears to be taking place. While iterating the claims, she acknowledges the lack of available research to validate these. She says:

> With respect to cognitive issues, there are three kinds of claims:
>
> 1. Cognitive skills are enhanced. Children learn better or differently....
> 2. Metacognition is enhanced. In a collaborative or peer teaching context, children learn about learning.
> 3. Children learn something about the nature of information - that it can be represented in different ways and organized flexibly, depending upon one's purpose.
>
> With respect to social issues, there are several claims made about the value of this learning context:
>
> 1. It enhances social interaction skills by facilitating working together and thus communicating the value of learning skills for joint efforts.
> 2. It contributes to children's positive views of themselves and their own competence.
> 3. It teaches children how to make use of resources available to them for help....

4. Finally, benefits have been claimed for the school community...Encouraging this sort of social organization of work in classrooms increases the amount of individualized instruction that occurs. (Hawkins, 1983, p.42-43).

Vygotsky's Theory

The theories of Lev Vygotsky, relating to developmental psychology, have come to provide a provocative framework within which social interaction and problem solving can be studied. Essentially, Vygotsky, who was basing his ideas on the Marxist position that the psychology of the individual can only be understood through the analysis of social interaction, claims that the development of all higher psychological functions takes place within social interactions.

While the premise that children learn from others around them, is in no way novel, as evidenced by the preceeding section, Vygotsky added an alternative perspective to such proposals. Day et al. (1985) say:

> First...Vygotsky claims that cognitive processes are transmitted through social interaction. Joint participation in an activity permits cognitive processes to be displayed, shared and practiced, so that the child is able to modify her or his current mode of functioning. Second, the adult or more capable peer lightens the cognitive "workload" for the learner by taking responsibility for some parts of a task while the child concentrates on one sub-component...Third, Vygotsky takes an unusual perspective on the relationship between learning and development...Vygotsky took the reverse perspective (to Piaget), claiming that learning preceded, and indeed enabled, development.
> (Day et al., 1985, p.35)

For Vygotsky, the essential developmental process is the personalizing and gradual internalizing of any given social activity in which the child was a participant. The skills which are first practiced with others gradually become available at the intrapersonal level. Wertsch (1979) refers to this process as the transition from other-regulation to self-regulation.

The role of speech is also central to Vygotsky's theories. Wertsch (1979) refers to the confusion that has existed in relation to the translation of the Russian manuscripts - the word "rech" which is "speech" has often been translated as "language", the Russian for which is "yazyk". This has, in some instances, led to rather narrow interpretations of some of Vygotsky's statements, in terms of "language systems or narrowly defined verbal phenomena", whereas, Vygotsky was actually referring to the more dynamic matter of how language systems (speech) are used in human social interaction.

Vygotsky says:

> 1) A child's speech is as important as the role of action in attaining the goal. Children not only speak about what they are doing: their speech and action are part of ONE AND THE SAME COMPLEX PSYCHOLOGICAL FUNCTION, directed toward the solution of the problem at hand.
>
> 2) The more complex the action demanded by the situation and the less direct its solution, the greater the importance played by speech in the operation as a whole. Sometimes speech becomes of such vital importance that, if not permitted to use it, young children cannot accomplish the given task.
>
> These observations lead me to the conclusion that <u>children solve practical tasks with the help of their speech, as well as their hands.</u>
> (Vygotsky, 1978, p.25-26.)

Furthermore, Levina (1979) says:

> In analyzing the representation of a formulation, Vygotsky thought that in the speech that follows an action one does not usually find a reflection of details (in normal children); rather, one finds the schema for the entire action and the essential elements.
> (Levina, 1979, p.288).

According to Vygotsky, the child moves from the interpsychological functioning of speech to function individually (intra-psychologically), with the final phase of the development being completed when the child is able to covertly label activity without having to proceed through these two earlier phases, that is without an audience. It is easy to see then, how these theories could become central to the development of theories to describe what happens when young children converse with each other in carrying out computer tasks, particularly if the tasks per se could promote divergent thinking.

The Notion of the Zone of Proximal Development

Vygotsky's concern with the child's development did not focus only on the *actual* development that a child moved through, but he was also concerned with looking at the potential developmental level that a child may reach. He called the difference between these two levels, the "Zone of Proximal Development", and defined it thus:

> It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers....
> The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state.
> (Vygotsky, 1978, p.86).

Day et al. (1985) assume that Vygotsky (1978) is claiming that this zone is created by learning. They also point out (p.52) that a child's scripted knowledge can form a basis for interactions within the child's zone of proximal development.

The implications of this notion would seem to be of great benefit to educators for both the testing and instructing of students. Vygotsky (1978) refers to the zone of proximal development as a tool for understanding the child's development and learning. He makes the distinction between development and learning. He proposes that learning *creates* the zone of proximal development.

> Learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. Once these processes are internalized, they become part of the child's independent developmental achievement. From this point of view, learning is not development; however, properly organized learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning.
> (Vygotsky, 1978, p.90).

Again, Day et al. (1985) propose what the implications of these statements are for schooling. They say that whilst any instruction given at the level of a child's completed development will increase the child's repertoire of knowledge, it is only when instruction occurs ***within*** the child's zone of proximal development that it can have its maximum effectiveness. Instruction beyond the child's zone will of course, be of little value to the development of knowledge or cognitive ability. They say, then, that

> the most effective teaching is therefore, somewhat, but not too much, in advance of development.
> (Day et al., 1985, p.36)

Thus the concept of the zone of proximal development has obvious implications for mental and/or intelligence testing of children and some of the work done by Brown and French (1979) reflects the influence of the Soviet psychologist in this domain.

<u>Speech and Conversations</u>

The centrality of the role of speech, for Vygotsky in the transition from interpsychological to intrapsychological functioning has already been referred to (see p. 49). His statements about speech are, according to Wertsch (1979) "comments about communicative social interaction." Furthermore, Vygotsky (1978) quite adamantly states that it is speech that helps children to "acquire the capacity to be both the subjects and objects of their own behaviour". It is important to remember however, that this "instrumental speech...develops out of socialized speech." (Levina, 1979).

Different types of speech and/or conversations come into operation in the movement between interpsychological and intrapsychological functioning. Vygotsky (1978) says that when children cannot solve a problem by themselves, they turn to one whom they perceive to possess the knowledge, and describe verbally, what it is that they cannot do by themselves.

> The greatest change in children's capacity to use language as a problem-solving tool takes place somewhat later in their development, when socialized speech <u>is turned inward</u>. Instead of appealing to the adult, children appeal to themselves; language thus takes on an <u>intrapersonal personal function</u> in addition to its <u>interpersonal use</u>. (Vygotsky, 1978, p.27).

When speech can guide, determine and dominate action *"the planning function of speech"* becomes effective. Levina (1979) in reporting some of Vygotsky's experiments outlines the development and effects of the planning of children's speech.

The first evidence of planning comes when the child who is faced with practical difficulties, makes some sense of the situation in words and then puts the plan into action. Thus, actions become more reflective - "they are prepared by a verbal plan." Once speech is being used in this way, the social milieu out of which the representation of actions arises, assumes even more importance. Children move through stages of revealing *future* action, carrying out, and finally acquiring verbal mastery over their own behaviour. Levina (1979) says:

> We see a general pattern in speech development. Initially, those surrounding the child direct his/her acts, and then he/she comes to master his/her own behaviour by the same means...
> The further development of the content of utterances of children confronted with a difficulty is in the direction of strengthening the planning elements. Up until five to six years of age in a practical situation and through six to seven years of age in a task involving pictograms, this planning guides the entire operation.
> (Levina, 1979, p.292).

Levina (1979) further reports that these children also engaged in spontaneous and verbose conversation with themselves. Some further control experiments were carried out and in his analysis, Vygotsky came to the conclusion that the high profile of speech in children's behaviour, is because this speech is not just an offshoot of the behaviour, but a function that actually guides it.

Vygotsky sees this planning-type speech as "mobilizing the child's experience." This function moves children from concrete situations to a reflective presence of past actions, thus enabling them to also act out of the experience of the past which they have reconstructed by speech.

Hawkins (1983) in observing the patterns of collaboration of children working in groups at computers, found that one of the major factors that influenced children to work together was the anticipation of occasions when they knew they were going to need help with a task. Unlike activities that seemed to take on purely social characteristics, in this instance children asked for information, not collaborative assistance. This, in some way replicated Levina's (1979) reports that children sought adult assistance when faced with practical difficulties.

Beaudichon (1981), in her controlled experiments of observing children both in isolation and with opportunities for collaboration with each other, found that six year olds placed in isolation, created opportunities for "rituals of adult telephone conversations", and exchanges whose function was to arrive at satisfactory precision levels. She says:

> The verbal activity consisted mainly of speech that attempted to obtain or provide information relative to the problem, or of speech in the form of commentaries, hypotheses, judgments relative to the problem, or to problem-solving strategies, consistent with the position of Vygotsky (1934/1962 and Luria (1961).
> (Beaudichon, 1981, p.370).

A final consideration of conversation is highlighted by Day et al (1985) who suggest that such social interaction also promotes metacognitive, as well as cognitive growth. Although they note the role of a teacher who in questioning activities, models some components of metacognitive activity for the learner, they refer to the fact that children also work independently of teachers, but ask these same types of questions aloud to themselves. These types of observations are also reported by Wertsch (1979). Day et al. (1985) state that even without the modelling of metacognitive activity, the social interchanges of learning environments often *induce* metacognitive skills, once children have moved beyond talking to themselves during a problem-solving exercise, What Is Problem Solving?

What constitutes a "problem" can be dependent on the perception of knowledge that one holds. Cooper and English (1984) state that their view of problem solving is based on constructivist epistemology and thus, they define a problem as "an initial state and a goal state which an individual is interested in achieving but must overcome a blockage to do so." This view is consistent with that of Newell and Simon, 1972; Meiring, 1980; and Charles and Lester, 1983.

In introducing her research into young children's problem solving capabilities, McClinton (1981) states that her work addresses a "point of impact between Piaget's theory of cognitive development and early childhood educational practice." (p.437). She presented four, six and eight year olds with two problems in verbal, visual and kinesthetic form, and found strong evidence to suggest that the younger children perform significantly better, when responding to verbal problems, than they do to problems in the other modes. She suggests that the visual and kinesthetic often complicates the tasks at hand, despite the strong emphasis on the visual in the child's experience of television, and the strong emphasis on touch in formal early childhood education.

Carpenter et al. (1981), although dealing specifically with problems which require arithmetic computation, showed that first-graders interpreted and generated solutions for verbal problems, long before they had received formal computational instruction. They then proposed that children could develop their natural ability to analyze problem structure from verbal presentation rather than algorithmic presentation as such. Although more discussion will be given to the role of word problems in arithmetic (see p. 57), Carpenter et al. (1981) are proposing the usefulness of this technique for problem solving situations.

It seems that attention to verbal problem solving is particularly relevant for young children, given the prominent role assigned to speech by Vygotsky (1978) and Levina (1979).

Domain Specificity

Before reviewing the research on the solving of arithmetic word problems as a particular example of problem-solving, it is necessary to comment on the issue of domain specificity. Cooper and English (1984) simply state that in relation to domain specificity, the "research findings are not equivocal" (p.129). Glaser (1984) states, after reviewing the research on problem solving carried out in the areas which are traditionally content-based, that the basis for expertise in problem solving comes from a development of a schematic comprehension of domain specific knowledge.

Burton (1984) argues just as convincingly that the development of say mathematical thinking is quite independent of the content area in which it is happening.

Sweller (1984) states that there is now

> strong evidence that domain specific knowledge rather than general problem solving skills is the primary determinant of successful problem solving.
> (Sweller, 1984, p.819)

Chi and Glaser (1985) show that knowledge of the domain from which the problem arises, does influence the use of general problem solving heuristics.

Arithmetic Word Problems

Rosenthal and Resnick (1974) state that arithmetic word problems are tasks requiring the integration of skills of language and arithmetic processing. A situation which requires some manipulation of quantities is described in words, and the task for the problem solver is to construct an arithmetic representation which will produce the desired solution.

Carpenter et al.(1981) indicate that the research shows several approaches to the description of word problems, each of which represents a slightly different orientation. Their own approach is based on semantics and problem structure, and as such is aligned with the work of Greeno (1978) and Vergneaud and Durand (1976), although they do introduce into their classifications some distinctions not previously included in other model types.

Their work and that of Carpenter and Moser (1982) deals specifically with problems involving addition and subtraction. As these are the problem operations which young children most commonly encounter, they are worthy of some further investigation.

Carpenter et al.(1981) make four different classifications for verbal addition and subtraction problems. These are: Joining/Separating, Part-Part-Whole, Comparison, and Equalizing. The researchers believed this schema enabled them to distinguish problems with syntactical and terminological differences from those with different semantic characteristics.

In addition to classifying the types of problems for which solutions are required, researchers have also tried to develop a *model* for competent problem-solving. Greeno (1982), Riley et al. (1983), and Mayer (1983) have all made significant and similar contributions to the development of such models. However, it is De Corte and Verschaffel (1985) and De Corte et al. (1985) who deal specifically with a model for the solving of addition and subtraction word problems by five and six year olds. Despite the logic of the model, Carpenter and Moser (1982) point out that young children generally do not solve basic arithmetic word problems by using an arithmetic operation, but rather by applying a variety of basic counting strategies. Their own research verifies that many young children successfully solve such problems *before* they have received formal instruction in the arithmetic processes. In fact the work of Carpenter et al. (1981) showed that first-graders, unlike older children, hardly ever chose the wrong type of operation for problem solution, and that very few of them depended solely on strategies that directly reflected the action of the problem statement, a fact that the researchers believe "illustrates that their problem-solving strategies involved some understanding of the nature of the operations." (p.37).

So why do young children fail to solve word problems involving addition and subtraction? Much research has been carried out on this issue and it has been consistently found that the failure takes place at the outset of the task, with the children building an inaccurate mental representation of the text of the problem. (Bem, 1970; Carpenter et al., 1981; Carpenter and Moser, 1982; Riley et al., 1983; De Corte et al., 1985; and De Corte and Verschaffel, 1985). De Corte et al. (1985) further add that the word problems given to children in classroom environments are usually stated with brevity and ambiguity, with the children unable to take account of various textual presuppositions. Their own research gives many anecdotal accounts of young children showing ability to solve the arithmetic operations of a problem, once they have mastered the semantic "problems", and been able to relate words to numbers. Furthermore, De Corte and Verschaffel (1985) also found that errors can occur through children not understanding isolated words and/or sentences, and this also leads to an incorrect text base.

In summary, young children fail to solve arithmetic word problems, not primarily because of the arithmetic operations involved, but rather, because of the semantic structure of the text and the use of words which children cannot understand. This leads to the children's failure to construct an adequate representation of the problem from which they can perform the necessary arithmetic operations.

Finally, of particular interest to the study, is the statement by De Corte et al. (1985) that the mental representation of the problem, constructed in the first phase identified of their model "is considered the result of a complex interaction of bottom-up and top-down analysis" (p.462). If such a classification is accurate, one could ask whether there could/would be any relationship between skills in computer programming and the ability to solve arithmetic word problems?

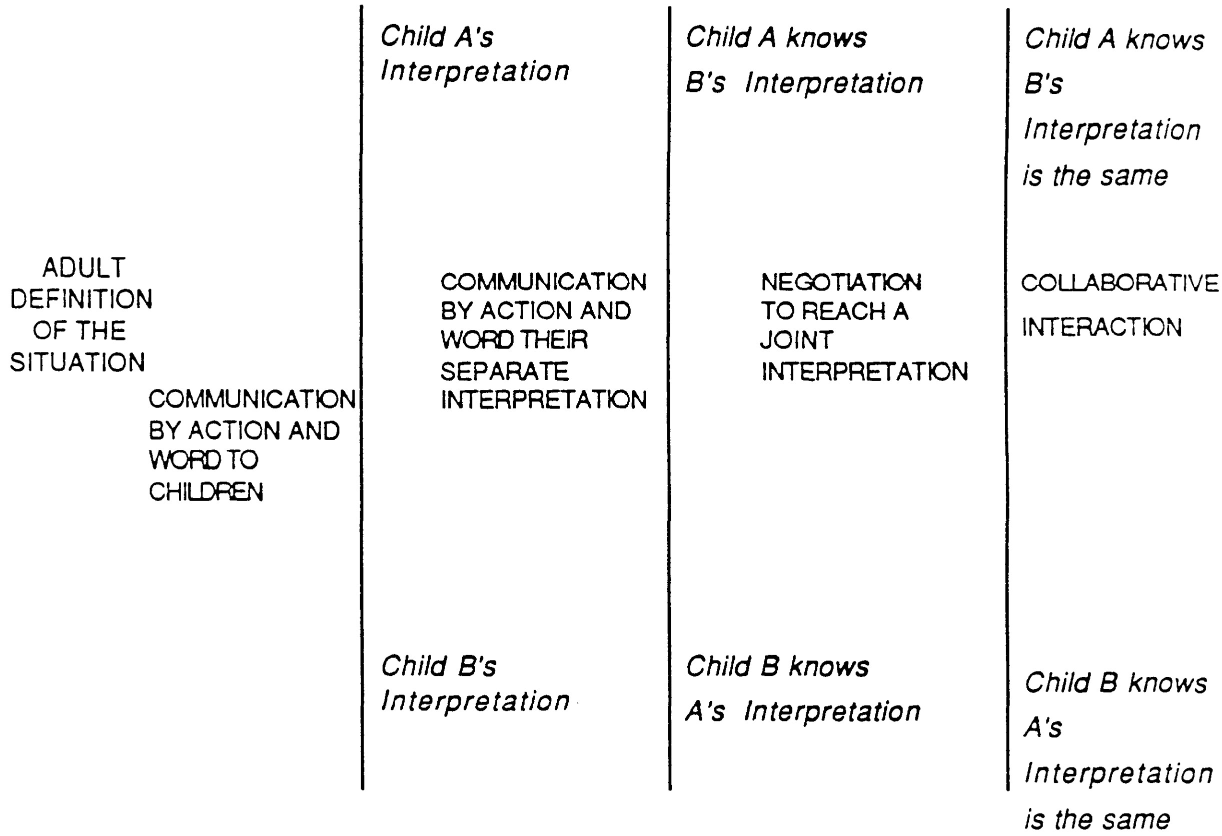
The Developmental Sequence of Collaborative Problem- Solving

While there is much discussion regarding the fact that computers will lead to social isolation, research evidence to the contrary is accruing (Clements & Nastasi, 1988, 1985; Swigger et al., 1983; Hawkins, 1983; Muller & Perlmutter, 1985; Hawkins et al., 1982; Papert et al., 1983). This being so, how does a group of children come together to engage in collaborative problem solving and what sequence do they move through, in carrying out the task?

Cooper (1980) working with children aged between three and five years identified a developmental sequence of increasing difficulty, for children engaging in dyadic interaction. Firstly, she says there is "reciprocal interaction". Then there is a level requiring abilities for tasks of referential communication. Here the child who has the information to solve the task at hand, must successfully communicate with the child who does not have the knowledge, but who seeks it from the other. Cooper (1980) found that the skills associated with effective collaboration were in the first instance, responsive interaction, collaboration, tutoring and persuasion. This effectiveness in collaboration was promoted by attention focussing, the expression of substantive hypotheses and comments, responsiveness to the partner, and the use of some sort of distinctive labels.

Renshaw and Garton (1984) further make the point that there is a high degree of complexity facing children asked to solve problems together, for it is imperative for the two children to establish that each has the same interpretation of the problem. They provide a model of the process of establishing a collaborative problem-solving dyad, as shown in Figure 3.1.

Hawkins (1983) found that children would prefer to choose their own collaborators, rather than be assigned a person to work with by the teacher. Renshaw & Garton (1984) noted that in their research, the most collaborative groups were female. This was evidenced by the fact that out of the twelve dyads set up for the occasion, only two - both female dyads, actually attempted to explicitly establish a joint understanding of the task. In the other instances, some joint understandings did emerge through monitoring of partners' choices, but there was no attempt to plan together.



A Model of the Process of Establishing a Collaborative Problem-Solving Dyad

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Figure 3.1

So what are the factors that affect effectiveness? Damon (1981) points out that not *all* children benefit from the problem-solving context being a social one, and he attributes this to the differences that exist in the social-interaction skills of children. He says that

> such skills, of course, may be expected to derive directly from children's comprehension of other persons, of themselves, and of social relations. To tap such comprehension, one needs...indexes of social cognitive development like perspective- taking ability, communication skills, self-awareness, understanding of other persons, and mode of interpreting interpersonal transactions and relations.
> (Damon, 1981, p.167)

Muller and Perlmutter (1985) also make the point that young children's capacity for meaningful communication with others may well be related to the information processing demands and ecological validity of the problem to be solved.

Beaudichon (1981) further maintains that the very intensity necessary for the communication, in fact detracts from the children's concentration on the task before them. She says that the continuous asking for information disrupts the child's ability to apply the information received, and that the activity often results in disorderliness. Children also need to keep repeating both the questions and the answers a number of times, and this also detracts from the problem's solution.

However, Day et al. (1985) found that where conversations were based on scripted knowledge, young children both spoke and acted in a manner beyond that which was usually anticipated from children in their age group. They conclude that this strongly suggests that young children can make a representation of an event, maintain the representation and recall it whenever they need to, provided that it is within their repertoire of scripted knowledge. Furthermore, it is their use of scripted knowledge that enables them to refer to objects not actually visible in the environment (Day et al., 1985, p.47).

The reason for the children being able to think and interact in a way that is considered to be superior for their age group however, rests on their having shared knowledge, which is the basis for genuine and productive conversation. Damon (1981) reports that Mugny and Doise (1976) have shown that problem solution is more likely to occur when children with different cognitive strategies work together, rather than when children with similar strategies do. Cooper (1980) also reported that the management of attention was of prime importance, and that she found children using attention-focussing devices, which as well as coordinating the effort of the dyad, served to reorient a distracted partner.

Both Brown and French (1979) and Day et al. (1985) anticipate cognitive and metacognitive growth for the novice partner in the problem-solving situation.

> The expert assumes metacognitive control of the situation, monitoring the novice's activities to see that they are appropriate for the task, goal-directed, and completed successfully. The expert's metacognitive control is essential in that the novice can gain awareness of and control over mental processes only after those processes have been used and practiced. Moreover, in fulfilling the executive function the expert has a chance to model important metacognitive processes for the child. (Day et al., 1985, p.35).

Brown and French (1979) also add that as the novice's full capabilities are exploited by the expert, the zone of potential development of the novice is being mapped out.

Computers and Social Interaction

The volume of research showing that computers promote collaborative problem-solving is steadily increasing. (Clements & Nastasi, 1988; Muller & Perlmutter,1985; Hawkins,1983; Hawkins et al., 1982; Levin & Kareev, 1980).

Muller & Perlmutter (1985) suggest that the computer can act as the focus for children's working together, and that there is the possibility that the very nature of the computer task and its inherent information processing demands, can stimulate social problem-solving. Hawkins (1983) says that there are quite obvious reasons why computers promote information exchange amongst children - these include the fact that the task being undertaken is made public by the visual display unit, the videogame culture in which children are already participants, and the often explicit nature of the problem steps.

Hawkins et al. (1982) report from their research that there was more "task-related interaction" while computers were being used, than during regular non-computer class activities. Hawkins (1983) also noted that in her work, the children themselves acknowledged that the computer context was the situation where it was more likely than in any other situation, that they would actually work together and ask each other for help.

Clements and Nastasi (1985) further identified that *particular* computer software produced increased social activity. They found that software which was open-ended promoted "more wondering and hypothesizing," and found that the use of Logo particularly increased social sensitivity. Similarly, Hawkins et al. (1982) say that

> when children use LOGO, both their instructions to the computer and the outcome of these instructions (i.e., what the computer does in response to these instructions) can easily be made visible to other children. Children can examine the steps by which another child is attempting to achieve some goal. This unique explicitness may facilitate joint involvement in activity.
> (Hawkins et al., 1982, p.367)

Muller and Perlmutter (1985) found that when children had to work on jig-saw puzzles they chose to work alone, but when they had to work at the computer they chose to work alone for only eleven per cent of the time, and that the work with the peer was interactive and cooperative. They also found that most of this cooperation was self-initiated, despite the fact that only about one-fifth of the interactions were between children who called themselves "friends."

Clements and Nastasi (1985), unlike Muller and Perlmutter (1985), found that the social interaction patterns for work at the computer were similar to other areas of free play, although children engaged in work with Logo *were* more likely to interact with their peers. White (in Callaway, 1982) reported that children working with computers socialized and asked questions, three times more often than in other classroom situations.

Hawkins et al. (1982) found that children were more definite in their choice of who they wished to work at computers with, than in their choice of partners for non-computer tasks. Children chose to work with those who had established their profile as computer "experts." They also point out that girls were hardly ever perceived as being these "experts", and were only chosen by other girls, not boys, although girls often chose boys as their "expert" partners.

So, what is the outcome of this socializing around the computer? Logo programming in particular, has been shown to give students enhanced self-confidence and self-esteem (Fire Dog, 1984; Kull et al., 1984; Brown & Rood, 1984). Clements and Nastasi (1985) also found that children working with LOGO resolved their conflicts more successfully than children in other conflict learning situations. In reference to LOGO, they state that

> the social interactions that occur in a Logo environment may be qualitatively different from those in other environments. For example, besides promoting cooperative work, these interactions may also enhance the development of problem-solving skills, effective motivation, and metacognitive abilities. In fact, child-child interactions during Logo programming may be as significant for cognitive development as are the child-computer interactions.
> (Clements and Nastasi, 1985, p.27).

Their later work (Clements & Nastasi, 1988) found that children working with Logo were more likely to negotiate problem-definitions and solution strategies, so as to gain a satisfactory result. Thus, Logo environments engender conflict, and also the negotiation and resolution of the conflict. They believe that such interactions, rooted in the theories of both Vygotsky (1978) and Piaget (1963), promote both cognitive and metacognitive development in the children engaging in them.

Conclusions

There appears to be a great deal of evidence to confirm the proposition that the social interaction of young children can influence the way in which they engage in problem-solving and that there is a particular type of social interaction that occurs when children gather around a computer.

Children seem to use skills during social interactions that are not available to them when in isolation. There is also a body of evidence that confirms that cooperative pairs are superior to individuals in concept attainment in a variety of specified situations. However, the "success" of problem-solving activity in social learning situations necessitates the presence of a "more capable peer" who assumes what can be termed a "metacognitive role". The problem solution is also more likely to occur when children with different cognitive strategies work together (Damon, 1981).

Finally, it has been shown that the presence of computers can enhance the quality of social interaction that takes place around them. In particular, Clements and Nastasi (1985) found that the use of Logo increased social sensitivity and promoted "more wondering and hypothesizing."

CHAPTER 4

METACOGNITION AND REFLECTIVITY

The Nature of Metacognition

John Flavell, the developmental Psychologist, has been the pioneer in research into the area of metacognition. In 1979 he noted that a variety of investigators had agreed that metacognition has a role to play in oral communication of information, oral persuasion, oral comprehension, reading comprehension, langauge acquisition, attention, memory, problem-solving, social cognition and various types of self-control and self-instruction (Flavell, 1979). Sternberg's (1980) models of intelligence also include metacognitive components.

During the past decade, the concept of "metacognition" has begun to appear in large volumes of literature in the study of psychology, language and education. However, Lawson (1984) points out that there is confusion in the literature concerning which aspects of cognition should be labelled metacognitive and what the relationship is of one to the other and to performance. Such conceptual confusion has led to conflicting research results through the use of unsuitable research techniques.

This review therefore will describe the various concepts of metacognition, and in particular, search out the implications of these concepts for understanding some metacognitive abilities in five and six year old children, and particularly in relation to reflectivity/impulsivity.

Flavell (1985) suggests that metacognition:

> has been broadly and rather loosely defined as any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise. (Flavell, 1985, p.104).

He further describes metacognitive knowledge, the knowledge referred to in the definition, as the section of one's world knowledge which has to do with cognitive matters. Flavell (1979) distinguishes within this knowledge, three categories or subdivisions, namely, knowledge about persons, tasks and strategies.

In looking at knowledge about persons, one can have knowledge about oneself (intraindividual differences), knowledge about others (interindividual differences), or knowledge about the similarities and dissimilarities which exist (universals of cognition) that is, some understanding of what the human mind is like in general. The task category is viewed from two perspectives: the nature of the information that is used in any cognitive task, and the nature of the task demands themselves. Finally, knowledge about strategies can either be straightforward relating to a current undertaking, namely a cognitive strategy, or more reflective, namely metacognitive strategies. Flavell (1985) refines this by adding that cognitive strategies are used to *make* progress in cognition, whilst it is the metacognitive strategies that *monitor* it.

Most metacognitive knowledge does not merely represent one of these categories, but usually results from a combination or interaction of knowledge about any two or all of these categories of persons, tasks and strategies. Metacognitive knowledge is also basically similar to other long-term memory knowledge in that it can be active or inactive, accurate or inaccurate, and probably acquired over long periods of time. It also informs or shapes cognitive or affective experiences, which pertain to cognition (metacognitive experiences), and conversely its information store is built up by these experiences.

Metacognitive experiences most often occur when there is need to monitor and regulate one's thinking, and are most likely to occur

> in a job or school tasks that expressly demands careful highly conscious thinking; in novel roles or situation, where every major step you take requires planning beforehand and evaluation afterwards; where decisions and actions are at once weighty and risky; where high affective arousal or other inhibitors of reflective thinking are absent.
> (Flavell, 1979, p.908).

Next to Flavell, the largest body of research relating to metacognition has come from Ann Brown (Brown: 1975,1976(a), 1976(b), 1977(a), 1977(b), 1981, 1982; Brown & Barclay 1976; Brown & Campione 1972, 1977, 1978; Brown, Campione et al. 1973, 1974, 1977; Brown & DeLoache, 1978; Brown & Lawton, 1977; Brown & Scott, 1971; Brown & Smiley, 1977(a), 1977(b). It would therefore seem appropriate to put forward Brown's definition and explanation of the nature of metacognition.

Although Brown gives nominal support to Flavell's definition, by her quotation of it (Brown, 1979, p.70), she quickly adverts to the question of whether the distinction between knowledge and metacognitive knowledge is a viable one (Brown, 1978, p. 80). Yussen (1985) says that Brown has "fine-tuned" Flavell's definition of metacognitive knowledge. Brown (1983) says that there are two types of knowledge - that which she calls static, and the other strategic. The static knowledge is the knowledge that people can talk about, whilst the strategic knowledge is the actions that people take in controlling their cognitive activity. Whilst acknowledging that the list of actions would be varied, Brown identifies the following as her list of general strategies: planning, prediction, guessing and monitoring. She argues that it is these forms of metacognition which offer the most scope to researchers in the field.

Brown has focussed much of her own research on metamemory, in particular, which she views as a most complex phenomenon, and one which in her opinion has been oversimplified in some empirical research because the investigators have focussed on very simple types of metamemorial skills (Brown, 1978, p. 81-82).

Yussen (1985) concludes that while there have been other major statements about metacognition (Borkowski,1984; Sternberg & Powell, 1983; Yussen & Santrock, 1982), it is Flavell and Brown who have had the major impact in the field.

Metacognition and Reflectivity/Impulsivity

One aspect of metacognitive activity referred to above by Brown (1983) identifies planning and monitoring as part of strategic knowledge, that is the actions people take in controlling their cognitive activity. The act of either reflecting or not on one's cognitive activity is now commonly referred to as one's "cognitive tempo" and is frequently expressed through the measurement of reflectivity/ impulsivity. The use of the phrase "control of cognitive activity" above, would seem to imply that there is some relationship between this cognitive control (which can also be referred to as "capacity to attend", see Chapter 7) and reflectivity.

Definition

The origin of the term "conceptual tempo" and the drawing of a distinction between reflective and impulsive performance is attributed to Jerome Kagan, and his Matching Familiar Figures Test (MFFT) is the standard even if controversial instrument for the assessment of reflectivity-impulsivity.

One of Kagan's earliest definitions (1965) of the disposition describes it as:

> the tendency to reflect over alternative-solution possibilities, in contrast with the tendency to make an impulsive selection of a solution, in problems with high response uncertainty. The primary operational index of this variable is response latency in complex visual discrimination tasks in which a standard stimulus and a fixed set of response alternatives are presented and the response alternative that matches the standard is not immediately obvious.
> (Kagan, 1965a, p.609.)

He further qualified this by noting that the generalized tendency is valid only when there are situations in which alternatives are present simultaneously, and the correct alternative is not immediately obvious (Kagan, 1965b). He stresses that reflection does not in any way refer to a "delay" resulting from fear of failure, or inability to execute the task at hand (Kagan et al., 1964.)

Kagan, Pearson and Welch (1966) further amplified the original definition by describing the following characteristics:

> Some children impulsively report the first hypothesis that occurs to them, and this response is often incorrect. The reflective child considers the differential validity of alternative answers, makes fewer errors in reading prose or in recalling serially learned material, and persists longer with difficult tasks.....
> The categorization of a child as reflective or impulsive implies a combination of speed and accuracy of response.
> (Kagan, Pearson and Welch, 1966, p.583, 592.)

Kagan subsequently acknowledged that his early research relied almost exclusively on the use of response latency for the classification of subjects, and his later research employed both response time and number of errors for classification, because of the need to differentiate between subjects whose fast response times led to many errors and those who had fast response times and were making no errors.

A volume of research into the characteristics of reflective/ impulsive thinkers has now been reported, and many though not all are supportive of Kagan's definitions. However, all agree that there are two components - latency and error count - that are pertinent to the identification of reflectivity/impulsivity and that any attempt to modify impulsivity can be directed at "improvement" on either component (Kagan & Kogan, 1970).

Kagan and Kogan (1970) concluded that the dimension can be detected by the age of 4-5 years and that it is operative in problem situations that elicit response uncertainty. Mann (1973) gave evidence that by middle childhood there was a clear relationship between reflectivity and caution in decision-making tasks. Kilburg and Siegel (1973) showed that reflective subjects performed more detailed feature analysis when the only basis for correct responding is that of visual features. Klein et al. (1976) concluded that subjects classified as reflective have much more stringent criteria for response selection than subjects who are impulsive. They defined those with stringent response criteria as those who do not select a response until there is a great deal of evidence supporting it.

Ward (1968) in his work with Kindergarten children agreed with Kagan's position that impulsivity could be an instance of a broader syndrome which included high motor activity and short attention span. He warned however that situational variables as well as the intrinsic disposition of the child play a role in determining reflective or impulsive performance.

Such a position is consistent with Kagan and Kogan's (1970) notion that it is probable that "a reflective or impulsive attitude can be in the service of several different forces" (p.1313.). In a similar vein, Bjorklund and Butter (1973) showed that cognitive impulsivity was not usually able to be predicted from observation of classroom behaviour. The implication from this is that impulsivity may well not be a part of a global impulsive behaviour pattern, but rather a relatively independent dimension of cognitive style.

Mack Drake (1970) used eye cameras to record eye fixations of subjects engaged in the Matching Familiar Figures Test, and found that the impulsive child took the directions given on face value and in his efforts to complete the task quickly, did not take time to work out the most efficient strategy. He did not make any detailed comparisons and engaged in brief periods of global scanning. He seemed to have no need to examine all variants before giving an answer.

Kagan (1976) in commenting on the research carried out by Zelniker and Jeffrey (1976), pointed out that one interpretation of their work was that generally speaking, reflective subjects are more careful when the task is difficult, and that reflectives are tuned to scan detail. Kagan points out that another possible interpretation of this data would be that reflectives are motivated to perform well on intellectual tasks, and that in turn leads them to adopt an analytic strategy on difficult problems. Wright (1976) does point out however, that Zelniker and Jeffrey's (1976) work shows that impulsives make fewer errors on global tasks than on detailed ones, and are clearly more efficient than their reflective peers on such tasks.

Duryea and Glover (1982) in their summary of the literature point out that the body of research shows a number of factors contributing to the impulsive cognitive style. They include such things as an orientation towards "quick success", quite low standards of performance and little anxiety about errors, lack of motivation to master tasks and less careful attention to and monitoring of stimuli. In contrast, the reflective is generally characterized by pausing before tasks or decisions and taking time to assess alternatives. The reflective subject tends to make fewer errors in word-recognition tests, serial learning and inductive reasoning.

Finally, Zelniker and Jeffrey (1976) have pointed to the fact that information processing strategy may in fact be the major difference between those classified as reflective and those classified as impulsives. On a task that required detailed information processing, reflective children analyzed visual stimuli into component parts, whilst the impulsives used a less effective global approach. Ault (1973) and McKinney (1973) also found examples of more efficient use of strategies by reflective children.

Another dimension of the classification of reflectives and impulsives subjects has been raised by Borkowski et al. (1983) in their work on metamemory. In general, their research showed that the children classified as reflective and impulsive possessed different levels of metamemory, and that reflective children could much better describe the workings of their minds when solving memory problems. Later work of Borkowski (1985) confirmed inter-relationships between cognitive tempo and metamemory.

Aspects that have been included in the above definition will be further explored in more detail in the remainder of the review.

Statistical Issues of Measurement

In his early research, Kagan (1964) used the measures of response time and error gained from the Matching Familiar Figures Test, separately for indexes of reflectivity/ impulsivity. Both the later work of Kagan and that of other investigators have utilized a dual index of response time and errors in order to distinguish between those subjects whose fast response times are maladaptive because they are linked to errors, and those subjects who have fast response times and few errors. Kagan, Pearson and Welch (1966) state:

> an alternative operational definition of the reflection-impulsivity dimension combines response time and errors. These purer groups were created by classifying a S as impulsive if he were both above the median on MFF errors and below the median on MFF response time for his sex. A reflective child was below the median on MFF errors and above the median on MFF response time.
> (Kagan, Pearson & Welch, p.591.)

Many researchers have continued to use this model. Eska and Black (1971) report how they divided the students into four groups - the reflective, who scored below the mean in errors and above the median in latency; the impulsive, who scored above the mean in errors and below the median in latency; the slow, who scored above the mean in errors and above the median in latency; and the quick, who scored below the mean in errors and below the median in latency. However, Duryea and Glover (1982) point out that researchers have tended to continue to divide the subjects into only two classifications rather than four, because the middle of a distribution is often a useful reference point.

In 1974, Block, Block and Harrington published their "misgivings" about the Matching Familiar Figures Test as a Measure of Reflection-Impulsivity. One of their major objections to Kagan's indexing of reflectivity/impulsivity was the fact that the subjects who initially did not clearly fall into the two quadrants which Kagan identified as either being the reflectives or the impulsives were often then excluded from the rest of the study. They also found the conceptual rationale for using response errors as well as the time factor for the rationalization of the dimension, puzzling. They argued that response errors themselves are not a definitive characteristic of conceptual tempo because errors have many sources - low intelligence, misunderstanding of instructions, anxiety - and that the negative correlations, usually about .4, found between response time and accuracy are not sufficient for classification as reflective or impulsive. They suggested that in order to overcome this difficulty, it was necessary to include in the analysis of the MFFT scores, those subjects who were Fast/Accurates and those who were Slow/Accurates. The study used to validate this hypothesis showed that 39% of their subjects fell into those two quadrants which in many studies, were usually ignored (Block, Block & Harrington, 1974).

Kagan and Messer (1975) in responding to their critics, acknowledged that Kagan's early work *would* lead the reader to conclude that the response time factor was the only consideration for both the conceptual and operational definition of reflectivity/ impulsivity. They pointed out however, that their later research used both response time and errors for classification of subjects and gave evidence of this. However they did not seem to address the criticism related to the omission of those subjects who did not fall into the two critical quadrants of the analysis.

Messer (1976) seems to offer some explanations of this, in what he refers to as an "artificial dichotomizing". He states that the median splits *do* eliminate valuable discriminating information, but that this dichotomization has frequently led to the use of analysis of variance, a technique that he does not believe is suitable for analysis of trait variables. He adds that a further problem associated with this type of analysis is that it leads to sample-based divisions rather than giving prominence to normative data, which would eliminate the possibility of one researcher's reflectives being another's impulsives. He then suggests that often multiple regression is the most appropriate statistic to use in analyzing the data, because it provides for latency and errors to be used as continuous variables. Furthermore, if researchers do use analysis of variance, they *should* use all four groups of the subjects rather than just those identified as either reflective or impulsive, but that how many and which of the groups they then choose to include, is dependent on the particular problem being investigated.

This use of MFFT response time and errors as continuous variables also eliminates according to Messer (1976), some of the reliability difficulties associated with repeated measures design. He does recommend, however, that when "a pretest-posttest design is employed, a test-retest/ only control group be included." (p.1030.)

Wright (1976) in his response to the work of Zelniker and Jeffrey (1976) takes up the work of Kagan and Messer (1975), and produces yet another conceptual definition emphasizing two different components: efficiency, the sum of speed and accuracy and strategy or impulsivity which was the difference between speed and accuracy. This they maintained, enabled distinctions to be made between ability-related efficiency and style-by-task strategy. He goes on to say that Kagan's (1976) identification of few errors and low latencies when taken together, should probably define what is "efficient information processing". It then can be hypothesized that children's choice or "trade-off" between fewer errors or lower latencies could indicate their strategic preference, especially when these two factors are negatively correlated.

The other group of researchers who have contributed to the measurement debate on reflectivity/impulsivity is Ault, Mitchell and Hartmann (1976). Essentially they make reference to many of the issues that were addressed by Messer (1976). They too are of the opinion that "low error reliability can be partially resolved by including repeated measures control groups for repeated measures designs" (p. 230). They also advocate the use of multiple regression methods to eliminate dichotomization. Their overall conclusion is that despite some problems associated with the Matching Familiar Figures Test, "its validity has been demonstrated over a wide variety of tasks which measure cognitive development" (p.230), and that users of the instrument should be cautious in their use of statistics, bearing in mind all of the strengths and weaknesses of the test that have been identified.

The Relationship of Reflectivity/Impulsivity to Intelligence

Much of the research which has investigated reflectivity/ impulsivity in children, has also tested for correlations between conceptual tempo and traditional measures of intelligence. In fact, Block, Block and Harrington (1974) question whether results gained on the Matching Familiar Figures Test may well be dependent on the subject's IQ. Messer (1976) therefore, scanned research reports for correlations between MFFT response time, errors, and IQ. He found that in general,

> there is a median correlation between MFFT response time and IQ of .165 (.14 for boys and .22 for girls). The correlation between MFFT errors and IQ is -.295 for boys

> and -.335 for girls. Thus, conceptual tempo is moderately related to IQ when IQ falls in the normal range, and the relationship is higher for errors than for response time and slightly higher for girls than for boys.
> (Messer, 1976. p.1034-1035)

He goes on to allude to the fact that the correlations could also bear some relationship to the age of the subjects, and that when the IQ test employed was the Wechsler Intelligence Scale for Children, there seemed to be some affect related to order of presentation of the two tests - WISC and MFFT.

Mollick and Messer (1978) report that it is more likely that there will be correlations between MFFT and Intelligence Tests, when the Intelligence Tests being used are of a multiple choice type, with some content or format similar to the MFFT. The study of Plomin and Buss (1973) seems to confirm that the correlations will be different for different tests, by showing that there was no reliable relationship between the MFFT and Verbal IQ, but that error scores on MFFT seemed to relate to several *performance* subtests on the WISC. They conclude that MFFT therefore taps abilities similar to these tests. These subtests - Block Design, Picture Arrangement and Object Assembly also involve simultaneous processing. Therefore, there is some evidence for an established relationship between MFFT and spatial reasoning.

Ward (1968) reports that his work with Kindergarten children supported the generality and pervasiveness of reflectivity/ impulsivity as a characteristic of individual difference in cognitive style, and that within his sample there were no significant effects for the child's age, sex or IQ.

Lewis et al. (1968) from their work with pre-school, 1st, 3rd, and 4th grade children, report that for all age groups, there was little relationship between response time and IQ, but that for both 4th graders and pre-schoolers, girls showed a higher correlation between intelligence and number of errors.

In the studies of Kagan (1965), Kagan et al. (1964), Adams (1972), and Ward (1968), no significant differences were found for gender differences. However, Ward (1968) does note that girls made fewer errors than boys, at each of ages, 4, 5, and 6. This was also reported by Kagan (1965) in relation to errors for 6, 7, and 8 year olds. The only study that seems to have found that girls have faster response times, is the work of Meichenbaum and Goodman (1969).

Lewis et al. (1968) reported statistically significant results for pre-school boys acting impulsively (shorter latencies) and making more errors than other boys who reflected longer, and this was independent of IQ. Meanwhile for pre-school girls, there was no effect for reflectivity/ impulsivity. For girls however, there seemed to be correlation between number of errors and IQ, not reflectivity.

Kagan, Pearson and Welch (1966) found that the results for first grade children assessed across three inductive reasoning tasks for conceptual tempo, clearly indicated that girls display a greater across-task consistency than boys for reflectivity/impulsivity. Roberts (1979) in relating reading ability and the conceptual tempo of seven year olds, found that girls were consistently more reflective than boys.

Messer (1976) points to the fact that a number of studies - Heider (1971), Mumbauer and Miller (1970), Schwebel (1966), Weintraub (1973), and Zucker and Stricker (1968), all indicate that children aged five to twelve years who are of lower socio-economic class, are consistently more impulsive on the MFFT measured by both response time and error, than are their middle class peers. Kagan and Kogan (1970) noted that the lower-class child had a "sparser language reservoir", and that this combined with a more impulsive style, contributed to the lower-class child's poorer performance in school. Eska and Black (1971) hypothesize that specifically, a fast response time regardless of number of errors, might be correlated with a lower socio-economic level because their data tended to suggest that both quick and impulsive groups were of a lower socio-economic level.

The Characteristics of Reflectivity/Impulsivity

Although the different reported studies have no uniform assessment of verbal abilities, there are some consistent and some differing relationships between MFFT scores and language and reading skills reported.

The Kagan, Pearson and Welch (1966) study shows that errors on MFFT were negatively correlated with WISC verbal -scale scores ($r = -.20$ to $-.25$), but that response time to MFFT was independent of verbal ability (r's ranged from .08 to .18). However, Kagan et al.(1964) report minimal relationship between MFFT and verbal skills (average $r = .11$). Kagan and Kogan (1970) in commenting upon a number of studies, say that "there is generally a low, usually nonsignificant relation between language skills and this dimension" (p. 1310) (reflectivity/impulsivity).

Messer (1976) refers to an unpublished manuscript reporting a study of Meichenbaum (1971), where the spontaneous verbal behaviour of a small group of 4-5 year-old impulsive and reflective subjects was studied as part of a program of behaviour modification for impulsive children. It was found that generally the impulsive subjects were less verbal than the reflectives, and that their speech tended to be highly egocentric, in contrast to the self-directive speech of the reflectives.

Kagan (1965) in his study of reading ability, showed that the child who had been classified as reflective on the MFFT (combined response latency and error scores), was most accurate in the recognition of words. The influence of verbal skills was then partialled out, and the relationship between conceptual tempo and reading errors still remained significant for the reflective subjects (partial r = .28 for both boys and girls). However Kagan points out that further analysis showed that for the low verbal subjects, it was the lack of basic reading skills rather than conceptual tempo, that contributed significantly to reading errors. He further found that the high reading errors of the impulsives persisted over a prolonged period of measurement through the first and second grades of school.

The study of Roberts (1979) with seven year old readers confirmed that in the sample of 70 subjects, the "poor" readers were consistently found to be classified as impulsive on the MFF Test.

<u>Personality and Behaviour Traits of Reflectives/Impulsives</u>

Several studies have tried to investigate the relationship between personality and social variables and reflectivity/impulsivity. Probably the one that has been reviewed the most frequently is that of anxiety and error. Messer (1976) cites a number of studies that point to the fact that reflectives are more anxious about their intellectual performance than impulsives, and that anxiety over error could even precede a reflective inclination. Block, Block and Harrington (1974) point out that whilst there may be validity in reflective subjects' concern about making errors, it is the impulsives who are anxious about basic incompetence on any given task. However Mack Drake's (1970) description of the behaviour of impulsive subjects whilst taking the MFFT, does not suggest that there was undue concern about competence on this particular task.

The Relationship of Reflectivity/Impulsivity to Problem-Solving Skills

Researchers across the decades have been seeking to define and model problem-solving abilities, in order to understand their generic nature and their domain specificity and to identify the relationship of problem-solving skills to other attributes such as intelligence and cognitive style. There has also been a considerable investigation of whether there exists any relationship between conceptual tempo and problem-solving ability.

The Chronology of the Problem-Solving Sequence.

In attempting to understand problem-solving skills it is first necessary to recognize what constitutes the problem- solving process. This is referred to in the literature as "the chronology of problem-solving." Duryea and Glover (1982) describe it thus:

> A description of the chronology of problem-solving includes four phases plus a reporting phase.
> Phase 1: Decoding of the problem; comprehension of the problem.
> Phase 2: Selection of a likely hypothesis on which to act in order to arrive at solution.
> Phase 3: Implementing the hypothesis.
> Phase 4: Evaluating the validity of the solution arrived at in Phase 3.
> Phase 5: Reporting the solution to an external agent.
> (Duryea and Glover, 1982, p. 228.)

They go on to suggest that it is in Phases 2 and 4 that conceptual tempo is most influential, and Kagan, Pearson and Welch (1966) point out that an impulsive child would be prone in a problem-solving situation, to choose an answer that was not thoroughly assessed.

The Relationship of the MFFT to Problem-Solving.

The greater body of the research focuses on the relationship between reflectivity/impulsivity and the role of evaluation in the problem-solving process. Kagan and Kogan (1970) confirm that the MFFT is therefore an adequate measure of evaluation in problem-solving in so far as it assesses the extent to which the subject reflects on the validity of solution hypotheses in problems with response uncertainty. Mitchell and Ault (1979) state that there has been inconsistency in the literature in relating the steps of the problem-solving process to conceptual tempo and point out that Messer (1976) has suggested that the "MFF is related to all the problem- solving processes" (p.1044). Their research investigated the relationship between the reflectivity/impulsivity, hypothesis generation and testing, and the evaluation of the quality of the subjects' own solutions. They concluded that the MFFT appeared to be strongly related to evaluation measures but not measures of hypothesis testing, if in fact these processes can be separated. Latency scores were predictive of other latency measures (hypothesis-testing variables) but unrelated to evaluation measures. Errors however, were significantly related to evaluation and hypothesis testing in problem-solving.

Approaches of Reflective/Impulsive Subjects to Problem-Solving Tasks

Kagan et al. (1964) identified the characteristics of the reflective and impulsive subject in a problem-solving situation, such situation being defined as one where several solution hypotheses are available simultaneously. Impulsive subjects acted upon their first hunches giving answers without any reflection upon their potential accuracy. Repeated failure arising from this, often led to anxiety which eventually resulted in withdrawal of involvement in intellectual tasks. They go on to state that such an approach could establish permanent apathetic or hostile attitudes towards these tasks, because it would assume a maladaptive cyclic nature. The later work of McKinney (1973) looking at the problem-solving strategies of second graders, confirmed Kagan's position that the reflective subjects produced hypothesis-testing strategies that were both more efficient and essentially different from those of their impulsive peers. His data further supports the notion that reflective children usually considered alternative hypotheses and tested the relevance of their conceptualizations whereas impulsive subjects used random trial-and-error strategies, usually not forming any abstract hypotheses.

However, one of the most interesting dimensions that has evolved from the investigation of the inter-relationship of cognitive tempo and problem-solving is an outcome of Mann's (1973) work that proposes that at least for children between ages 6 and 8, reflective characteristics in problem-solving are closely related to caution in decision making at least in tasks which involved them personally. Mann (1973) goes on to hypothesise that an implication of this is thât "caution does not increase with age past 6 years", and "that decision-making habits and tempo are more or less fixed by that age" (p.278). However Mann (1973) does acknowledge that the age range of the subjects used in the study may have skewed the results, and that a wider range of age groupings would need to be used to gain clearer insights into the nature of the developmental aspects of decision making.

Mann (1973) further found that across various decision problems, reflective children had longer response latencies than impulsive children and that this latency tended to increase with age. Other studies, including the work of Ault, Crawford and Jeffrey 91972), Mack Drake (1970), Nelson, (1969) Siegelman (1969), Zelniker et al. (1972) and Ault (1973) investigated the scanning patterns of subjects rather than response time, to check if this related directly to the problem-solving strategies that impulsives employed. There was concurrence that both reflectives and impulsives appeared to use a strategy of paired comparisons between the standard and the variants rather than checking on each variant in turn for one detail. Ault (1973) points out that there are some differences in the proportion of paired comparison fixations, but further analysis to check what information was sought was not carried out.

Messer (1976) reports that on most problem-solving tasks which contain response uncertainty, whether they be of perceptual, conceptual or perceptuomotor nature, impulsives will demonstrate lower quality performance than reflectives who appear to behave in a more mature manner.

A different perspective on problem-solving is taken by Klein et al. (1976). In examining Kagan's classification of reflectivity/ impulsivity according to MFFT, they refer to the fact that subjects can exercise response-selection criteria which they term as either "stringent" or "loose". They point out that since the measurement of conceptual tempo is "defined in terms of latency and error rate on this task," subjects would be classified as reflective when exercising stringent criteria selection, and as impulsive when they showed loose criteria selection.

Conceptual Tempo, Problem-Solving and Metamemory.

Borkowski et al. (1983) studied the acquisition, maintenance and generalization of organizational strategies as a function of reflectivity/ impulsivity and metamemory. The data gathered suggested that metamemory acted as a mediator in strategy transfer for both reflective and impulsive children. They refer to the fact that earlier theories trying to establish similar facts (Flavell, 1978; Kendall et al., 1980), rested on the assumption that metamemory facilitated the actualization of strategic behaviours and that in turn, metamemory was enriched through the efficient use of strategies. Borkowski et al. (1983) suggest an alternative view, in that it is lack of development of metamemorial abilities and ineffective strategy use that lead to behaviour that is classified as impulsive, through a child responding rapidly and carelessly in a variety of problem-solving contexts. The correlational analyses gained from the study were such that Borkowski (1985) suggests that metamemory also played a role in predicting strategic behaviour. Further investigation by Borkowski (1985) suggests that when an available strategy is used consistently by children, they become increasingly aware of the value of the strategy and therefore it is likely that they will use the strategy in new tasks. Perhaps, then metamemorial ability more than cognitive tempo, prescribes how effectively a strategy will be used when transfer is required.

Conceptual Tempo and Spatial Coordination.

Piaget and Inhelder (1956) claimed that children under seven years of age are incapable of completing a spatial coordination task, because up until this age they are still egocentrically bound to make spatial conceptions through their own viewing positions. However the results of other studies (Borke,1975;

Fishbein, Lewis & Keiffer, 1972; Shantz & Watson, 1970, 1971) suggest that this is not valid and that young children in an environment that is favourable to their acquisition of spatial concepts will acquire such concepts and demonstrate a capacity for spatial processing. However, none of the researchers actually identified the environmental factors that would promote this capacity.

Associations between the individual differences and information processing differences related to conceptual tempo have been made by Wright and Vliestra (1975). They argue that situations which involve spatial coordination tasks are usually ones of high response uncertainty, and that in these situations impulsive children process the information associatively, whereas reflective children would do so at the cognitive level (White, 1965,1967). The logic of this hypothesis suggests that differences in spatial abilities would be related to differences in conceptual tempo, and that impulsive subjects would give quick, egocentric responses to spatial coordination problems, whilst reflective subjects would give slower, more correct responses (Shlechter & Salkind, 1979). They subsequently tested this hypothesis with a group of thirty three 5 and 6 year olds, and generated three potentially important results. Data analysis showed that the subjects' spatial cognition was partially a function of environmental conditions, and that these conditions also affected the latencies of the subjects' response to the task. From this they further hypothesized, but did not confirm that children's coordination of spatial perspectives was enhanced by environmental differentiation. Data analysis further showed that impulsive children were more influenced by the environmental factors than the reflective subjects and that led to the conclusion that an interaction between environmental and organismic conditions gave rise to the young children's spatial egocentrism. Furthermore, spatial egocentrism is highlighted when there is response- uncertainty, and when response-uncertainty dominates, conceptual tempo becomes identifiable. Thus, both those of the Piaget and Inhelder (1956) school and those who are proponents of the environmental theory seem partially correct, but the fact that there is evidence supporting the presence of an environmental factor which can be interplayed with conceptual tempo opens up further areas for investigation.

Reflectivity/Impulsivity and Attention

Reference will be made in Chapter 7 to the Russian neuropsychologist, A.R. Luria's (1973) definition of "attention" or "cognitive control" as it will be referred to.

There is however another way in which the concept of attention is often portrayed - that is, attention as it relates to the process of attending to a particular task. This is usually referred to as attention span (Lindsay & Norman, 1977), and it is this concept of attention which is seemingly meant when the word "attention" is used in the literature on reflectivity/ impulsivity.

The deployment of attention has been investigated when trying to understand children's conceptual strategizing. Mack Drake (1970) and Siegelman (1969) have suggested that there are important differences in the way that reflective and impulsive subjects deploy attention. Other studies have tried to use attention deployment in training programmes for increasing performance of children with short response latencies on certain given tasks (Meichenbaum and Goodman, 1971; Nelson, 1968).

Zelniker and Jeffrey (1976) proposed that one difference between reflective and impulsive thinkers may be expressed in terms of analytic and global processing. Reflectives and impulsives were shown during concept attainment tasks to have adopted quite different strategies of analytic and global processing, despite the fact that both groups were equally successful. This suggested that the contrast between subjects classified as fast/accurate and those who are impulsive may be a difference in attention span, whilst the difference between fast/accurate subjects and reflectives may be in the use of information processing strategies.

Zelniker et al.(1972) point out that if as Kagan, Moss and Siegel (1963) suggest one reason for low performance on MFFT is due to the subject's inability to sustain attention to the task over a long period of time. If this is so, changes in strategy will have no effect unless the subject's attention can be sustained by increasing the interest level of the task. Their research confirmed this opinion and they then added that a defining characteristic of an impulsive subject could be the inability to sustain attention. However they also stated that even if there were unalterable constitutional components such as inability to sustain attention within impulsivity, there were also "ways to modify behaviour in order to achieve better problem-solving performance." (p.334).

Messer (1976) reports research of Campbell (1973) showing that 4 and 8 year olds who have been classified as reflective are attentive to play for longer than those classified as impulsive. The younger children were likely to stop their activities for a conversation or a wander around, whereas reflectives seemd to be able to hold conversations and attend to their play. Likewise Kagan et al. (1964) showed that impulsive subjects often displayed lapses in attention while engaged in school tasks, by looking out of the window or looking at a friend or showing that they were distracted by extraneous sounds.

Reflective subjects showed that they were less open to distractions during intellectual activity.

In general there seems to be evidence to support the notion that short attention span is one of the characteristics of cognitive impulsivity, when such impulsivity is classified by means of the MFFT, thus making differences in attention span a distinguishing characteristic between reflectives and impulsives. On the other hand, the literature seems to establish that it is differences in cognitive processing strategies that may be the distinguishing characteristics for those classified as fast/accurate and those classified as reflective.

The Stability and Generalizability of Reflectivity/Impulsivity

Psychological attributes are often not characterized by stability over time. So the question relating to the stability of reflectivity/ impulsivity over a period of time has been addressed by a number of researchers.

Kagan (1965) in his early work relating conceptual tempo and reading ability, showed that over a one year period there was satisfactory stability of the response time for both boys and girls : $r = .48$ for boys, and $r = .5$ for girls, with $p < .01$. The error scores were not so stable for boys but were for the girls : $r = .25$ for boys, and $r = .51$ for girls. These children were assessed in Grades 1 and 2.

Yando and Kagan (1970) tested the stability of reflectivty/ impulsivity across a set of problems with different numbers of response alternatives. They held ten different testing sessions over a ten-week period. They found remarkable stability across problems with differing numbers of alternative responses.

Regardless of task difficulty, fewer errors were made by reflective subjects, whilst impulsive children responded quickly and made many errors. They therefore saw reflectivity/impulsivity as an important characteristic of the child's psychological organization. Kagan & Kogan (1970) cite three other studies showing long- term continuity for the conceptual tempo classifications based on MFF testing.

However while the classification may be stable in itself, the question of generalizability across and to other tasks must also be addressed. Again, Kagan & Kogan (1970) offer "evidence for the consistency of this disposition in the cross-task generality of the tendency"(p.1310). They offer examples from the work of Kagan et al. (1964) and Kagan (1965) where correlations for response times for MFFT and Haptic-Visual Matching Task ranged between .61 and .87 for many groups of children in the first three grades of school. However it should be noted that this generalized tendency has only been validated in situations where several alternatives were presented simultaneously and it was not immediately obvious which was the correct response. Messer (1976) points out that the specific problem context is important in obtaining generality.

The work of Ward (1968) and Klein et al. (1976) together with those cited above appear to lend support to the notion that there is stability and generalizability of reflectivity /impulsivity across tasks in which there is some degree of response uncertainty.

A Theoretical Basis for the Relationship Between Logo and Reflectivity/ Impulsivity

In their report of the research to date on the use of Logo with children, Clements and Gullo (1985) give a number of exploratory hypotheses. One of these is that children doing Logo programming may develop reflectivity as they think about their errors and the correction of them. In validation of their research, they say:

> the nature of programming in Logo necessitates thoughtful advanced planning, reflection on one's thinking, and explicit analysis of errors in "debugging"... (Clements & Gullo, 1985, p.1056.)

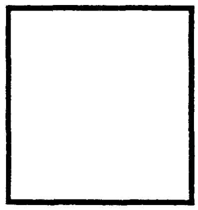
This opinion is also confirmed by Mohamed (1985) and by work done by Young (1982) when she found that all twelve second-graders whom she had classified as impulsive according to the MFFT, had after being successful in writing Logo procedures, shifted in the direction of a reflective cognitive style.

Within the literature on reflectivity/impulsivity several dimensions that can be related to the structure and processing of the Logo language are identified. Kagan (1965) states that individual differences in performance on tasks that require a choice among several alternative responses reflects differences in conceptual tempo. In fact Logo programs are confronting children with such choices all the time. For example within some types of maze exercises, there is the possibility of more than one correct route. Within "free play" programming, children have access to a range of commands that give them alternative ways to achieve their ends - the child who wants to draw a square can use any of the three methods shown below:

Example 1:
```
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
FD 50
RT 90
```

Example 2:
```
REPEAT 4[ FD 50 RT 90]
```

Example 3:
```
TO SQUARE
        (Use either Example 1 or Example 2)
END
```



On each occasion the square would turn out exactly the same as shown here.

Zelniker and Jeffrey (1976) looking at the relationship between strategies of information processing and cognitive style showed that there was a greater tendency for impulsives to employ the whole-scanning strategy, whilst reflectives employed the part-scanning strategy. They say:

> In the present experiment, the difference between the two cognitive style groups was expressed in a tendency to focus on or to examine a single dimension or component at a time versus several dimensions of the stimulus simultaneously. (Zelniker & Jeffrey, 1976, p.36.)

Given the extensible nature of the Logo langauge and the fact that procedures are built up from a series of individual commands, it is quite feasible to suggest that certain types of programming exercises could advantage the child who examined each component singly rather than the child who had a more global approach. For example in building a procedure, one must pay attention to the details of each individual command. In the "debugging" exercise the programmer is forced to examine each individual command as suggested above by Clements and Gullo (1985). This could account for the shift in a reflective direction to which Young (1982) refers.

Another perspective that can be taken is that of the whole problem-solving sequence referred to on p. 84. It was noted there that reflectivity/impulsivity tends to be influential in the problem-solving phases of selecting a likely hypothesis on which to act in order to arrive at a solution and in evaluating the validity of the solution which had been implemented. Again these relate to the tasks involved in Logo programming sequences and the subsequent "debugging" activities that follow. Thus engagement in Logo programming provides an opportunity for children to be "trained" in more appropriate problem-solving strategies.

In his commentary on the work of Zelniker and Jeffrey (1976), Wright (1976) refers to the fact that "Kagan has repeatedly stressed the concern manifested by reflectives to avoid errors, a motive which is much weaker among impulsives " (p.57). If this is so and it seems from the research that it is, then the reflective child's programming should be characterized by less "debugging" activities. Yet given the fact that one of the qualities of Logo as proposed by Papert (1980), is that children are not made to feel that there is anything "wrong" with being "wrong", it is possible that impulsives will exhibit a more creative and flexible approach to programming exercises and turn their "mistakes" into "better ideas", as Papert has suggested.

Conclusions

This review provides evidence for accepting that reflectivity/ impulsivity is a component of metacognitive activity. There is also evidence to suggest that there is a need to explore the potential relationship between reflectivity/impulsivity and information processing. Such evidence adds strength to the use of the model of individual differences in the present study.

Although there has been much debate about the measurement aspects of the Matching Familiar Figures Test, the literature suggests that cautious interpretation of measures gained through the inclusion of all subjects in a given study, will lead to valid classification of the subjects.

There is evidence to suggest the stability and generalizability of reflectivity/ impulsivity across tasks in which there is some degree of response uncertainty, and that such response uncertainty does exist in most problem-solving tasks and in the use of the Logo language for programming. Thus, the investigation of possible interrelationships between reflectivity/ impulsivity and the use of Logo, as well as between reflectivity/impulsivity and problem-solving would seem to be justified. Finally, the suggestion that differences in conservation abilities and spatial abilities are correlated with an interplay of environmental factors and with differences in conceptual tempo lead to investigations of the conservation and spatial abilities of young children in the following chapters.