CANADIAN THESES

THÈSES CANADIENNES

Learning Math Through LOGO: A Procedure-Based Approach

Marion Anne Barfurth

A Thesis

in

The Department

of

Mathematics

Presented in Partial Fulfillment of the Requirements
for the Degree of Master in the Teaching of Mathematics
Concordia University
Montréal, Québec, Canada

August 1987

ISBN 0-315-37080-7

ABSTRACT

Learning Math Through LOGO:
A Procedure-Based Approach

Marion Anne Barfurth

This study, in the form of a teaching experiment, describes the design, implementation and analysis of a special procedure-based LOGO environment. A task-oriented environment was created to teach specific mathematical concepts implicitly and specific programming concepts explicitly. Six grade-four children (i.e. 10 year olds) participated in a twelve-session implementation of the environment. Dribble files, video tapes and workbooks were analysed to identify the children's salient mathematical and programming responses.

This thesis is dedicated to Alan Carrier
and Klaus D. Barfurth

Acknowledgements

The author wishes to express her appreciation to all of the people who helped to make this thesis possible. To begin, my advisor, Stanley H. Erlwanger, for his inspiration, guidance and insight into the world of children learning mathematics. To the mathematics education group of Concordia University and in particular to David Wheeler and Joel Hillel for sharing their knowledge and experience. To the Mathematics Department and in particular the chairman, Dr. M.A. Malik, for his generous support throughout my studies. Special thanks goes to the children who participated in this study and their school principal Mrs. Arnold for being so cooperative. An cornucopia of thanks to my typist Bonnie-Jean Campbell for her diligence and availability on weekends. The thesis could not have been created without all of the encouragement and support from my husband, family and our friends.

INDEX

CHAPTER 5 - CONCLUSION

CHAPTER I

STATEMENT OF THE PROBLEM

During the past few years microcomputers have become readily more available to everyone and their applications have increased dramatically. These developments have raised questions about the possible uses of microcomputers in education. Bork (1985) predicts that in the future "computers will comprise the dominant delivery system in education for almost all age levels in most subject areas" (p. 1). He identifies five uses of computers, each corresponding to a different pedagogical need, as the main ways of using computers in an educational context. These are: programming, computer literacy, intellectual tool, computer-based learning, and computer management. Educators have begun to study each of these uses for classroom adaptations. In the area of mathematics education, for example, an extensive list of research studies on how computers can be used in each of these various applications has been compiled by M. Suydam [1986].

Stemming from the Artificial Intelligence language LISP, LOGO is a programming language created in the late 1960's and designed specifically to be used by children. Early research with LOGO which took place at Bolt Beranek and Newman Inc. was aimed at investigating the merits of learning programming for the understanding of mathematical ideas. Since this initial study both the LOGO language, as well as other research projects using it have evolved (see Clements 1985).

This study is concerned with the use of the programming language LOGO as an intellectual tool in the teaching of mathematics. According to Bork an intellectual tool is seen as an "extender of the human intellect" (p. 41) of which there are two types: general purpose tools, those which cut across subject areas, and specific tools, those for learning a particular subject. Two early research projects with LOGO were done, one at MIT and the other at the University of Edinburgh. At MIT, under the guidance of Papert, LOGO was used both as a general purpose intellectual tool for developing problem solving skills and as a specific tool for learning mathematical concepts via Turtle Geometry. The MIT philosophy is to create a new learning environment that is child-centered and fosters implicit learning largely through self-discovery and self-initiated projects. At Edinburgh, under Howe, LOGO was used as a specific tool in an attempt to teach certain math concepts explicitly. The Edinburgh philosophy was to incorporate LOGO into the traditional classroom setting with the exisitng curriculum.

Both the MIT and Edinburgn approaches are significant pioneering efforts in attempts to use LOGO in the learning of mathematics The Edinburgh approach had some moderate success in secondary school classrooms and was carried out primarily by the originators. In contrast, the MIT approach has had the widest appeal among researchers and educators. Consequently most LOGO research and classroom uses have been based on the latter approach.

These pioneering attempts by MIT and Edinburgh each represent almost diametrically opposed approaches to learning and teaching with LOGO. Each of these research projects together with other studies based on them have begun over the past five years to focus attention on shortcomings related to the exclusive use of either of these philosophies. In particular, there are questions on the one hand about the benefits of the Edinburgh approach where LOGO is adopted in such a way that it does not disturb most of the traditional features of teaching mathematics. Similarly, on the other hand, there are also questions about the MIT approach which seems to be rather too revolutionary for most teachers to understand and accept [Leron (1985), Moursand (1984)].

In recent years, some members of the LOGO community have begun to reflect on the actual advancements of LOGO in an educational context. Leron [1985] calls attention to the fact that the use of LOGO as described in the book Mindstorms is a vision and that there is a need to work on interfacing this vision with an operational context of the real world. He suggests that rather than adopt and work with one of the "opposing positions", e.g. Piagetian learning vs conservative classroom teaching, that it would seem more useful to adopt a position somewhere in between. In a similar vein, Bork [1985] recommends that "much additional research coupled with the development of curriculum material is needed to determine how LOGO can be used as an intellectual tool in a variety of areas" (p. 56). Such remarks clearly show that the LOGO community has begun to recognize the need for more pioneering research on alternative ways of using LOGO as an intellectual tool.

The study reported here is an exploratory venture in this direction. It is an attempt to develop an intermediate and more realistic approach to using LOGO as an intellectual tool in an educational context. It is based on the assumption that LOGO has the potential to enhance the learning of mathematical concepts given appropriate designed learning contexts. The underlying philosophy is that these contexts can be designed so that the process of learning programming concepts in Turtle Geometry induces the learning of corresponding mathematical concepts.

The general purpose of this study is to design a task-oriented LOGO environment with overall and specific programming and mathematical objectives appropriate for grade 4 children. If the responses of the children show that they are able to achieve these objectives through their performance of the given tasks, the principles of the research design may be used by teachers as a model of how to design a LOGO learning environment that will empower the achievement of particular curriculum goals.

CHAPTER II

REVIEW OF THE LITERATURE

This review focuses on two areas relevant to this study. First, it compares and contrasts the main characteristics of two prototype LOGO environments represented by the MIT and Edinburgh approaches. Secondly, it reviews the research with respect to these characteristics and with respect to the mathematical and programming concepts identified in the environments.

The MIT vs the Edinburugh LOGO Environments

We shall compare and contrast both approaches with respect to the philosophy and design, the role of LOGO, and of the teacher.

a) MIT LOGO

According to Papert, LOGO is not just a programming language but a new philosophy for education (Papert, 1980. p. 217). That is, LOGO is a general intellectual tool that can be used to revolutionize education. The MIT LOGO philospky removes LOGO from the traditional classroom into an ideological environment that is entirely dependent on LOGO itself and the microcomputer. Papert considers as a fundamental aspect of learning that "what an individual can learn and how he learns it depends on what models (are) available (to him)" (Papert, 1980: p. vii). He adds that a crucial factor in any learning environment is that it is "rich in those materials that (will) make the concept simple and concrete (Papert, 1980: p.7). For Papert, "LOGO environments are artificially maintained oasis where people encounter knowledge" (p. ~~181)~~ (Papert, 1980: p. 181).

Design of the LOGO environment

The LOGO environment reflects a use of LOGO as both a general intellectual tool as well as a specific tool for learning a subject like mathematics. The specific characteristics of the environment include:

- learning and using LOGO for Turtle Geometry drawings in a child centered environment without the constraints of objectives or content of an organized curriculum.
- learning by self-discovery through individual projects
- creating a situation in which the role of the teacher is largely providing help when it is asked for and answering questions..
- using ideas such as 'playing turtle' as a way of dealing with Turtle Geometry concepts

b) Edinburgh LOGO

The Edinburgh approach for using LOGO is quite different. Indeed, this group began by using a similar approach to MIT but concluded from the experience that: "they (the students) needed so much time and so much individual help that it rapidly became clear that the unstructured approach suggested by Papert could not be managed in a U.K. classroom, with one teacher and perhaps thirty pupils." (Ross, 1982: p. 2).

The ~~philosophy of~~ the Edinburgh group is based on an interpretation taken from Children's Minds (Donaldson, 1978):

> "Teaching a child is not just a question of devising task situations which encourage the growth or use of new memory structures: part of the process of communicating knowledge involves taking account of the effect of existing knowledge and using it to advantage whenever this is possible." (Howe, 1980: p.7)

That is, whereas the MIT approach is based on a revolutionary philosophy of learning without a curriculum or teacher, the Edinburgh approach is more of a reform in which LOGO is used in a structured environment within the content of the traditional classroom and curriculum.

Consequently the general teaching guidelines of the Edinburgh group are (a) build on a child's existing knowledge, (b) use familiar materials as manipulable models or as metaphors to make teaching and learning more manageable, (c) view classroom activities as partnerships between teacher and pupil in which the teacher organizes the objectives and content and the child is given as much responsibiltiy as possible for choosing, formulating and solving problems and (d) use feedback to assist learning.

Again, unlike the MIT approach where LOGO programming is learned in the context of using it to do Turtle Geometry, the Edinburgh group separates learning LOGO from learning mathematics. The group focuses on the "context" in which a child learns with computers. They believe that "a novice's ability to learn to program is impeded by the fact that he lacks an adequate mental representation of the machine he is trying to use." (Howe, 1980. p 8) Hence they use a simplified model of a computer "to provide a descriptive model as a context for introducing programming concepts, for interpreting the machine's responses and for establishing a small vocabulary for talking about programs and the activity of programming" (Howe, 1980: p 8) The approach uses worksheets consisting of objectives, a sample program, exercises which are modifications of the program and opportunities to adapt the program to the situations.

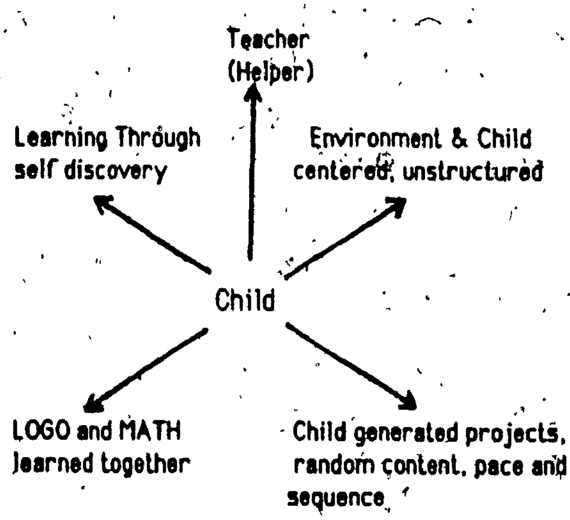
According to the Edinburgh Group, LOGO can be used in mathematics learning: "once pupils are able to understand how LOGO procedures are executed, programming provides a basis for making concrete interpretations of a variety of basic mathematical skills and concepts." (Howe, 1980: p.10) Their objectives for using LOGO in mathematics are to improve a child's (i) understanding of basic concepts and skills, (ii) ability to handle math topics (iii) mathematical self confidence. Worksheets are used based on the programming worksheets. Thus, LOGO is simply a programming language that could be replaced by another language.

SUMMARY

To summarize, we see from above that differences in the philosophies of MIT and Edinburgh towards LOGO learning lead to differences in the ways in which LOGO environments are designed and used for learning. These differences are illustrated in the diagrams below.

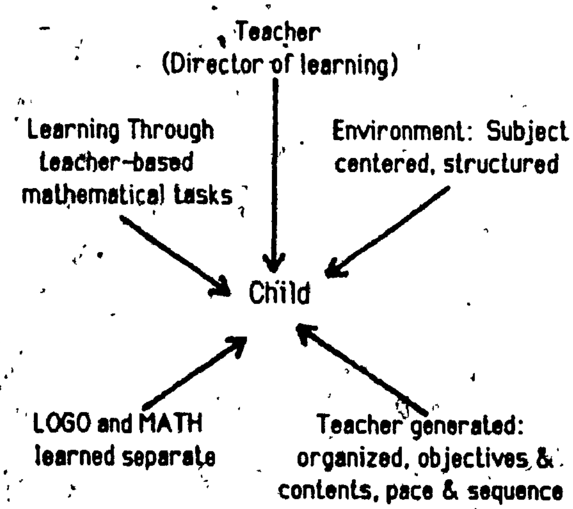
MIT

LOGO a general intellectual tool for thinking and problem solving.



EDINBURGH

LOGO as a specific intellectual tool for learning specific subject matter e.g. math.



Research on LOGO in Education

LOGO has been used in research studies since the nineteen-seventies (Brown et al., 1973, Solomon, 1975). This early period of research included experimentation in the construction of a suitable learning environment in which LOGO was to be used and observing children's behaviours working in the environment (Brown et al., 1973, Howe et al., 1978, 1980). However, with the publication of Papert's book Mindstorms (1980), the nature of LOGO research changed significantly. In his book, Papert describes his teaching philosophy and a corresponding learning environment to be used in conjunction with LOGO. Much of the LOGO related research thereafter tended to imitate the environment as described in Mindstorms and observations were concentrated on the way students learned LOGO and the effects of LOGO programming on students (see Clements, 1985). As a result of this, a large collection of reports of childrens behaviours working with LOGO is available; unfortunately, accompanying them, is relatively little detail on the contexts in which these observations were made.

As this study concentrates on both the development of the learning environment and the corresponding children's behaviours, the review of the literature focuses on the early LOGO research as well as the more recent. The early research, and more specifically the works of Brown, Howe and Solomon, are analyzed with respect to the details of their respective learning environments. The more recent research is reviewed with respect to the mathematical and programming concepts present while working with LOGO (Hillel, Noss, Papert et al.).

Structured contents and curriculum

The idea of structuring the contents for learning LOGO in early research projects has been attempted in three different forms; **worksheets** (Howe, 1980: p. 9, 11), **projects** (Solomon, 1975: p. 18) and **curriculum guides** (Brown et al., 1972: p. 7). The major difference between these structures is that worksheets and projects were designed to be used directly by the students whereas a curriculum guide was suggested outline available to the teacher.

In Edinburgh two sets of worksheets were produced. One was for learning LOGO programming and the other for working with mathematical topics (Howe, 1980). The framework of the worksheets remained the same for both types. The learning strategy involved three stages; repeating or copying something from the worksheet (a procedure for example), modifying it in a minor way and finally adapting it in a new situation. Programming concepts were taught in ordered sequence e.g. procedures, sub-procedures, variables and recursion. Topics for the math worksheets however, were chosen based on the following two criteria 1) on their presenting difficulty for the children who were at the time learning LOGO and 2) topics which lent themselves to a 'concrete interpretation' that LOGO could provide. Topics from arithmetic, algebra and geometry from the upper elementary curriculum were chosen and included such items as number lines, adding positive and negative numbers and geometric figures.

Howe provides us with only one sample math worksheet on the addition of positive and negative numbers (Howe, 1980: p. 11 and Appendix 2). The available details from this sample worksheet seem to suggest that a traditional teaching method for the particular subject was used. In the case of the addition of positive and negative numbers, an approach using semi-circles to represent each type was adapted for use on the computer. In this case, the technology (computer with LOGO) acted only as a vehicle for the lesson.

Suggested projects were used both by Brown at Syracuse and Solomon at MIT. The Syracuse group, which had been experimenting with curriculum design from the very beginning of their research with LOGO, created a hierarchical set of projects. These suggested projects were classified into three categories: 'simple projects', 'projects with variables' and 'projects with decision points' (Brown et al., 1973, p. 10). An example from each group includes designs of initials, arithmetic or language games, and games with limits and conditional branches.. Solomon suggests to the teacher a list of 'early topics and projects' (Solomon, 1975, p. 180). Examples of projects included are drawing a circle, making a face and 'rolling a square'. Each project is described in terms of a suggested teaching strategy through sample discussions for introducing the idea to the child

The idea of suggesting projects provided a guideline for a progression in the learning of LOGO programming skills. For instance, in the Syracuse group together with the listing of the projects is also some information, not very detailed, of the new programming concepts and commands that will be encountered with each particular project group (Brown et al., 1973 p. 10). For example in the category of 'simple projects' the new concepts are identified as procedure, sub-procedure, editing, recursion, and filing and the new commands listed are TO, END, EDIT, SAVE, GET, LIST, ERASE, and turtle commands. What is not explicit at this stage in the research is the identification of the actual mathematical concepts that are required by a child in order to succeed in achieving the final goal. And, hence, it is not clear for the teacher what exactly the child is required to know or what exactly it is the child is learning.

The idea of a **curriculum guide** was first described in the Syracuse report (Brown et al. 1973). Its purpose was to provide an outline for the teaching of the elementary LOGO programming concepts. It was designed for teachers to be used for introducing LOGO into the classroom. The guide provided a hierarchical sequence of topics for the introduction of basic LOGO programming skills. These topics tended to follow the traditional sequence in which a programming language is taught. In all, the guide consisted of a list of sixteen items which were accompanied with very little detail. For example, item one of the guide which reads: "familiarization with machinery, typing, signing on and off" provides a minimum of information (Brown, 1973, p. 7).

All three forms, **worksheets**, **projects** and **curriculum guides**, were the result of early attempts at developing methods for introducing computers and programming to children using the LOGO language. Much of the developmental work with structured contents was replaced with experimentation with exploratory learning environments as described in Papert's book Mindstorms (see Clements, 1985).

Learning Materials

The idea of developing and using **learning materials** in conjunction with LOGO appeared in the early research works of Brown, Howe and Solomon. The learning materials developed correspond to the different stages of learning to program; pre-planning, planning and programming. The three major types of learning materials are **idea charts, paper and pencil,** and **teaching aids**. Each one is reviewed below.

Idea charts were developed as part of the Syracuse project (Brown, 1973, p. 19). Their main goal was to help stimulate ideas at the onset of LOGO activities (pre-planning). The ideas for the charts evolved from projects from both the children and the teachers. The chart consisted of both written ideas (e.g. kite, house, initials) and pictorial ideas (e.g. drawings of a heart, fish, drum). No further information, explicit or implicit, about the projects was provided with the chart.

The use of **paper and pencil** as part of the learning material in the LOGO environment in the early research is discussed mostly at the planning stage. In principle, paper and pencil was seen as a useful tool for providing a bridge between the original idea and the actual programming activity. Its role in early research is seen as a planning tool. The Syracuse group, for example, designed an actual planning sheet which was divided into three parts; "my idea, my plans, how it worked" (Brown, 1973: p. 23). The use of notebooks for children to record their activities is also suggested in the early research work (Solomon, 1975: p. 14).

Solomon developed teaching aids whose principle function was to simplify the actual LOGO programming environments. Having observed conceptual difficulties with first graders using the existing LOGO syntax, Solomon developed new primitives (procedures) which simplified the requirements of the programming task. The use of "TEACH" to create a procedure, for example, automatically saved a procedure after it was defined (Solomon, 1975. p. 6). Another example of a teaching aid developed is Hillel's slowed-down version of the turtle for which the commands FD, BK, RT, LT are replaced with GFD, GBK, TRT, TLT to produce the same effect only at a slower pace. His rationale was that with the slower-paced turtle both its rotations as well as the process of a program would be made visually more explicit (Hillel, 1985 p 31)

It seems that the pioneering researchers working with LOGO and young children recognized quite early in their experience that there was a need for additional learning materials in the 'LOGO and microcomputer' environment. Combined experiences from the various projects indicate that there was a necessity for them at all the varying stages of learning to program with LOGO i.e. pre-planning (project ideas), planning and the actual activity of programming itself. Since the adaptation of the MIT exploratory learning environment as the pricipal learning environment, little attention has been focused on continuing the development of learning materials despite a very probable continued existing demand for them.

Computer Games and Playing Turtle

The use of games as teaching aids for facilitating the understanding of LOGO and its accompanying concepts was adapted into the very early research experiences (Brown et al., 1973, Solomon, 1975). **Computer games** were designed for learning about computer operations and programming logic. An example of this type of game is: the child is asked to take the role of the computer and the teacher gives the child a computer command. The child's interpretation of the given command reflects the child's perception and understanding of the computer's logic and hence allows for clarification of a misconception if present (Brown et al, 1973: p. 15).

The game 'playing turtle' refers to a game which is used in a similar vein to a computer game but which is designed to be used specifically with Turtle Geometry. Two methods for playing turtle are described by Solomon. They are: 1) playing turtle by pen and paper, i.e. hand simulation of the turtle activity and 2) the child becoming the turtle itself and acting out its part (anthropomorphizing) (Solomon, 1974. p. 14). Playing turtle has remained an important element in the LOGO learning environment. Its use as a teaching aid has continued in many LOGO projects. For example, in the conclusion of the Chiltern project the following is noted with repect to playing turtle: "(playing turtle is) a very powerful aid in helping children to form a mental model of the internal workings of the machine:" (Noss, 1984: p. 149).

THE LEARNING ENVIRONMENTS IN LOGO RESEARCH

This section reviews the literature with respect to LOGO learning environments and the components which define them It begins with a discussion on LOGO learning environments themselves and then reviews the following aspects thereof: **role of LOGO; teacher/child role; teacher intervention; teaching strategies; tasks; procedures.**

LOGO Learning Environment

A very important part when analyzing a learning experience is the knowledge of the context in which the observed learning takes place. Much of the LOGO research has neglected reporting on this factor. Attention seems to have been focused establishing the validity of LOGO as a learning tool by solely reporting on the successful projects that were observed. Very little detail has been provided on the surrounding circumstances leading to the success. Hillel, who defines the learning 'environment' to include the components which "clearly influence the behaviour of children interacting with LOGO", stresses the importance of reporting on the detail of these components (Hillel, 1985: p. 4). Some of the research reports have revealed or expressed points of view and afterthoughts on some of these components, but a complete picture of the environment is usually not available in any single report. The components which have been discussed and that are considered important for this study are analyzed below.

The Role of LOGO

The role given to LOGO, although not always stated explicitly, tends to be reflected in the type of research project undertaken. Three roles given to LOGO can be distinguished in the research. These are: 1) LOGO programming is itself the activity 2) Using LOGO to create the activity and 3) LOGO programming is itself the activity but with restrictions Research projects such as the Brookline and Chiltern in which children are given access to all the LOGO features and then observed working on projects are examples where LOGO programming has the role of being the activity itself (Papert et al., 1979, Noss, 1984). Teaching programming and mathematics through LOGO worksheets as designed by the Edinburgh group is an example in which LOGO is used to create the activity (Howe et al., 1980). Working with certain features of LOGO programming on specific projects and tasks considered appropriate to the age level is an example of LOGO programming still providing the main activity but with the addition of certain restrictions (Erlwanger, 1985, Hillel, 1985).

Teacher/Child Role

Both the teacher and the child have been given specific and varying roles in the LOGO research. The role of the teacher which tends to be different from the traditional classroom role varies slightly from one LOGO project to another. For example, Solomon, who strongly suggests the improvement of the overall learning environment in general, tries to convey the idea of a "teacher-and-student as research collaborators" (Solomon, 1978: p. 23). The approach used at Syracuse for the teacher role stressed the idea of guiding a child rather than to provide direct answers (Brown et al., 1973: p. 11). And Noss in the Chiltern project, describes the teacher role as: "the teacher has a vital, if subtle and delicate role to play in helping children to learn LOGO" (Noss, 1984: p. 12). Although new teacher roles have emerged from the research projects, very little detail by description or examples is available on how the role actually took shape. In describing the obersvations of the children's work, the precise role that the teacher had while the child was working is not available. This leaves the roles vague and difficult to implement into a real classroom situation.

Learning with LOGO and a microcomputer has created environments in which new roles for the child as learner have emerged. In many of the major research projects with LOGO, the child is given much more responsibility in the learning activity. The child is often given the role of a researcher/explorer by using a teaching strategy in which "children pose their own problems and develop their own approaches" (Noss, 1984: p. 12).

Although the new role has brought much optimism and excitement for educators it does at the same time raise the question of how realistic a learning situation is in which children are left with the responsibility of posing their own problems and setting their own goals. In an initial study with LOGO, Hillel observes that children changed their goals as a way to avoid dealing with errors. Hillel suggests that this frequent change of goal can become an obstacle to learning and that perhaps a more balanced approach between exploratory and goal oriented activities would be more productive (Hillel, 1985: p. 14, 31).

Teacher Intervention

Teacher intervention has become a very important component in a LOGO learning environment because of the often passive yet strategic role the teacher is assigned. Too often, though, the research provides little description or record of the actual intervention that has taken place in an oberved learning situation (see for example Brookeline Project, 1978). At least two strategies from teacher intervention can be extracted from the information provided in the research projects. These are: 1) using intervention as the means of teaching and 2) using intervention as a control mechanism on the learning activity.

In the case of the first strategy, using intervention as the means of teaching, the situation observed is one in which the teacher's interventions are of the following type; suggesting a new idea, reviewing work already done, helping a child plan a project (Noss, 1984: p. 150). These types of intervention, even though intended to be as discreet as possible, are similar to traditional teaching activities although on a more individual basis. In the case of the second strategy, using intervention as a control mechanism on the learning activities, the situation observed is one in which the teacher interventions are pre-defined to meet a specific goal(s) regarding the learning activities themselves. This use of intervention was defined by Hillel and included such goals as "(achieving) a balance between exploratory activity and goal-oriented acitivity" and " a balance between planning-in-action and pre-planning" (Hillel, 1985: p. 31).

Describing and defining intervention is a very important element in any LOGO learning environment but just as important is detailed reporting on the actual interventions that were present in the learning experiences. This type of reporting provides a clearer picture of the context in which an activity is observed and in turn allows for a more detailed analysis of the observations made.

Teaching Strategies

Two very global strategies for teaching LOGO can be identified from the research. In the first strategy the LOGO concepts are taught in a predetermined order according to an overall developmental plan. In the other, the concepts are taught in the order determined by the requirements of the project or task at hand. This strategy tends to be characteristic of project-oriented LOGO learning environments in which children work on projects and are taught LOGO concepts as they become required (Brookline Project (1975), Chiltern Project (1984)). Teaching LOGO in an ordered-sequence corresponds to the situation in which LOGO programming concepts are taught in a hierarchical progression often similar to that used for other programming languages. This teaching strategy tends to be characteristic of curriculum-based LOGO learning environments in which children learn LOGO syntax and semantics in a progressive sequence (Brown et al., 1973).

Regardless of the teaching strategy being applied, the general tendency is to begin teaching LOGO wth the four basic primitives FD, BK, RT, LT, which is then followed by an introduction to the LOGO syntax for procedures. Usually what follows thereafter varies slightly from one research project to the other. In general, the introduction to LOGO programming tends to be at a relatively fast pace (see Abelson, 1982). Introducing LOGO in this manner may perhaps be successfull for teaching LOGO programming skills. However, quite often relatively sophisticated concepts underlie many of the programming features. For example, with young children, the syntax for the command REPEAT can be grasped with relative ease. However, understanding exactly what is being repeated, in what order and how many times may not be so evident. Depending on the teaching goals, the order in which LOGO programming concepts are taught as well as the pace should perhaps be considered more carefully.

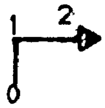
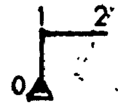
LOGO Tasks

Designing, analysing, and implementing LOGO tasks to meet specific objectives (programming and/or mathematical) does not appear in the LOGO learning environments as described in the research. Tasks have been used as part of the learning environment but rather as a means of demonstrating a particular concept. Hillel, for example, used tasks to demonstrate the modularity of the geometric product of a procedure in Turtle Geometry (Hillel, 1985: p. 32). However, the use of designed LOGO tasks as a means of providing a situation in which very specific and sequential mathematical and programming concepts are encountered as part of the learning environment has not been emphasized.

LOGO learning activities have, in general, been more concentrated on LOGO projects rather than tasks. These projects, although sometimes classified with respect to their degree of difficulty are more often viewed with respect to their degree of learning experience e.g sub-procedures, recursion etc. This learning experience although potentially very rich becomes one in which it is very difficult to identify and control its contents. This can result both in teacher frustration because it is not clear what exaclty is being learnt and in child frustration as a pre-required concept may not yet be present in the child's existing knowledge structure.

Procedures

The distinction between the process and the product of a LOGO procedure has been well documented in the LOGO research. The Brookline project clearly recognized the difference between a procedure's "internal constraints (process logic)" and "external properties (product logic)" (Papert et al., 1979: p. 4.5). These two characteristics of a procedure play a very important role in any LOGO learning environment. Observations from the various research studies done with LOGO stress the importance of the need for children to understand not only the procedure/product relationship but also the process underlying a given procedure. The Chiltern project, for example, concludes that "it has appeared that the obstacle to effective use of the idea (of a procedure) has been a failure to see the underlying process involved in it " (Noss, 1984: p 147).

With respect to this use of procedures and from a slightly different perspective, Hillel recognizes that "since procedures actually describe a process of construction, they are not uniquely defined by the object" (Hillel, 1985: p. 17) i.e., although two procedure products may look identical the processes used to produce the effect may be quite distinct. He comments further that the possible variations in the process of construction of a procedure (e.g. AS  OR  OR ) will affect the degree of difficulty associated with using that procedure in the making of other constructions (Hillel, 1985: p. 17).

Providing a LOGO learning environment which facilitates the learning of the process/product distinction of a procedure seems crucial for the learning of LOGO and more fundamentally the learning of programming concepts. Furthermore, and perhaps at the next learning level, is the importance for children at a relatively early stage of learning to program to experience situations in which different processes resulting in the same product can be explored. Procedures are not only a key to programming in LOGO they are also a key to understanding the concept of a program

PROGRAMMING AND MATHEMATICAL CONCEPTS UNDERLYING LOGO/TURTLE GEOMETRY

This section reviews the programming and mathematical concepts which have been encountered by children in the various LOGO research projects. The focus is on those concepts which are relevant to the learning environment designed in this study for grade four children (9-10 years old). Although different environments may have promoted or accentuated different aspects of LOGO, the aim of this review is to summarize the global ideas discussed in the research.

Programming Concepts

The programming concepts generally associated with the early stages of learning LOGO are: command, procedure, functional naming, interfacing, debugging and modularity. Each one is discussed below.

Commands

The first commands taught in LOGO are usually basic commands which control the turtle (FD, BK, RT, LT). Two concepts fundamental to programming underlie this very basic programming function. These are i) that the command itself has a very specific structure and ii) each command results in an action particular to that command The Brookline project recognizes that with respect to using commands that "it may require some time to develop a purposeful sense of deliberatly controlling the turtle by particular commands" (Papert et al., 1979: p. 4.2). In the case of very young children, these ideas although very basic to LOGO programming can easily fall subject to being overlooked or underestimated in terms of time required to grasp the associated concepts

Procedure

In addition to the product/process idea of a **procedure** , from a programming point of view, procedures also have an internal and external component. The internal component is the sequential order implied by a procedure's definition. i.e. Once defined a procedure will always do the same thing. The external component of a procedure is its command behaviour i.e once defined a procedure is used in the same way as a command/primitive. These internal and external components are what the Brookline project refer to as "developing the notion of a procedure as an entity" (Papert et al., 1979. p. 4.2) . They are crucial to understanding procedures from a programming point of view and are encountered with the very first experiences of defining and using procedures. Although, this is a subtlety with respect to learning about and using procedures, it is a very important aspect of them and the research in general has not focused on observations of children's ease or difficulties with it.

Functional Naming

Functional naming of procedures although less significant in early stages of programming is nonetheless an important programming concept. Noss, for example, observes that "the names of children's early procedures usually bore no relation to their effect" and comments that the children's names and initials were often popular choices (Noss, 1984: p. 18). Although naming procedures in this manner does have effective benefits, functional naming can easily be demonstrated which later can become a very useful and powerful idea in any programming environment.

Interface

In early stages of programming, the **interface** between two procedures usually consists of adjusting the turtle's heading and/or position. Two steps are required for interfacing The first is that of recognizing that an interface is required. i.e. Recognizing that the turtle's heading and/or position needs to be changed. The second step involves finding the appropriate inputs for the length and/or angle so that the turtle's position and heading is correct for a successful interface. Hillel identifies that for children this second step is often where the difficulty lies (Hillel, 1985: p.15).

Debugging

Debugging is an important part of any programming experience. Generally what is referred to by the term debugging is the location and correction of an error in a program. With respect to LOGO/Turtle Geometry environments correction of errors have been analyzed with respect to first of all avoiding them altogether i.e. use of Clear Screen or starting over. Other debugging strategies observed with children include: i) Using the direct inverse of a command i.e. return the turtle to the exact state it had before the error was made. ii) "Adjusting for the error directly" i.e. position the turtle directly to the state originally desired before the error was made. iii) Playing turtle. (See Hillel, 1985: p. 28.) Debugging is seen as a very important element of the LOGO experience as it provides an opportunity for errors to be encountered in a positive context that is significantly different from the traditional classroom approach.

Modularity

Because LOGO is a procedural language, **modularity** is an important concept inherent in it. The simplest form of modularity is the modularity of the product of a procedure itself. A classic example of this is using a procedure which produces a square to make a diamond. With respect to learning modularity, the research seems to suggest that children's difficulties with it can be related to the perception of a problem. Noss, for example, observed with one group of children who had just built several different sized rectangles that when asked to build a tower (constructed with rectangles) the children suggested an outline strategy i.e. to draw the outline of the tower as opposed to stacking the rectangles Because so many strategies to solving a problem in LOGO are possible, the concept of modularity need never be encountered However, it is a very powerfull idea in LOGO and general problem solving that should be fostered in the learning environment

Mathematical Concepts

LOGO has been promoted by Papert as a powerful tool for learning mathematics. Different research studies have concentrated on different aspects of the math related experiences. The Chiltern project, for example, analyzed the children's LOGO activities with respect to very global mathematical concepts such as generalisation, particularisation and conjecture (Noss, 1984 p. 148). The Brookline project analyzed the LOGO environment with respect to many geometrical and mathematical ideas These include modularity, coordinate systems, number worlds and group properties of numbers (composition and inversion) (Papert et al., 1979. chapter 5) A more detailed study by Hillel focuses on mathematical concepts which were present for children who were novice LOGO users (Hillel, 1985). His ideas of 'spontaneous concepts' and other theorems emerging from the LOGO activity are discussed in greater detail below. Although there is a general consensus that LOGO is very rich in terms of math related concepts, by no means all of these have yet been identified and spelled out clearly. Ongoing research today should continue to observe and identify children's mathematical behaviours.

Formalization of Children's Mathematical Behaviours in Turtle Geometry

In his study, Hillel observed children's behaviours with respect to displacement and rotation. He identifies what he calls three 'spontaneous concepts'. These are: i) that outputs vary directly with inputs, so larger inputs will produce larger effects ii) that two successive displacements (rotations) is a displacement (rotation) iii) displacement FD X, FD Y is longer than displacement FD X i.e, FD X, FD Y > FD X and FD X, BK Y < FD X and analogously for rotations (Hillel, 1985: p. 23). Other theorems emerging from the LOGO activities are with respect to relative measure, additive measure, subtractive and proportional measure. These are theorems i) to iv) in the report. They are given below:

i)	relative measure	$X < Y \iff \lvert FD\ X \rvert < \lvert FD\ Y \rvert$ $X < Y \iff \lvert RT\ X \rvert < \lvert RT\ Y \rvert$
ii)	additive measure	$\lvert FD\ X, FD\ Y \rvert = \lvert FD\ (X + Y) \rvert$ $\lvert RT\ X, RT\ Y \rvert = \lvert RT\ (X + Y) \rvert$
iii)	subtractive measure	$\lvert FD\ X, BK\ Y \rvert = \lvert FD(X - Y) \rvert \quad Y < X$ $\lvert RT\ X, LT\ Y \rvert = \lvert RT(X - Y) \rvert \quad Y < X$
iv)	proportional measure	$\lvert FD(rX) \rvert = r \lvert FD\ X \rvert$ $\lvert RT(rX) \rvert = r \lvert RT\ X \rvert$

The formalization of these mathematical ideas encountered in Turtle Geometry provides a more precise point of reference which can be used for interpreting children's mathematical behaviours.

CHAPTER 3

METHODOLOGY & PROCEDURE

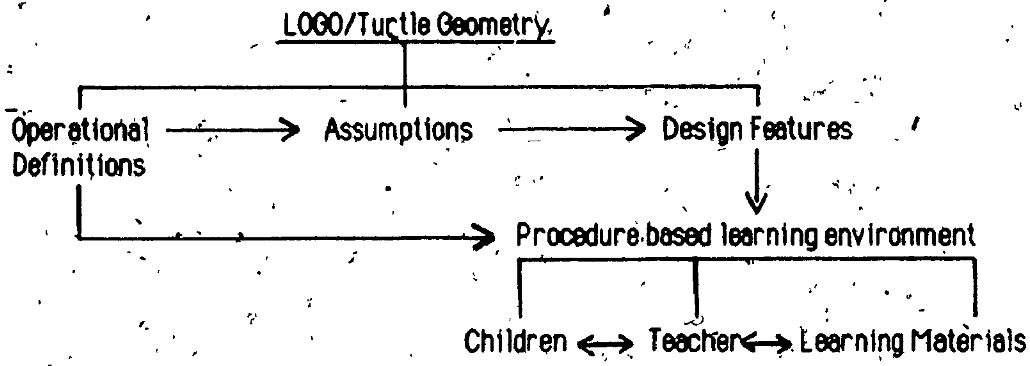
This chapter consists of two sections. The first describes the methodology of the study and the second the research procedure

SECTION I - METHODOLOGY

This study is in the form of a teaching experiment aimed at developing a LOGO environment through which the math and programming behaviours of grade four children working in it can be observed. The organization of this Turtle Geometry LOGO environment is deliberately designed so that certain mathematical and programming concepts and skills are present. The underlying assumption is that programming geometric tasks in a procedure-based LOGO environment should provide opportunities for the children to acquire and use corresponding mathematical concepts. Using the teaching experiment model [Kantowski, 1979] allows for ongoing changes to be made in the environment. The clinical approach [Ginsburg, 1981] is used throughout the study to permit more in-depth observations of the children as well as the teaching process itself.

The environment consists of three main components: the children, the teacher, and learning materials. An overall design strategy is used to organize these three components into a dynamic LOGO learning environment. The design strategy stems from LOGO/Turtle Geometry and includes operational definitions, assumptions and design features. Each aspect of the design strategy is discussed below.

Overall Design Strategy



OPERATIONAL DEFINITIONS

Some common techinical terms/jargon related to LOGO are given operational definitions that are congruent with the design features of this environment. These are:

Programming Concepts:

This environment has two types of programming concepts: those related specifically to Turtle Geometry and those which are global to programming. These include:

Programming Concepts

Turtle Geometry	Global
turtle	commands
position/heading	control
turning	procedures
a pen (with an eraser)	functional naming
non-state/state transparency	interfacing
	debugging
	modularity
	repeated occurence

Mathematical Concepts:

As this environment is designed for grade four children, the mathematical/geometrical concepts which are focused on include:

Mathematical Concepts

number
angle
inverse
proportion
estimation
rigid transformation

Task:

A task in this environment is defined via a visual geometric construction, a written instruction or a combination of the two

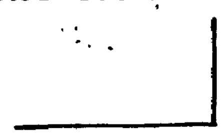
Example.

visual
(I)

Write a procedure to draw
a line 50 turtle-steps long

written
(II)

Use LINE50 to draw:

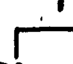


Combination of (I) & (II)

LOGO Procedure:

LOGO Procedures in this environment for grade four children represent simple open geometric shapes.

Examples.

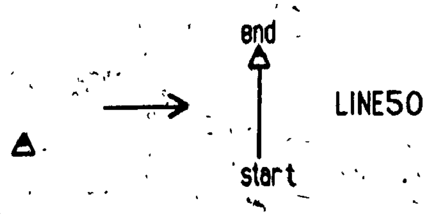
Procedure		Geometric Product
LINE50	⟶	
EL2040	⟶	

<u>Note</u>: EL for the letter "L" has been adopted for describing open geometric shapes consisting of two unequal lines joined at a right angle. The numbers where follow give the lengths of each of these lines. (Erlwanger, 1985)

<u>Non-state transparent</u>:

A non-state transparent LOGO procedure is one in which the final state of the turtle is diferent from its original state.

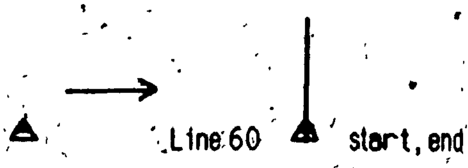
<u>Example</u>:



<u>State Transparent</u>:

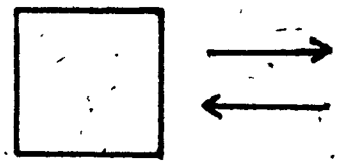
A state-transparent LOGO procedure is one in which the turtle always returns to its original state.

<u>Example</u>:



<u>Perceptual & Conceptual Understanding of a LOGO Procedure:</u>

A distinction is made in this study between the perceptual and the conceptual understandings of a LOGO procedure: The <u>perceptual</u> understanding of a LOGO procedure is the ability to associate a picture <u>product</u> with a name of a particular procedure (see figure 1). This seems to require little or no knowledge of the mathematical and programming concepts related to the procedure and its use.



SQUARE

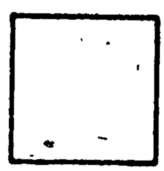
(product) (LOGO procedure name)

figure 1

In contrast the <u>conceptual</u> understanding of a LOGO procedure is the ability to define, interpret and use a LOGO procedure. It requires knowledge of the actual <u>process</u> of a procedure. This involves understanding (i) the effect of each command on the turtle in a LOGO procedure and (ii) the sequence of commands required to achieve the desired effect. Consequently, a conceptual understanding of a procedure requires knowledge of mathematical and programming concepts consistent with the demands of that procedure and its use.

<u>Perceptual Product</u>

SQUARE =



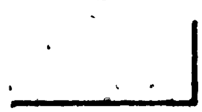
<u>Conceptual Process</u>

<u>Math/Geom</u>	<u>Programming</u>
4 sides	turtle advanced
equal lengths	then turns
angle; turns 90^0	turtle state

<u>Program</u>:

The term "program" in this study is a sequence of commands, or commands and LOGO procedures, that are required to execute a given task.

<u>Example</u>: Use LINE50 to draw:



Example of <u>Program</u>:

```
RT 90
LINE50
LINE50
LT 90
LINE50
```

Interface:

The type of interfacing used for this study is that of a command with a LOGO procedure.

Examples:	RT 90	EL2040
	EL2040	RT 90
		EL2040

In both these examples, RT 90 is the interface.

Paper & Pencil (PP):

Paper & pencil materials used by the children include; workbooks, homework books and homework sheets

Concrete Materials (CM):

The concrete materials used by the children include: A (40 x 40 cm) wooden board representing the screen; small foam rubber triangles (Δ) coloured at one tip representing the turtle; wooden popsicle sticks cut into different lengths used to represent procedures or to model tasks.

Computer (C):

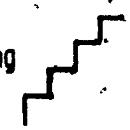
The computer used in this study is an Apple IIe which has been booted with LOGO II prior to the children's arrival.

ASSUMPTIONS:

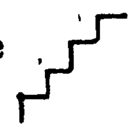
The design features used in the creation of this environment are based on the following assumptions:

1. Turtle Geometry involves the use of mathematical and programming concepts and skills. Thus in the attempt of writing a program to draw a square there are opportunities for one to use as well as become aware of different mathematical properties related to that square.

2. One can distinguish in Turtle Geometry between the process and the product of a LOGO procedure. For instance, given a LOGO procedure for drawing a square the process is in the effect of the sequence of commands while the product is in the picture that can be displayed on the screen.

3. The mathematical and programming concepts related to a procedure lie in the dual processes of **constructing** as well as **using it**. For instance the activity of drawing  using  as a building block involves:

   a) Writing the LOGO procedure to draw  using programming concepts in conjunction with corresponding mathematical/geometrical properties of . to decide on the commands, their sequence and their inputs.

   b) Using the LOGO procedure for  to write the program to draw the  by correctly interfacing the LOGO procedure with itself.

4. **A)** The explicit use of programming concepts in Turtle Geometry may require the implicit use of mathematical concepts.

   B) It is possible to design geometric tasks in LOGO appropriate for grade four children that involve selected mathematical and programming concepts.

DESIGN FEATURES

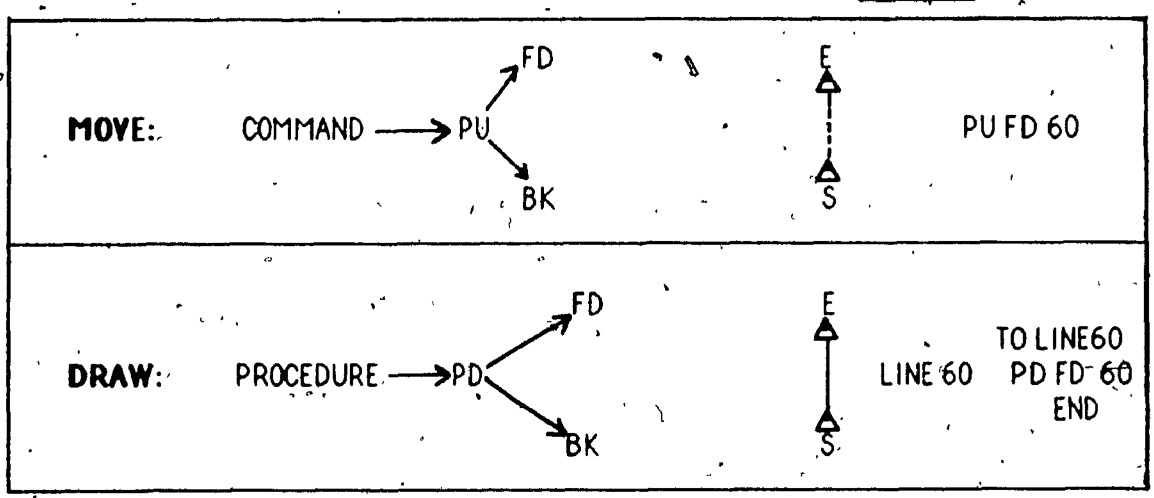
The design features are the specific mechanisms for creating the learning environment. These include: procedure-based environment; designed tasks; teaching strategy; roles. Each of these features is described below:

Procedure-Based Environment

The general design strategy is to create a learning environment in which the process/product idea of a <u>LOGO procedure</u> plays a fundamental role. Consequently, it is described as a <u>procedure-based</u> environment with several characteristics. (Erlwanger, 1985). It distinguishes clearly between using <u>commands</u> to **<u>MOVE</u>** the turtle on the screen and using <u>procedures</u> to **<u>DRAW</u>** with the turtle on the screen. This distinction inhibits a child (user) from using commands in direct mode to draw geometric shapes. In a sense, this feature forces the child to focus more on the process of a procedure than on its product. This feature is strengthened further by the omission of the HOME command in the LOGO environment. The HOME command tends to give novice users opportunities to obtain a product for which the process is not necessarily understood. The table below summarizes the restrictions due to this distinction.

<u>LOGO commands used for MOVING & DRAWING</u>

<u>Examples:</u>



It is worth noting that although PD FD 60 and LINE 60 both give the same product, there is an important pedagogical difference associated with their use. If the goal is to obtain only the <u>product</u> then PD FD 60 is a shorter and a more direct way. However, if the goal is to learn the mathematical and programming concepts associated with a <u>process</u> then the use of a procedure (in this case LINE60) is necessary.

Designed Geometric Tasks

Tasks in this environment are designed to meet specific programming and mathematical objectives. This is achieved through:

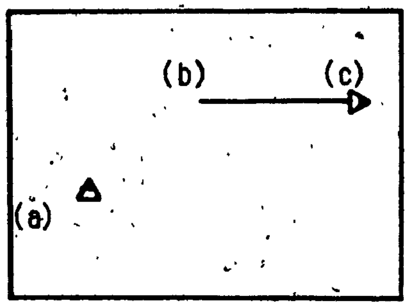


figure 2

1) **The task including a LOGO procedure(s) to emphasize both the product and process related to the use of that procedure.**

For example, given a task to draw a horizontal line with a procedure some vertical and horizontal distance away from the origin (see figure 2).

a) Choosing a path and moving the turtle with its pen up a vertical and horizonal distance.

b) Knowledge of a procedure name and the ~~product~~ it produces. e.g. A procedure called LINE50 producing | .

c) Correctly positioning the turtle at (b) to interface it with the procedure. This requires knowledge of the process of the procedure to be used. e.g. does the procedure begin with a turn or does it begin by drawing forward?

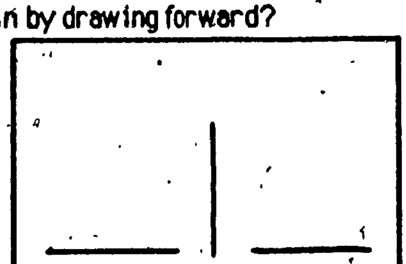


figure 3

2) The structure of the procedure-oriented tasks having explicit requirements which focus on its product and implicit requirements which focus on the process.

The following is an example of a task from session 5 which involves the use of a straight line procedure to produce the task shown in figure 3. This task was the fifth task given to the children that involved moving the turtle and drawing with a LINE procedure. It was the first task which involved drawing more than one line on the screen at the same time. Although the structure looks relatively simple it actually requires new programming and mathematical concepts which had not previously been encountered by the children in this environment These are turning the turtle through 180 degrees or using BK and centering a line between two others. The requiremens of the task can be analyzed as follows.

<u>Explicit task requirements.</u>

i) Moving the turtle. (i.e. PU FD, PU BK)

ii) Drawing with the turtle using a procedure.

iii) Turning the turtle through 180 degrees.

iv) or using BK.

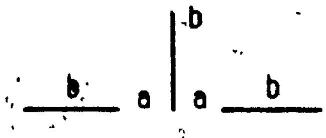
v) Turning the turtle through 90 degrees.

vi) Backtracking (i.e. the turtle is required to retrace a part of its path)

<u>Implicit task requirements:</u>

i) That the distance from the vertical line and the horizontal line on the right be the same as the distance from the vertical line to the horizontal line on the left.

ii) The turtle needs to retrace its path on the horizontal line which requires that the distance between the vertical and horizontal line be doubled or repeated twice. i.e.



b + 2a + b
or b + a + a + b

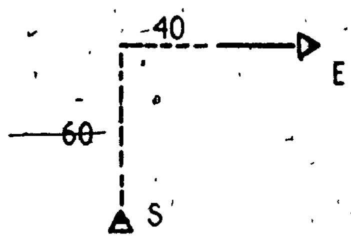
3) **Using 'structured' and 'semi-structured' tasks. (A structured task is a task which has one and only one precise solution and a semi-structured task has many possible solutions.**

An example of each type is given below with a description of the successful solution(s) related to each task.

<u>Examples</u>

<u>A. A structured task</u>

Use LINE30 to draw.

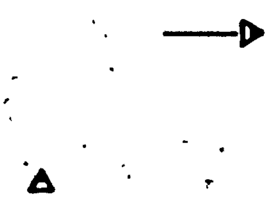


<u>Successful Solution</u>

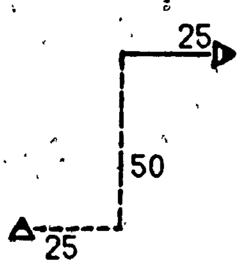
PU FD 60
RT 90
PU FD 40
LINE30

<u>B. A semi-structured task</u>

Use your LINE25 or LINE50 procedures to do the following:



Successful Solution: There are many possible successful solutions. They will be dependent on the choice of path, distances and length. One example is:



RT 90
PU FD 25
LT 90
PU FD 50
RT 90
LINE25

It is worth noting the pedagogical differences between a structured and a semi-structured task. The structured task creates a situation in which specific objectives can be met. This can be very useful for introducing a new programming or mathematical concept. e.g. In example A above for structured tasks the information given with the task explicitly demonstrates: a path for MOVING the turtle and the choice of inputs for the vertical and horizontal distances. Implicitly it demonstrates proportionality.

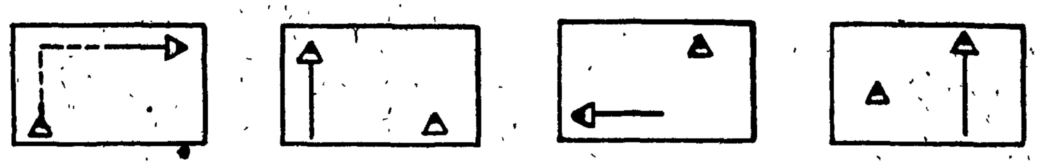
The semi-structured task creates a situation in which objectives that are more global to a concept can be encountered. e.g. In example B the child is required to choose and indicate a path and the desired distances and lengths. The restriction on the choice of procedures, i.e. LINE25 or LINE50, implicitly requires an appropriate choice for the distances for proportionality to be present, e.g 25, 50, 25 or 50, 100, 50.

4) Using a built-in hierarchy in a series of tasks to develop a programming and/or mathematical concept.

This design strategy is present throughout the teaching experiment. Its purpose is twofold. From the point of view of the learner it provides an opportunity for newly acquired concepts and skills to be used in varied situations. Form the point of view of the teacher it provides an opportunity to observe the learners using these acquired concepts and skills and evaluate the learners understanding.

Example: (from session 4)

Use the LINE30 or LINE60 procedure to draw:



(a) (b) (c) (d)

This series of tasks involves moving the turtle to a desired state and using a procedure to draw. The programming concepts being developed include: i) choosing a path, ii) changing the turtle position and heading, iii) varying the order of the change in the position and heading, i.e. change position then heading, change heading then position, iv) interfacing. The mathematical concepts being developed include i) proportionality of distance and length, ii) using different quadrants on the screen, iii) use of a 180 degree rotation or BK, iv) in task (d) crossing over two quadrants and making the appropriate position/length adjustment

TEACHING STRATEGY

The teaching strategy for this environment involves five elements: **teacher, children, tasks, materials** and **homework**. Each of these elements is discussed below.

Teacher: The teacher is the creator of this particular procedure-based learning environment in which grade four children are expected to encounter suitable learning experiences.

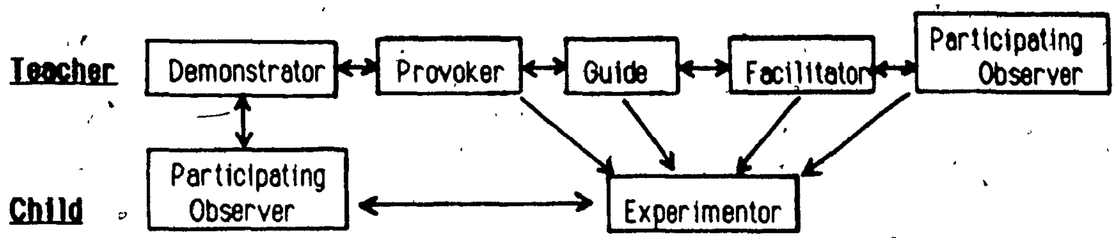
Children: The experiment which involves designing concrete materials uses 9 - 10 year old children who are in the concrete operational stage of development (Ginsburg, 1969) The children are the subjects under study and in order to evaluate the effect of this particular learning environment they should have no previous experience with LOGO. The children are grouped in pairs as this is a convenient small working group for an experiment

Tasks: The tasks are geometric products. The goal is to recreate each product by using LOGO procedures. Consequently a task provides a precise goal for which the associated process to achieve it involves certain programming and mathematical concepts that are appropriate for a 9 - 10 year old.

Materials: Several types of materials are present in the environment. In order to focus on the process required by a task, paper and pencil activities are used for detailed planning of a solution for the task. To facilitate the understanding of what is being asked in a task, concrete manipulatives are used to construct a model task. Finally, in order not to eliminate the planning stage by working in direct mode, the computer is used as a checking and feedback device.

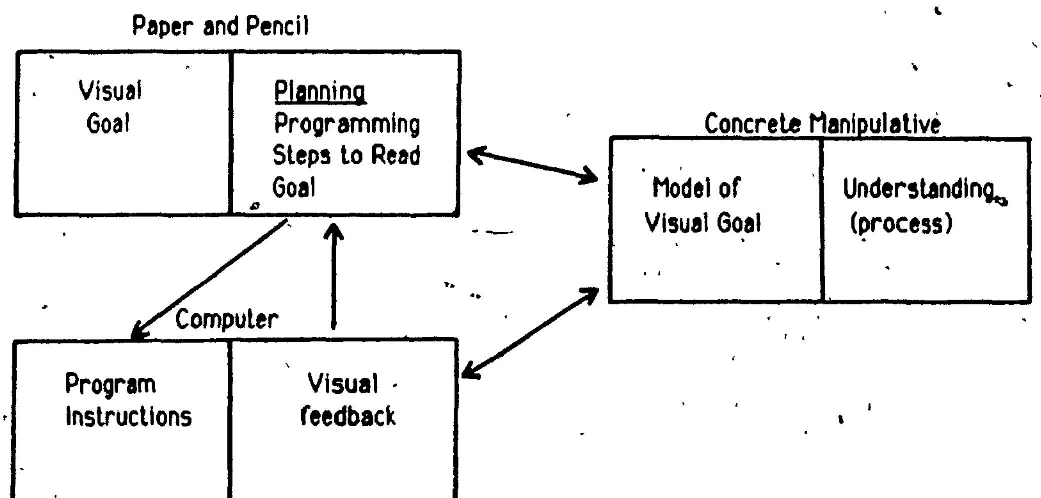
Homework: Homework is given to the children in order to provide some continuity between the actual session and an opportunity for the children to work individually. (i.e. without their partner.)

Roles: Each of the three main components (teacher, children, materials) have specific and changing roles creating a dynamic element in the learning environment. Each of these roles is described on the following page.



The diagram above represents the various roles of both the teacher and the child and how these roles interact with one another. Both can change their roles to correspond with the immediacies of the learning environment. The change is therefore spontaneous and free flowing. During the time that the teacher is playing the role of a demonstrator, the child is acting as a participating observer. At all other times, the child is the experimenter and the teacher can move in and out of any of the other four teacher roles (provoker, guide, facilitator, participating observer). These various roles permit a dynamic interaction between the teacher and the child to occur

Materials



The three types of materials used in the learning environment each correspond to a stage in solving a task, i.e. paper and pencil: planning, concrete manipulatives: understanding, computer: visual feedback. The activity of solving a task in the environment requires understanding, planning, checking and depending on the outcome a possible return to understanding or planning and through the cycle again until the task is solved. Going through these stages for solving a task results in a corresponding dynamism between the material used in the learning environment.

THE ANALYSIS

The aim of this study is to analyse two things in the learning environment: what were the specific programming and mathematical concepts present and the children's behaviours in learning and using them. This involves a detailed analysis of each task to identify its precise structure and requirements followed by a detailed analysis of each pair of children working to solve the task.

Task Analysis

Each task is analyzed under five categories: **nature, structure, requirement(s), successful solution** and **key teacher intervention(s)**. The nature of a task is necessary in order to identify the context in which it is presented. The explicit and implicit structure of the task is required in order to be able to accurately determine all of the programming and mathematics that will be required to do the task. The task requirements, also explicit and implicit, are listed to determine precisely what the children are required to do in attempting the task. The, or an example of, a successful solution is provided to demonstrate how the solution looks. And finally, key teacher interventions are identified to aid and clarify the children's behaviour working with the task.

Analysis of the Children's Behaviour

As this study is a teaching experiment, the type of analysis of the children's behaviour is qualitative. In order to capture as much of the behaviour as possible three things are used in the final analysis: The workbooks, worksheets and homework sheets which contained the children's planning stages; a video tape which recorded the computer screen and the oral content for each session; a dribble file of the programming sequence typed into the computer also for each session.

SECTION 2 - RESEARCH PROCEDURE

This section deals with the research procedures used in selecting the children, the working arrangements in the study, the organization and methods used in the LOGO sessions, the collection of data and the procedures used for the anlaysis of the task and the children's behaviour working the the environment.

Selection of the Children

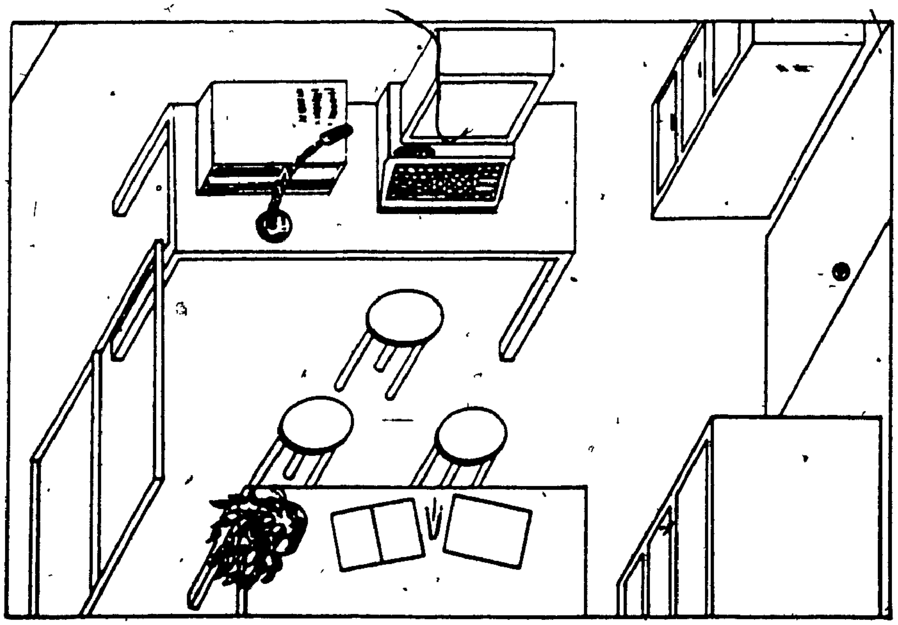
Six children, two females and four males, participated in the study. The children were between the ages of 9 and 10 years old and attended a grade four class at St. Ignatius of Loyola (a public) primary school, located in close proximity to the Loyola campus of Concordia University. A list of interested candidates was compiled based on the response to a letter that was sent to each grade four parent (see Appendix 1). From the list, six children were randomly selected and paired based on their availablity to attend the sessions after school on one of the three given days (Tuesday, Wednesday, Thursday).

Working Arrangements

The study was conducted during the months of October through December, 1985. The sessions were held after school beginning at 3:45 p.m. and lasting for one and a quarter hours. Appendix I below shows the attendance record of each pair of children for the twelve sessions.

The study took place at the university in a small office in the mathematics department. Upon entering the room, on the left hand side there was a large open shelving unit and a desk with two long and narrow shelves above it. On the right hand side was a long table which held an Apple IIe computer and recording equipment, a small stand-up green chalkboard and a filing cabinet. In all there were three stools on wheels.

The desk on the left hand side of the room was used for the paper and pencil and concrete manipulative activities and the table on the right hand side (opposite) of the room was used for the computer activities (see diagram below). The stools were moved back & forth by the children and the researcher to the appropriate side of the room.



The following equipment was used for recording/observing the children's work: (i) a VCR (Beta) recorder for recording the conversations and the computer screen during the session; (ii) dribble files of the computer work of each session; (iii) the children's workbooks, worksheets and homework books and homework sheets.

Planning of the Sessions

Each session was planned by the researcher at the beginning of the week. This involved the following sequence of stages: **1)** review previous session(s); **2)** set the objectives; **3)** choose the procedure(s) and design a series of task that meet the objective; **4)** prepare the paper and pencil, and concrete manipulatives that may be required by the tasks

Preparation of the materials

Following the planning of the session the materials were prepared. This involved **a)** constructing (when necessary) the manipulatives to be used in the session and select from any existing ones; **b)** preparing the children's workbooks and/or worksheets and homework books or homework sheets; **c)** setting up the dribble files on each group's diskette

Organization of a Session

Each session followed a similar structure. In general, a session was organized around a series of tasks. These tasks were designed and prepared prior to the beginning of a session. The design of the tasks took into consideration the children's responses in the previous session(s) to which some new element(s) would be added. The preparation of the tasks involved transcribing the designed tasks into the workbooks for each group. Two things should be noted with respect to the preparation of tasks. **1)** The tasks were manually entered into the workbooks which possibly resulted in minor differences from one workbook to another. **2)** There was an implicit scale in the paper & pencil representation of the tasks due to the use of squared paper.

In general, the first task for a session was the homework from the previous session. Thereafter the children would refer to their workbook for the next task. A new page was used for each session. The first task usually involved defining the procedure(s) that was going to be used.

This was followed by another 3-4 tasks which required some use of this procedure. The following is an example of a workbook page for session 6:

1) Write a procdure to draw a line 25 Turtle steps long.

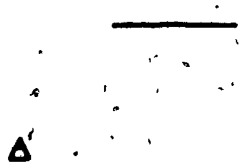
Procedure

2) Write another procedure to draw a line,50 Turtle steps long.

Procedure

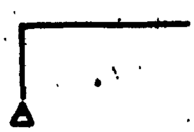
Use your procedures to do the following.

3) Program

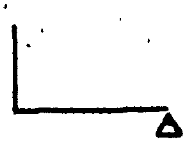


4) Program

5) Program



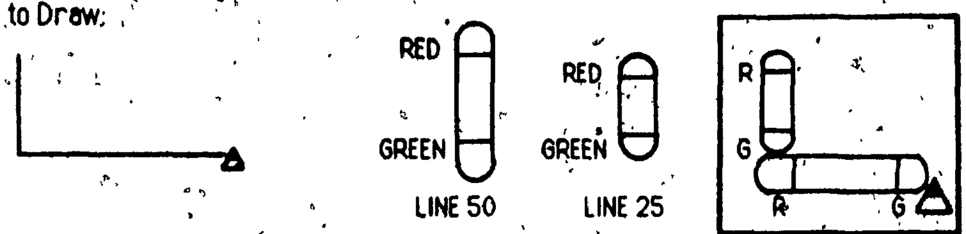
6) Program



The Children

Children working on a task go through three stages (i) planning (ii) checking (iii) revising. **Planning** is done with the use of concrete manipulatives and paper and pencil materials. A concrete representation of the procedure used in the tasks is either already available or constructed by the children. It is painted green where the turtle starts and red where the turtle ends. A model of the task using this concrete representation is then constructed on the toy screen to aid in the paper and pencil planning. (Playing turtle is also used during this stage).

Example: Task Use LINE 25 and LINE 50 to Draw: Manipulatives provided: Model of Task:



For the paper & pencil stage the children were encouraged to use the following planning strategy.

1) Indicate on the drawing of the task.

a) Where the turtle starts (S) and where the turtle ends (E).

b) The final state of the turtle (▲).

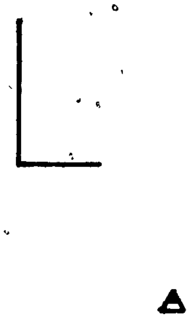
c) If necessary the path of the turtle (using a dotted line).

d) The choice of inputs for distances and lengths.

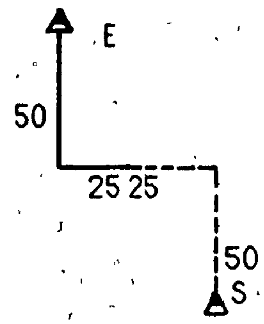
2) Write down the program

Example:
Given the following task:

Use LINE25 & LINE50 to draw



Upon completion of the above steps the workbook should look as follows (depends also on choice of path).



PROGRAM:

```
PU FD 50
LT 90
PU FD 25
LINE25
RT 90
LINE50
```

Checking follows the planning stage. It is done by typing the program into the computer and comparing the results on the screen with the drawing in the workbook. If the results are correct, the children move onto the next task. If however a discrepancy exists, the children begin the revising stage. In general a task is attempted until a succesful solution is found. A possible exception is when lack of time prevents completion.

Revising involves returning to the planning phase and verifying the paper and pencil work using the concrete manipulatives and playing turtle.

The children worked in pairs. Distribution of the work was encouraged. For instance, during the planning activity one child would follow the manipulative representation of the task and verbalize the commands while the other child would write the commands in the workbook; when checking, one child would read from the workbook while the other child would write. During the revising of a task, the children were encouraged to reverse their above roles. The researcher ensured that a regular change of these roles would take place so that the children would not dominate in a particular (possibly favorite) role, e.g. always typing.

The Teacher

During a session the researcher (acting as the teacher) changed roles according to what was judged as needed at a particular time in the session. For example, the researcher acted as: a demonstrator to introduce new LOGO commands, a provoker to give tasks and ask questions; a guide to help steer the order of planning, checking and revising; a facilitator to provide, clarify or suggest; and an observer to allow the children to work independently. The principal source for feedback of the children's work was the computer.

Collection of Data

The sessions were recorded in two different ways. The first was a visual/audio recording of the sequence produced on the screen and the conversation in the room. this was done with a VCR recorder with two direct connections; one to the computer monitor and the other to an external microphone. The second form of recording was via dribble files. The dribble file records each LOGO command that is typed into the computer. This is saved into a designated file on a diskette which can later be used to produce a hardcopy of the session.

Overall Analysis

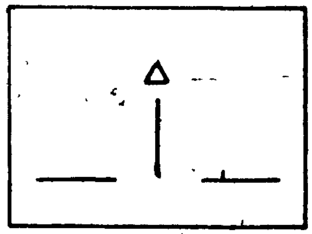
Both the learning environment and the children's behaviour working in the environment were analyzed. The analysis of the learning environment involved a systematic analysis of each task given to the children. Each task was analysed to determine its: nature; explicit and implicit structure; explicit and implicit requirements; successful solution(s); and key teacher interventions. An example of a task analysis is provided on the following page.

The analysis of the children's behaviour working in the environment involved a careful study of the children's paper and pencil work, the dribble files and the audio/video tape for each session. A large worksheet was used to map on a single sheet the paper and pencil and computer work done by each group for each task. The tapes were then listened to and excerpts of conversations revealing about the subject under study as well as selected teacher interventions were transferred onto the worksheet in its corresponding location for the task and group. Once a map was complete it was analysed to identify the mathematical and programming behaviour for each group attempting the task. This analysis was done for the twelve sessions, each session consisting of approximately four tasks.

Example of a Task Analysis

Session 5 - Homework (from session 4)

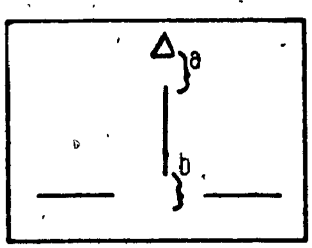
Nature: The homework is presented as a diagram with written instructions in the homework books. The diagram is composed of a square representing the screen, three solid lines and a partially shaded triangle representing the turtle The written instructions are as follows: Write a program for the turtle to draw what is in the box



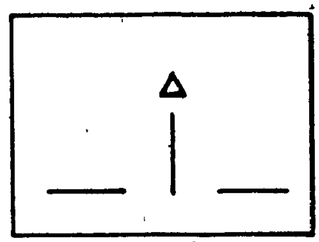
The diagram for GR I differed form the given to GR II & III.

(see structure below).

Structure



(a)
Task for GR I



(b)
Task for GR II & III

Explicit: The task consists of three detached lines of equal length, one vertical, two horizontal. The lines are situated in the bottom half of the screen below the drawing of the turtle. The initial state of the turtle is indicated but not the final. No path between the solid lines is provided.

Implicit: The horizontal lines are equidistant from the vertical. For GR I, the distance from the turtle to the first line (a) is the same as the distance from the vertical line to the horizontal lines (b). For groups II & III the vertical distance b is not present (see figures a and b).

Task requirements: There are many possible solutions. Application of both equal length and equidistance is required.

Explicit:
1. Moving the turtle
2. Drawing with the turtle
3. Use of 180 degrees or BK
4. Turning the turtle through 90 degrees
5. Back tracking i.e. to go over the part or part of the path a second time

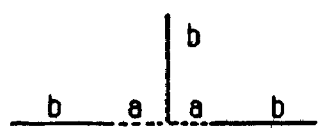


figure (c)

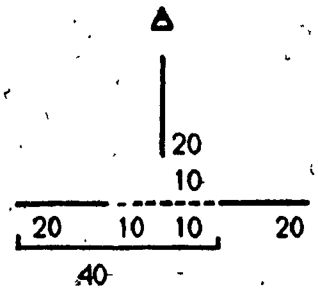
Implicit: The horizontal lines should be symmetrical about the vertical line. This requires.

1. That the distance from the vertical line and the horizontal line on the left be the same as the distance from the vertical line to the horizontal line on the right.
2. The structure of the diagram requires that the turtle retrace its path at least on the horizontal lines. The mathematical consequence of this requires that the distance between the vertical and horizontal line be doubled or repeated twice to draw the second horizontal line.

e.g.

```
PU FD A
PD FD B
PU BK B + 2A    or    PU BK B + A    or    PU BK B
PD BK B               PU BK A              PU BK A
                                           PU BK A
```

Successful solution: The following is a sample of a successful solution



PU BK 10
PD BK 20
PU BK 10 for GR I only
LT 90
PU FD 10
PD FD 20
PU BK 40
PD BK 20

CHAPTER 4

ANALYSIS OF THE ENVIRONMENT AND THE CHILDREN'S BEHAVIOURS

The analysis of the environment and of the children's behaviours working in the environment is presented session by session. For each one, an **overall description** is given followed by an analysis of its tasks and the children's behaviours while attempting the task. Each session is then concluded with a summary of the **general observations**

The overall description contains information of the contents of the session, the objectives, the sequence of the tasks as well as the strategies and embedded hierarchies underlying the sequence. Each task is then individually analyzed identifying its **nature**, **structure** (explicit, implicit), **requirements** (explicit, implicit), **successful solutions(s)** and **selected teacher interventions**. A description of the **children's attempts** while doing a task is given through a detailed account of each group's paper and pencil activities together with the corresponding excerpts from their respective dribble files. This is followed by an analysis of the children's behaviour. Each session is then concluded with a summary of what was observed under the heading **general observations**.

SESSION I

Overall Description

The overall objective of the first session was to introduce the children to Turtle Geometry and the learning environment. A series of activities was used to lead an introduction to the LOGO turtle and Turtle Geometry commands. The activities were as follows:

1. Introduction and discussion on the computer components: screen, keyboard, computer, diskdrive, diskette.

Concrete Materials:

2. Introduction to the LOGO turtle (on the screen),
3. Construction of computer turtles. Each child made a computer turtle out of cardboard and crayons.
4. Introduction to the toy turtle and toy screen
5. Playing turtle FORWARD (FD) number of turtle steps
   BACKWARD (BK) number of turtle steps

Computer Activities:

6. Two computer tasks

The computer activities~~,~~ which consisted of two tasks, were designed to require the explicit use of the commands FD and BK and the implicit use of the mathematical concepts of measurement, estimation of distance, and total distance. The first task involved giving the turtle a command and observing its behaviour. The second task continued with this but the children were asked to meet specific objectives as described by the teacher. Teacher intervention is a key element in the learning process associated with doing these particular tasks. A detailed description of these tasks and the childrens' attempts and behaviour while doing them is given below.

Session 1 - Task 1

Nature: The task was the first computer activity for the children. It immediately followed a game of "playing turtle" which introduced the children to the commands forward and backward. At the computer, the children were told of the abbreviation for forward (FD) and backwards (BK) and then verbally asked "How many steps do you want to tell the turtle to take?"

Structure:

Explicit: The task is defined by the vertical movement of the turtle with the commands FD and BK. The pen is intentionally up and the fence option for the screen is turned off. i.e. FD and BK move the turtle without drawing and wrapping is possible.

Implicit: The task demonstrates:

1. The effect of an input with FD and BK on the action of the turtle.
2. The relation between the size of the number input and the distance travelled by the turtle
3. Relativity of the turtle step to the size of the screen. e.g. How far the turtle goes with FD 140 compared to FD 20.
4. That FD and BK are inverses.

Task Requirements:

Explicit: There is no precise solution for this task. To perform the task successfully the following are required.

a) Correct use of the syntax for the commands FD and BK.

b) Choice of input that is not out of bounds for the turtle. e.g. FD 90000 is out of bounds.

Implicit: Use of the keyboard for typing commands and numbers. Use of the return key.

Successful Solution

FD (space) distance
BK (space) distance

Selected Teacher Interventions

The teacher: a) Guides the children in using the correct syntax.

b) Suggests to the children to watch the turtle just prior to pressing the return key.

c) Asks and discusses with the children what they have just observed.

d) Asks the children if the turtle takes large or small steps.

Children's Attempts:

GR I	GR II	GR III
FD 10	FD 6	FD 3
BK 64	BK 4	BK 3
FD 1	FD 9	FD 2
	FD 10	BK 2

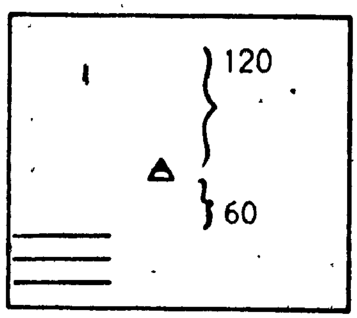
For this task each group tried both commands FD and BK. Group I entered three inputs and Groups II and III each entered four. For the choice of inputs, Groups II and III tended to use numbers such as 2, 3, 4, 6 that were the same as those used in the "play turtle" activity. Group I used 10 and 64.

It is interesting to note that initially there was some confusion regarding how many steps the turtle actually took. After entering his first command FD6, Robert noted: "Hey, he only moved once." and then asked, "Should I press return again?". It seems that Robert expected to visibly see the turtle take each step, perhaps similar to what he had just experienced while playing turtle.

Session 1 - Task 2

Nature: The task involves moving the turtle vertically from one extremity of the screen to the other. i.e. top/bottom, bottom/top. It immediately follows the first task as a consequence of the researcher's intervention: "How many steps do you think it will take to go to the top of the screen?" This is later continued with two more interventions which ask that the turtle be moved to the bottom of the screen and then once again to the top.

Structure:



Explicit: The task is defined by the screen size in turtle Geometry. i.e. 120 turtle steps from the centre to the top and 60 turtle steps from the centre to the beginning of the writing on the bottom. The turtle is able to wrap around the screen as the fence option is not in use. The turtle's pen is placed in the up position. The starting point for each group is different. It is determined by the turtle's final position after the first task.

Implicit: The task demonstrates the overall distances required to keep the turtle within the vertical boundaries of the screen.

Task Requirements: A precise solution to this task requires:

Explicit: 1. That the turtle be moved foward the number of required steps to reach the top. This number is dependent on the turtle's position at the beginning of the task.

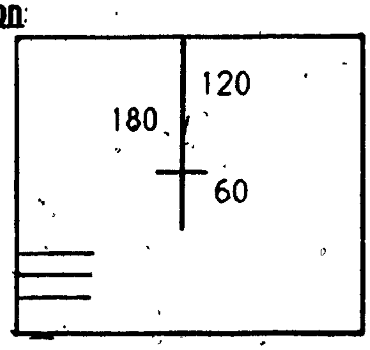
2. Once at the top of the screen the task requires that the turtle be moved backwards 180 turtle steps.

Implicit: 1. The task requires estimating in turtle steps the distance between the turtle and the top or bottom of the screen.

2. An appropriate choice of a value for input with FD and BK. i.e. an input within the turtle's bounds.

3. An estimation of the total distance from the top of the screen to the bottom or vice- versa. This requires the addition of the values of the appropriate inputs.

Successful Solution:



From the center of the screen:

a) to the top 120

b) to the bottom 60

From one extremity to the other: 180.

Selected Teacher Interventions:

Upon completion of the first estimation to the top and the second estimation to the bottom, each group was asked the following question: "How far have you gone from here to here?" (pointing to the top and bottom of the screen).

Children's Attempts:

	GR I	GR II	GR III
1)	FD 200	FD 17	FD 2
2)	BK 90	FD 19	FD 8
3)	FD 30	FD 19	FD 9
4)	FD 20	FD 22	FD 14
5)	FD 30	FD 29	FD 10
6)	BK 16	BK 100	FD 50
7)	FD 6	BK 500	FD 60
8)	BK 16	FD 10000	FD 5
9)	FD 5	FD 90000	FD 2
10)	FD 5	FD 90	FD 3
11)	FD 3	FD 90	FD 60
12)	FD 2	FD 10	FD 80
13)	BK 1	BK 3	FD 50
14)	BK 90	BK 9	BQ 2
15)	BK 80	FD 5	BK 1
16)	BK 6	FD 1	BK 1
17)	BK 5	PD	PD
18)	FD 182	BK 181	FD 10
19)	BK 20	CS	BK 80
20)	PD	BK 400	BK 90
21)	FD 9	CS	CS
22)	BK 146	FD 90	FD 80
23)	CS	CS	
24)	FD 200		

The children showed relative ease in using the LOGO syntax as seen in their computer work in the table above

Two different situations arose following the first intervention which asked the children to get the turtle to the top of the screen. All three groups experienced a wrapping effect which brought them to the bottom of the screen as opposed to being closer to the top. Group 1, which had just input FD 200 (GR I, line 12) to cause the wrapping, countered it with BK 90 and continued to work on their original goal. Groups II and III did not counter the effect and restarted the task of getting the turtel to the top of the screen this time from somewhere nearer the bottom than where they originally started.

The children's use of measurement and estimation skills appears to improve if one uses the number of attempts required for each goal within each individual group as a measure. Group I uses 13 moves for the first goal and 4 and 3 for the second and third. Group II used 8, 7 and 1 and Group III, 10, 6, 2 for goals 1, 2, 3 respectively. Although the number of attempts for each goal differ from one group to another, within each of the three groups the number of attempts is reduced.

When asked to calculate the total distance from the top ~~to~~ the bottom of the screen Group I for example, repsonded with the following:

Benny:	"First we tried 90, then 80."
Jennifer:	"91?"
Benny:	"No, you have to add them."
Jennifer:	"90 + 90?"
Benny:	"90 + 80 is 170 + 6 is 176 + 5 is 181."
Jennifer:	"182."

This seems to imply that the children knew what they wanted to add together to calculate the total distance and this was observed with all three groups. However there were arithmetic errors such as in Group II where Gregg says that "90 + 90 is 190".

General Oberservations

The session was aimed at introducing the programming commands FD and Bk and their associated concept of a value input. This involved learning the proper syntax for each command and working on tasks that are designed to provoke the application of the mathematical skills of measurement (in turtle steps), estimation of distance and total distance.

Prior to this first computer activity the children's only experience with input values for the commands FD and BK were those while "playing turtle". The given computer tasks provoked the children to:

a) **Obtain** a sense of the size of a turtle step relative to the screen.

b) **Adjust** this image to match the results of the various input attempts.

c) **Measure** the approximate distance from where the turtle is to the top or bottom of the screen (depending on their goal).

d) **Calculate** the total distance by adding together the required individual distance used in achieving their goal.

In summary, on the programming side the children showed no difficulty in adopting the LOGO syntax for the FD and BK commands. They had all initially been guided at the computer on the syntax and typing procedures related to each one. There was no evidence of any related problems for the remaining of the session. Regarding the mathematics, the children did demonstrate estimation skills and definition of total distance. The errors that did occur tended to be arithmetical in nature.

SESSION 2

Overall Description

The overall objective of session 2 was to introduce the children to moving the turtle. The session consisted of a game of playing turtle followed by two tasks presented on paper and pencil involving moving the turtle along a specific path.

To introduce the children to what the paper and pencil diagram represented, a game of playing turtle in which various lengths of planks of wood joined at right angles were positioned on the floor to represent a path. The children each took a turn being the LOGO programmer and gave the verbal instructions to move the turtle (the other child) along the planks. This activity was followed immediately by the first paper and pencil activity (task 1) which now represented the turtle's path in their workbooks with a broken line.

The session introduced the children to the LOGO commands RT and LT used with the input 90, the toy screen and toy turtle and using the computer as a checking device. The objectives for task 1 and task 2 were:

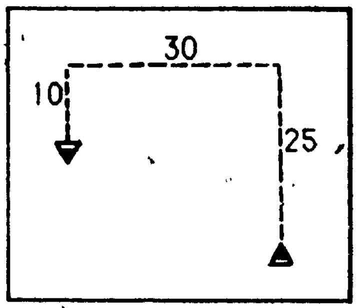
1) Introducing the use of PU to move the turtle.
2) Navigating the turtle: providing various settings for right and left 90 degree turn combinations.
3) Demonstration of effects of various length inputs, i.e. the greater the input the longer the distance.
4) Demonstration of combinations of varying lengths and their overall effects.

Task 1 and 2 and the children's attempts are described in detail below.

Session 2 - Task I

Nature: The task was presented in the children's workbooks as a broken straight line diagram on squared paper representing the turtle path on the screen with its pen up. The children were asked to write the program to follow the original path taken by the turtle

Structure:



Explicit: The task is an open shape consisting of three straight lines at right angles. As shown in the diagram the length of each side is given in turtle steps as well as the initial and final states of the turtle.

Implicit: The task demonstrates

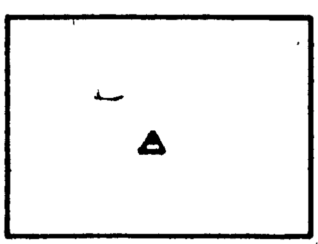
a) moving the turtle forward as the first command

b) the net effect of a series of commands on the turtle state

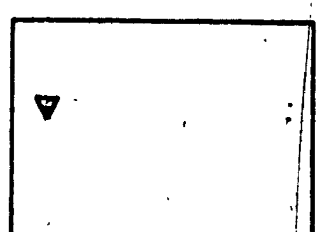
c) moving the turtle into the upper left hand quadrant of the plane.

Task requirements

a) screen at beginning of task



b) screen after task is completed



Explicit: A precise solution of this task requires

1. Moving the turtle forward.
2. Use of given turtle steps as number inputs.
3. Turning the turtle left through 90 degrees twice.

Implicit: The task requires that each programming step be verified with the effect of the turtle on the screen as no trace is being left by the turtle.

Successful solution:

PU FD 25
LT 90
PU FD 30
LT 90
PU FD 10

Selected Teacher Interventions: Direction regarding the order of activities. i.e. PP, CM, C

"Watch the turtle"
"Did the turtle go where you wanted it to go"

Children's attempts:

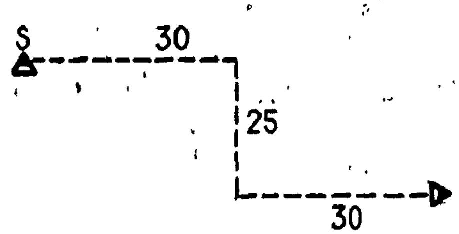
	GR I		GR II		GR III*	
	PP	C	PP	C	PP	C
1)	PU FD 25	PU FD 25	PU FD 25	PU FD 30	PU FD 25	PU FD 25
2)	LT 90	LT 90	RT 90	RT 90	LT 90	LT 90
3)	PU FD 30	PU FD 30	PU FD 30	LT 90	PU FD 30	PU FD 30
4)	LT 90	LT 90	LT 90	LT 90	LT 90	LT 90
5)	PU FD 10	PU FD 10	PU FD 10	PU FD 30	PU FD 10	PU FD 10
6)				PU FD 30		
7)				LT 90		
8)				PU FD 10		

This task was the first paper and pencil task for the children. It followed a game of "playing turtle" in which a path was used as defined on the floor with wooden planks. From the above paper and pencil and computer work it is observed that in general the children had no difficulty writing down five commands as a series. Errors were not related to following the path and recording the commands but if present tended to suggest lateralization problems. e.g. GR II line 2.

Session 2 - Task 2

Nature: The task was presented as a broken straight line diagram on squared paper representing the turtle path on the screen with its pen up. The diagram was drawn in their workbooks. The children were asked to write the program to follow the original path taken by the turtle.

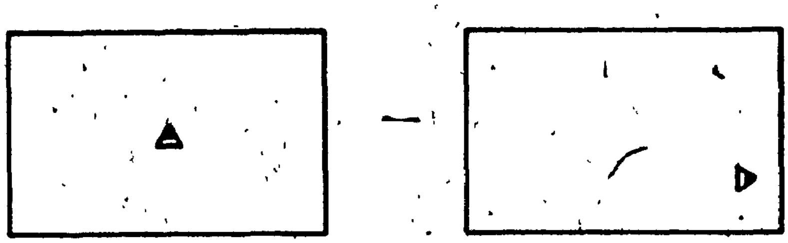
Structure:



Explicit: The task is an open shape consisting of three straight lines at right angles. As shown in the diagram the length of each side is provided as are the initial and final states of the turtle.

Implicit: The task demonstrates 1) the net effect of a series of commands on the turtle state; 2) turning the turtle as a first step instead of FD or BK; 3) moving the turtle into the lower right hand quadrant of the plane.

Task requirements:



a) screen before task b) screen after task

Explicit: A precise solution of this task requires:

1. A total of three turns 1) △ ↷ ▷ 2) ▷ ↘ ▽ 3) ▽ ↗ ▷
2. To begin the solution with a right turn
3. Use the given turtle steps as number inputs

Implicit: The task results in the turtle only moving on the screen and not drawing or leaving a path. The child must therefore check the screen after each input to verify his/her programming step with the visual result. (Hand-eye coordination).

Successful solution —

RT 90
PU FD 30
RT 90
PU FD 25
LT 90
PU FD 30

Selected Teacher Interventions:

1. Direction regarding order of activities
2. Instruction to watch the turtle on the screen after a command input

e.g. "Watch the turtle"
"Did the turtle go where you wanted it to go?"

Children's attempts

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	RT 90	LT 90	RT 90	RT 90
2)	PU FD 30	PU FD 30	PU FD 30	RT 90	PU FD 30	PU FD 30
3)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
4)	PU FD 25	PU FD 25	PU FD 25	PU FD 30	PU FD 25	PU FD 25
5)	LT 90	RT 90	LT 90	RT 90	LT 90	LT 90
6)	PU FD 30	PU FD 30	PU FD 30	PU FD 25	PU FD 30	PU FD 30
7)				LT 90		
8)				PU FD 30		

The task required a series of six commands for which there was no evidence of difficulty in the coordination of following the path and recording the appropriate commands. Errors, if present, again were with lateralization (GR, PP: line 1) and not with the interpretation of the drawing. At this stage, the environment is requiring a lot of direction regarding the sequence of activities (PP, CM, C) by the teacher.

Correction of lateralization errors

Two methods for correcting lateralization errors have been observed so far.

1) The first is to correct an incorrect turn with the turn in the opposite direction being used twice. eg. LT 90 corrected with RT 90 RT 90 (task 2, GR II, C: lines 1, 2, 3)
2) The second is to correct an incorrect turn that is written in the workbook before it is typed into the computer. i.e. using the visual cue from the screen and evaluating the effect of the next command before it is actually typed in. (GR I: Task 1, line 4; Task 2, line 5)

General Observations

Session two introduced the concept of a LOGO program as a series of turtle commands. The programming activities required the navigation of the turtle through a path as described in a drawing. Added to the commands FD and BK introduced in session 1 were the commands LT, RT and CS. All of the tasks involved "Moving" the turtle and hence PU was used.

In general the children are not having difficulties with using turtle commands. They were able to successfully follow a path and write down the corresponding commands for the turtle as a series in a program. The errors observed were with lateralization. Although no information was provided regarding the successful solution for the task, much guidance on operating in the environment was present. Examples of this type of guidance include the teacher directing the children to write down their program before going to the computer and suggesting the use of manipulatives.

The commands LT and RT were introduced while "playing turtle". In response to the question "What do you think the 90 is in LT 90 ?" the following was observed: "a number", "90 steps", "90 turtle steps". The word degrees was never mentioned in the session by either the teacher or the children.

It is perhaps worth making a special note regarding the structure of the two tasks in the session Although the tasks had a very explicit description in the children's workbooks the final visual production on the screen was quite different. This can be seen from the diagrams 2 & 3 for task 1 of this session. The aim of the learning experience is twofold. Overall, the task demonstrates an example of moving the turtle to a specific location on the plane (controlling the turtle). But it also demonstrates the importance of focusing on the process. Because, in order to know whether the task was successfully solved (which was required) it was necessary to check the turtle's position on the screen after each command as no trace is left when the turtle's pen is up. And, in the end, verify its final heading with that drawn in the original figure.

SESSION 3

Overall Description

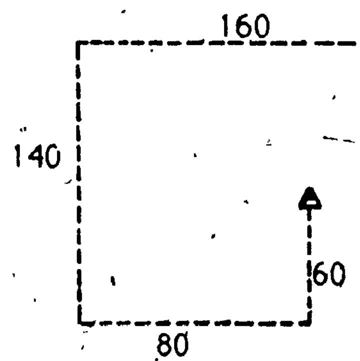
An overall objective of this session was to give the children more opportunity to familiarize themselves with controlling the turtle and the actual learning environment that they were working in. The contents of the session built on and extended that which was covered in sessions 1 and 2.

The session consists of two tasks which continue to emphasize moving the turtle. New concepts related to this and included in the session are turning the turtle through 180 degrees, the final state of the turtle requiring a change in its heading, and distance estimation. The first task is similar in nature to those designed in session 2 with modifications to its requirements. The second task differs in its nature as it is presented to the children in the form of a maze placed over the computer screen.

Session 3 - Task 1

Nature: The task was presented as a broken line diagram representing the turtle path on the screen with its pen up. The diagram was drawn in their workbooks. The children were asked to write the program and to follow the original path taken by the turtle.

Structure:



Explicit: The task is an open shape consisting of four straight lines at right angles. The length of each line was given in turtle steps. The initial and final states of the turtle were drawn as shown in the diagram.

Implicit: The task demonstrates:

a) turning the turtle through 180 degrees or using BK

b) the net effect of a series of commands on the turtle state

c) moving the turtle over a larger area of the plane

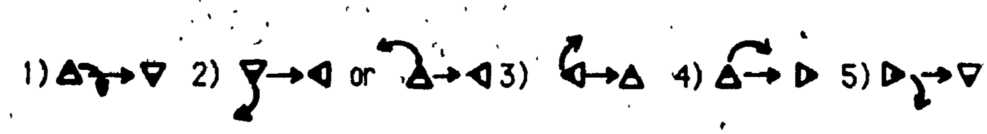
d) using larger numbers as inputs

Task requirements:

Explicit: A precise solution of this task requires

1. turning the turtle through 180 (90 + 90) or using BK
2. use of given turtle steps as inputs

3. A total of 4 or 5 turns depending on whether 180 or BK was used:



4. The final state of the turtle requires a conscious additional 90 degree turn at the end of the program so that it faces vertically downwards.

Implicit: The task requires that each command be verified as it is put into the computer as the turtle's pen is up.

Successful Solution: There are two possible solutions.

1	2
RT 180	PU BK 60
PU FD 60	LT 90
LT 90	PU FD 80
PU FD 80	RT 90
RT 90	PU FD 140
PU FD 140	RT 90
RT 90	PO PD 160
PU PD 160	RT 90
RT 90	

Selected Teacher Interventions:

"Did you have to go back all the way?"

Children's Attempts

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LT 90	Not done on	LT 90	LT 90	RT 90	RT 90
2)	LT 90	the computer.	LT 90	LT 90	RT 90	RT 90
3)	PU FD 60		PU FD 60	PU FD 60	PU BK 60	PU BK 60
4)	RT 90		LT 90	LT 90	LT 90	PU FD 60
5)	PU FD 80		PU FD 80	PU FD 80	PU FD 80	PU FD 60
6)	RT 90		RT 90	CS	LT 90	LT 90
7)	PU FD 140		PU FD 140	RT 90	PU FD 140	LT 90
8)	RT 90		RT 90	LT 90	RT 90	LT 90
9)	PU FD 160		PU FD 160	LT 90	PU FD 160	PU FD 80
10)	RT 90		RT 90	LT 90	RT 90	LT 90
11)				PU FD 80		RT 90
12)				PU FD 60		RT 90
13)				PU FD 60		PU FD 140
14)				CS		RT 90
15)				LT 90		PU FD 160
16)				LT 90		RT 90
17)				PU FD 80		
18)				PU BK 80		
19)				PU FD 80		
20)				PU BK 20		
21)				CS		

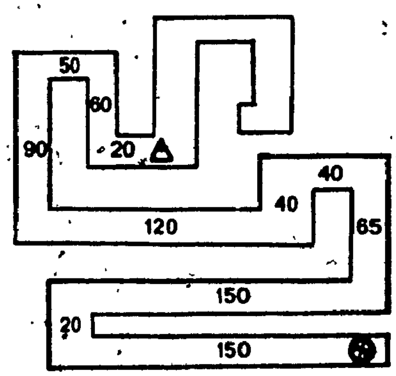
Groups II and III both had errors in their paper and pencil work whereas group I had none. Group II had a lateralization error at line 4. Their computer work involved three phases as divided by the command CS. In phase I (lines 1-5) they saw that they had an error. In phase (lines 7-13) this time they typed RT 90 instead of LT 90 (line 1 of PP) and corrected it with using LT 90 three times. Their second error occurred when they typed PU FD 80 (line 11) instead of PU FD 60 (line 3 of PP) their first attempt to correct it was to type in the command that they originally wanted (PU FD 60). They did this twice (lines 12 & 13). In phase III they again made the error of typing PU FD 80 instead of PU FD 60 only this time corrected it by using PU BK 80. Lines 19 and 20 arose due to an intervention by the teacher which asked the children "did you have to go back all the way?". Group III had two lateralization errors (lines 4 & 6) and one command error (line 3) in their paper and pencil work. Two different strategies were used in correcting the lateralization errors the first (lines 6, 7, 8 in C) involved continuing to turn the turtle in the same direction and the second (lines 10, 11, 12 in C) used the reverse turn twice. For correcting the command error of PU BK 60 instead of PU FD 60, the group repeated the command PU FD 60 twice (lines 4 & 5) to move the turtle to the desired location.

In summary, none of the children used 180 degrees (i.e. additive nature of angles) or BK, they all used multiples of 90 (LT 90, LT 90). All three groups finished their programs (GR I, II, III: PP:10) with the required final turn of the turtle.

Session 3 - Task 2

Nature: The task was presented to the children as a lined diagram depicting a maze. A turtle was drawn in the center and a fly at one of the ends. The maze was drawn on a sheet of clear plastic and placed directly over the screen. The children were asked to get the turtle to the fly.

Structure:



Explicit: The task consists of vertical and horizontal paths joined at right angles. The length of each path varies and is not specified. The initial state of the turtle is the centre of the screen which is marked on the maze with a triangle. The final position of the turtle is indicated on the maze by a drawing of a fly. The pen was in the up position for the task.

Implicit: All vertical path segments and all horizontal path segments of the successful path are similar in length allowing for the use of relative proportionality.

Task Requirements:

Explicit: A precise solution of this task requires:

a) out of two possibilities choosing the path which leads to the fly.

b) turning the turtle through 90 degrees so to follow the path

c) positioning the turtle so that when it is turned that it remains on the path

d) estimateing the correct length of each path segment. (within 5 turtle steps)

e) completing the task in a minimum number of moves.

Implicit: The task which was restricted by the instruction to a minimum number of moves provoked:

a) use of estimation and proportiality

b) memory use of previous length of a similar distance

c) appropriate correction of an over or under estimation

d) careful lateralization decisions

Successful solution:

LT 90	FD 40
FD 20	RT 90
RT 90	FD 65
FD 60	RT 90
LT 90	FD 150
FD 50	LT 90
LT 90	FD 20
FD 90	LT 90
LT 90	FD 150
FD 120	
LT 90	
FD 40	
RT 90	

Selected Teacher Interventions:

"Remember, you want to do this in the least number of moves."

Children's Attempts: The children worked directly at the computer

	GR I	GR II	GR III
1)	LT 90	LT 90	LT 90
2)	PU FD 5	FD 1	PU FD 10
3)	PU FD 7	FD 5	PU FD 5
4)	PU FD 4	FD 3	RT 90
5)	LT 90	RT 90	PU FD 50
6)	RT 90	LT 90	PU FD 6
7)	RT 90	FD 2	LT 90
8)	PU FD 60	FD 2	PU FD 56
9)	LT 90	RT 90	PU BK 10
10)	PU FD 30	PU FD 10	LT 90
11)	PU FD 15	PU FD 19	PU FD 100
12)	LT 90	PU FD 90	PU BK 10
13)	PU FD 90	BK 90	PU BK 10
14)	LT 90	PU FD 19	RT 90
15)	PU FD 210	PU FD 6	LT 90
16)	PU BK 210	LT 90	LT 90
17)	PU FD 80	PU FD 10	PU FD 100
18)	PU FD 15	PU FD 19	PU FD 6
19)	PU FD 10	PU FD 5	LT 90
20)	LT 90	PU FD 10	PU FD 20
21)	PU FD 40	PU FD 1	PU FD 6
22)	RT 90	LT 90	RT 90
23)	PU FD 35	PU FD 30	PU FD 26
24)	RT 90	PU FD 30	PU FD 10
25)	PU FD 60	PU FD 5	PU FD 2
26)	RT 90	RT 90	RT 90
27)	PU FD 138	LT 90	PU FD 55
28)	LT 90	LT 90	RT 90
29)	PU FD 30	PU FD 60	PU FD 100
30)	LT 90	PU FD 30	PU FD 46
31)	PU FD 140		LT 90
32)	PU FD 3		PU FD 21
33)			LT 90
34)			PU FD 146
35)			PU FD 3

In general the children had no difficulty moving the turtle through the maze. Each group had a lateralization error which was corrected by going two turns of 90 in the opposite direction. Overestimation was corrected with BK and underestimation with moving the turtle more forward. Length estimation satisfied the path of the maze within a difference of approximately 5 steps.

Estimation:

2 types of estimation strategies were observed

1) Using a ratio of one to one half:

		1st estimation	2nd estimation (1/2 of first)
GR I:	required 45	FD 30	FD 15
GR III:	required 150	FD 100	FD 46

2) Following the first estimation using increments of 10 for adjustment purposes.

	Estimation	increment of 10	focus
GR III required 40:	FD 26	FD 10	FD 2
GR III required 80:	FD 100	BK 10	BK 10
GR III required 50:	FD 56	BK 10	none

General Observations

Session 3 was essentially designed as a summary and revision for the LOGO environment of what was experienced in sessions 1 and 2. The first task was similar in its explicit structure as those seen on session 2. The second task, the maze, was similar in implicit structure to the second task in session 1 - moving the turtle at the top & bottom of the screen. No new LOGO or programming commands were introduced. Implicit mathematical activities were introduced. These activities included turning the turtle through 180 degrees, estimation and use of proportionality.

In general the children had no difficulty in controlling the turtle. In these first three session, they have had the opportunity to use the commands FD, BK, RT and LT in varying situations. Lateralization errors occur occassionally in the three groups and the children seem comfortable correcting these errors. From the observations of the children attempting the maze task, it appears that they apply some strategy in estimating distances (see task 2 children's attempts). In summary, the programming and mathematical concepts encountered in these first three sessions include.

Programming concepts	Mathematical concepts
turtle commands: FD, BK, RT, LT	distance
turtle position	total distance
turtle heading	estimation
error correction	

SESSION 4

Overall Description

This session introduces procedures, functional naming and drawing with the turtle. It begins with an introduction to two procedures LINE30 and LINE60 and a discussion about their names. This is then followed by four tasks which involve moving and drawing with the turtle.

The procedures are written in the children's workbooks with TO and END in red to emphasize the syntax. The children are asked to type these procedures (one at a time) into the computer, test them and draw what each one produces into their workbooks. This activity initiated a discussion on the procedure names, what they mean and how they can be useful. The children were then asked to begin the series of tasks.

The four tasks designed for the session involved moving the turtle and then using a procedure to draw with the turtle. The learning hierarchy designed within these tasks took into consideration the path, the measurements, and the initial state of the turtle. The tasks were designed as follows:

Task 1: The path, measurements, and initial state of the turtle were all provided.

Task 2: The path and initial state of the turtle were provided. No measurements were given.

Task 3: The path, measurements and initial state of the turtle were not provided.

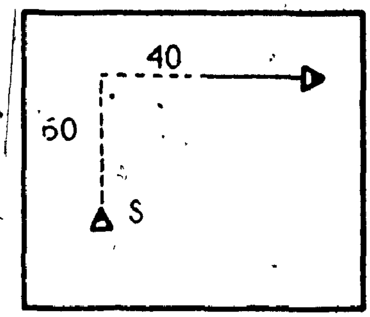
Task 4: Same as task 3 only this task further required an implicit displacement calculation.

As analysis of each task and a description of the children's attempts working on the tasks is provided below

Session 4 - Task 1

Nature: The task is presented as a broken line and solid line diagram on squared paper representing the turtle's path on the screen with its pen up (broken line) and pen down (solid line). The diagram was drawn in their workbooks. The children were asked to write and then verify the program to follow the original path taken by the turtle.

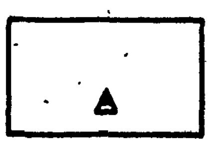
Structure



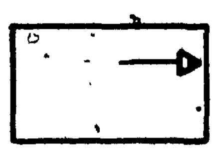
Explicit: The task is an open shape consisting of one broken line and one half-broken half-solid line joined at right angles. As shown in the diagram only the lengths of the broken line segments was given as were the initial and final states of the turtle.

Implicit: The task begins with the turtle going straight forward. The line segment drawn by the turtle is in the upper right hand quadrant. The turtle is moved a vertical and horizontal distance away from the origin before it draws. The procedure is used to produce a horizontal line.

Task Requirements



(a)
Screen before the task



(b)
Screen after the task

Explicit A precise solution for this task requires

1. Moving the turtle forward 60 and 40 turtle steps with a right turn of 90 degrees.
2. Using the procedure LINE30 to draw the solid line.

Implicit 1. As only the measurements of the broken lines are provided the child must use proportionality to determine which of the two line procedures is the most appropriate

2. During the computer activity a visual check after each command is required to determine if the turtle is in the correct location as the screen only displays the solid line segment of the task.

Successful solution

PU FD 60
RT 90
PU FD 40
LINE30

Selected Teacher Interventions

"Do you have a line procedure which could do that?"

Children's Attempts

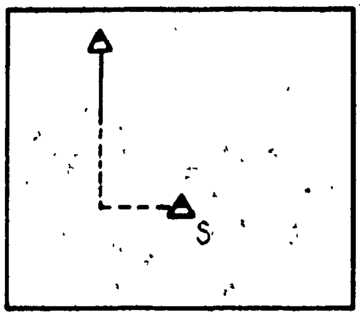
	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	PU FD 60	PU FD 60	PU FD 60	PU FD 60	PU FD 60	PU FD 60
2)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
3)	PU FD 40	PU FD 40	PU FD 40	PU FD 40	PU FD 40	PU FD 40
4)	LINE30	LINE30	LINE30	LINE30	LINE30	LINE30

All three groups were able to successfully complete the task on their first attempt. Overall, the amount of guidance required regarding the order of activities (PP, CM, C) is diminishing. The only difficulty is with the children wanting to work directly on the computer. Attempts at using PD were foiled with the suggestion of: "Do you have a line procedure which could do that?". Each of the three groups chose LINE30

Session 4 - Task 2

Nature: The task is presented as a broken and solid line diagram, hand drawn, on squared paper representing the turtle's path on the screen with the pen up (broken line) and the pen down (solid line). The diagram was drawn in their workbooks. The children were asked to write and then verify the program to follow the original path taken by the turtle

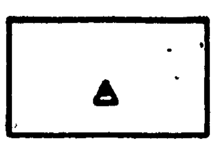
Structure



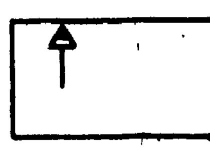
Explicit: The task is an open shape consisting of two broken lines and one solid line (see diagram). The initial and final states of the turtle are drawn as is the starting point. No measrements are provided only the implicit reference from the use of squared paper.

Implicit: The task begins with the turtle turning left. The line segment drawn by the turtle is in the upper left hand quadrant. The structure is at a 2:2:3 ratio.

Task requirements.



Screen before the task



Screen after the task

Explicit: A correct solution for this task requires

1. That the turtle be turned to the left 90 degrees.
2. Move the turtle a horizontal & vertical distance.
3. Use the LINE30 or LINE60 procedure depending on the choice of input for part 2.

Implicit: 1. As no measurements for the task are given the child must rely on proportionality to determine an appropriate choice of inputs.

2. During the computer activity a visual check after each command is required to determine if the turtle is in the correct location as the screen displays only the solid line segment of the task.

Successful Solution:

LT 90
PU FD 40 or 15
RT 90
PU FD 40 or 15
LINE60 or 30

Selected Teacher Interventions: None

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LT 90	RT 90	LT 90	LT 90	LT 90	LT 90
2)	PU FD 40	LT 90	PU FD 40	PU FD 40	PU FD 15	PU FD 15
3)	RT 90	LT 90	RT 90	RT 90	RT 90	RT 90
4)	PU FD 40	PU FD 40	PU FD 50	PU FD 50	PU FD 30	PU FD 30
5)	LINE60	RT 90	LINE70	LINE70	LINE60	LINE60
6)		PU FD 40		LINE70		
7)		LINE30		TO LINE 70		
8)		LINE30		PD FD 60		
9)				END		
10)				EDIT "LINE70"		
11)				LINE70		
12)				BK 20		

Inaccuracy with the drawing as a result of it being done by hand allowed for legitimate varied interpretations in the children's attempts. The children's attempts showed group I interpreting the diagram as intended with a 2:2:3 ratio. However, groups 2 and 3 both interpreted the first broken line as being shorter than the second (GR II: 40:50:70 and GR III: 15:30:60)

During the attempt of this task GR I discovered the additive nature of procedures (GR I, C: line 7 and 8). Having completed the task, the group decided that their original choice for the length of the line segment was not long enough and they wanted to make it longer. This initiated the following discussion between one of the group members and the researcher:

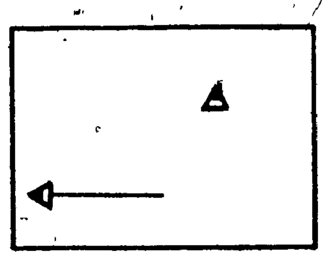
Researcher:	"What do you want?"
Jennifer:	"LINE60"
Researcher:	"What do you have?"
Jennifer:	"LINE30."
Researcher:	"What are you missing?"
Jennifer:	"Another 30."
Researcher:	"How can you get it?"
Jennifer:	"PU (ahh) PD FD 30."
Researcher:	"But, do you have a procedure that already does that?"
Jennifer:	"Yes, LINE30." (She proceeded on her own to type LINE30.)

Group II, while attempting the task, used LINE70 in their paper and pencil planning (GR II, PP: line 5). Once at the computer and having received an error message, they simply defined a new procedure (GR II, C: lines 7, 8, 9). Although there appeared to be some confusion regarding the choice of length for LINE70, this strategy, for solving the task, had not been anticipated by the researcher. Group III, as with task I, solved the task without any errors.

Session 4 - Task 3

Nature The task is presented as a diagram representing the screen with the turtle in its starting state and a solid line a vertical & horizontal distance from it. The diagram was drawn in their workbooks. The children were asked to fill in a path from the turtle to the solid line using a broken line and write, then verify, the program to follow the chosen path taken by the turtle.

Structure

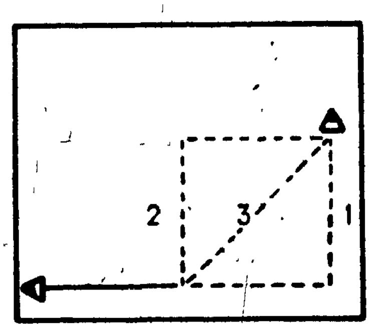


Explicit The task is a solid line drawn below and to the left of the center of the screen The initial and final states of the turtle are indicated but the start or end are not labeled. No measurements are given, only the instruction that they are to use LINE30 or LINE60 to do the task

Implicit 1. The task begins with turtle turning through 180 degrees or using BK The proportions in the diagram are 4:3:2

2 Concept of the (x,y) coordinate system where x is the horizontal distance and y the vertical

Task Requirements



Explicit A precise solution is not required however application of distance proportion is present.

1. Choosing a path to move the turtle in the position required to draw the line. There are three possibilities (see diagram) Indicate where the turtle starts and where it ends.
2. For paths 1 and 2 the task requires that the turtle be moved a vertical and horizontal distance in approximately a 4.3 proportion
3. An interface turn is required to correctly position the turtle to draw the line
4. Use LINE30 or LINE60 depending on the choice of inputs for step 2 where the approximate proportion is 4.3:2.

Implicit

1. The child must identify the requirements of the task.
2. As no measurements are provided, the child must choose a point of reference (yardstick) and for success use the properties of proportionality
3. During the computer acitivity a visual check after each command is required to determine if the turtle is in the correct location as the screen displays only the solid line segment of the task.

Successful Solution

Option 1	Option 2
PU BK 60/120 or RT 180, PU FD 60/120	LT 90
LT 90	PU FD 45/90
PU FD 45/90	LT 90
LINE30/60	PU FD 60/120
	RT 90
	LINE30/60

Children's Attempts

	GR I PP	GR I C	GR II PP	GR II C	GR III PP	GR III C
1)	LT 90	LT 90	LT 90	LT 90	LT 90	LT 90
2)	LT 90	LT 90	LT 90	LT 90	LT 90	LT 90
3)	PU FD 40	PU FD 40	PU FD 60	PU FD 60	PU FD 60	PU FD 60
4)	RT 90	RT 90	RT 90	LT 90	RT 90	RT 90
5)	PU FD 30	PU FD 30	PU FD 50	RT 90	PU FD 30	PU FD 30
6)	LINE30	LINE30	LINE40	RT 90	LINE15	LINE15
7)				PU FD 50		LINE30
8)				LINE40		
9)				TO LINE 40		
10)				PU FD 40		
11)				END		
12)				LINE 40		

The children were able to assign their largest measurement to the longest line. They then either perceived the drawings as the horizontal distance being equivalent to the solid line or just slightly longer. Although their inputs were not precisely in a 4:3:2 proportion they did indicate their implicit understanding of relative measurement.

Two observations regarding using procedures. In groups II and III the children used undefined procedures in their paper and pencil activity. During the computer activity the errors were solved differently in each group:

GR 2. Defined the new procedure that they had wanted to use. (GR I, C. lines 9, 10, 11)

GR 3. Changed their procedure to an existing available one but as a result changed their choice of input and proportionality. (GR III, C: lines 6, 7)

Session 4 - Task 4

Nature The task is presented as a diagram representing the screen with the turtle in its starting state and a solid line a horizontal distance away from it. The diagram was drawn in their workbooks The children were verbally asked to fill in a path from the turtle to the solid line using a broken line and write and then verify the program on the computer

Structure

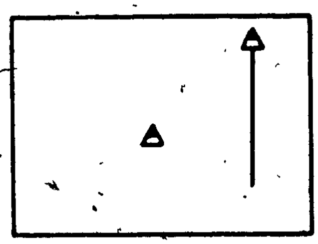


figure (a)

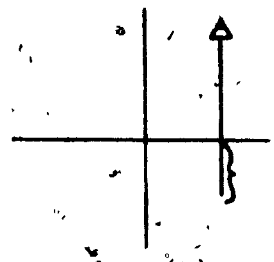
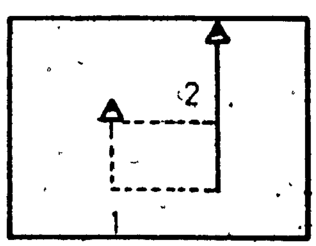


figure (b)

Explicit The task is a solid vertical line situated to the right side of the center of the screen The initial and final states of the turtle are indicated but the "start" or "end" are not labeled. No measurements are given.

Implicit The solid line crosses both the upper (I) and lower (IV) right hand side quadrants of the plane and hence crosses the x axis. As a result of the line crossing the x axis there is a negative component (a displacement) equivalent to the distance from the x axis to the beginning of the line in the 4th quadrant (see figure b)

Task requirements



Explicit A precise solution is not required, however, application of distance proportion is present.

1. Choose a path to move the turtle to the begining of the line to be drawn.
2. The task requires moving the turtle in a vertical and horizontal distance in an approximately 1:3 proportion
3. The task requires turning the turtle through 180 degrees or using BK.
4. Use a line procedure to draw the solid line.

Implicit

1. The child must identify the requirements of the task
2. As no measurements are given, the child must use proportionality to determine the inputs
3. Because of the displacement feature in the task's structure, the chosen vertical distance for moving the turtle is equivalent to approximately 1/3 of the length of the line, or, upon visual inspection, the horizontal length of the broken line is equal to the length of the solid line.

Successful Solution

Option 1

```
BK 10/20   or   RT 180 PU FD 10/20
LT 90 or  RT 90
PU FD 30/60
LINE30/60
```

Option 2

```
RT 90
PU FD  30/60
FT 90  or  LT 90
PU FD  10/20  or PU BK  10/20
RT 90
RT 90
LINE30/60
```

Children's Attempts

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	LT 90	LT 90	PU BK 10	PU BK 10
2)	RT 90	RT 90	LT 90	LT 90	RT 90	RT 90
3)	PU FD 5	PU FD 5	PU FD 40	PU FD 40	PU FD 30	PU FD 30
4)	LT 90	LT 90	RT 90	RT 90	LT 90	LT 90
5)	PU FD 15	PU FD 15	PU FD 60	LT 90	LINE60	LINE60
6)	LT 90	PD FD 20	LT 90	LT 90		
7)	PD FD 20	PE BK 20	LINE70	PU FD 60		
8)		LT 90		LT 90		
9)		PD FD 20		LINE70		

The children did not see the precise proportions of the diagram. They all recognized that in moving the turtle, their vertical distance was smaller than the horizontal, using approximately 1 to 3 proportion (5,15)(40,60)(10,30) However, the relationship between the horizontal distance and vertical distance varied even though they were equivalent in the diagram (15, 20)(60,70)(30,60)

The children had little difficulty with the programming None of the children have to date discovered the additive property of angle inputs but one group did use BK instead of RT 90 RT 90 (GR III, PP line 1)

Use of procedures. GR I. used PD FD 20 instead of a procedure

GR II used their personally defined LINE70

GR III used LINE60

They seem to understand what the procedures LINE30 & LINE60 produce as when their desired input is not of the length 30 or 60 they either use PD FD or define a new procedure.

General Observations:

This session introduces the children to writing and using procedures Two given procedures, LINE30 and LINE60, are written in the workbooks. The children themselves enter the procedure into the computer and observe what each one produces. A series of tasks is then given which involve vertical and horizontal 90 degree transformations of a procedure away from the origin.

Although the tasks were quite structured in that the children were asked to use LINE30 & LINE60 they did find room for creativity. Two things were observed with the children using procedures. One group in particular (Group II), upon discovering that in order to use a procedure it must first be defined, defined new procedures as they required them. Another group (Group III) not being satisfied with the lengths of the given procedures went around the problem by using PD FD and the desired input. Although these activities were outside the task design, they did enlighten the researcher on the children's understanding of the LINE30 and LINE60 procedures.

The implicit mathematics in the activities was principally related to proportionality of distance and length. The children seemed to have used visual estimation as opposed to geometric properties and relationships as implied by the squared paper. The visual estimations were all satisfactory with no errors of scale. (ie a shorter distance was never given longer length than a longer distance.)

The children are more skilled in the programming environment, choosing without hesitation the correct commands and syntax for their desired goals, even to the extent of surpassing expectations as demonstrated in the examples related to the use of procedures above.

The children were, when required, able to choose a feasible path as well as appropriate starting and ending points. In the case of group I, working on task 2, the teacher intervention provoked the discovery of the additive property of procedures. This intervention had been the result of the researcher responding to the immediate need of the situation.

SESSION 5

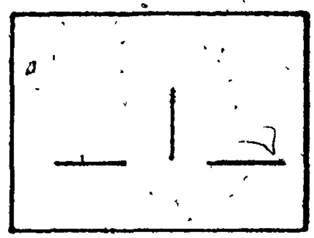
Overall Description

This session is centered around a homework task that had been given in the previous week and a worksheet given out during the session Both of these activities were attempted by the children working individually. There were no new procedures or commands introduced in this session

The homework task involved moving and drawing with the turtle. The pattern created by the three lines which made up the task was symmetrical therefore implicitly requiring the children to write a program that would preserve this characteristic The worksheet consisted of four questions each made up of three diagrams representing a sequence of moves of the turtle In the third diagram the children were asked to write the command that would result in the desired effect(s). Each of these activities and the children's attempts at doing them is described below. In the conclusion, certain programming and mathematical strategies used by the children so far are discussed

Session 5 - Homework (from session 4)

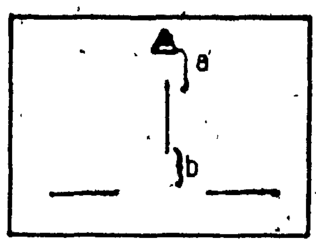
Nature: The homework is presented as a diagram with written instructions in the homework books. The diagram is composed of a square representing the screen, three solid lines and a partially shaded triangle representing the turtle. The written instructions are as follows: Write a program for the turtle to draw what is in the box.



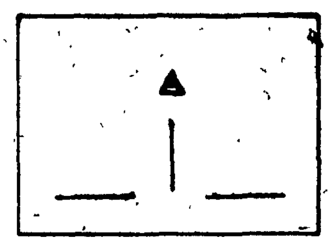
The diagram for GR I differed from the one given to GR II & III.

(see structure below).

Structure:



(a)
Task for GR I



(b)
Task for GR II & III

Explicit: The task consists of three detached lines of equal length, one vertical, two horizontal. The lines are situated in the bottom half of the screen below the drawing of the turtle. The initial state of the turtle is indicated but not the final. No path between the solid lines is provided.

Implicit: The horizontal lines are equidistant from the vertical. For GR I, the distance from the turtle to the first line (a) is the same as the distance from the vertical line to the horizontal lines (b). For groups II & III the vertical distance b is not present (see figures a and b).

Task requirements There are many possible solutions. Application of both equal length and equidistance is required

Explicit 1. Moving the turtle

2. Drawing with the turtle

3. Use of 180 degrees or BK

4. Turning the turtle through 90 degrees

5. Back tracking i.e. to go over the part or part of the path a second time

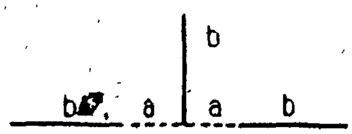


figure (c)

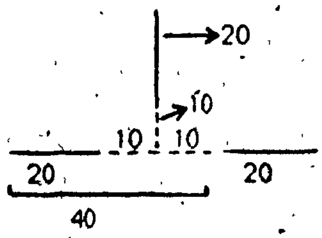
Implicit The horizontal lines should be symmetrical about the vertical line. This requires.

1. That the distance from the vertical line and the horizontal line on the left be the same as the distance from the vertical line to the horizontal line on the right

2. The structure of the diagram requires that the turtle retrace its path at least on the horizontal lines. The mathematical consequence of this requires that the distance between the vertical and horizontal line be doubled or repeated twice to draw the second horizontal line

e.g	PU FD A				
	PD FD B				
	PU BK B + 2A	or	PU BK B + A	or	PU BK B
	PD BK B		PU BK A		PU BK A
					PU BK A

Successful solution The following is a sample of a successful solution



PU BK 10
PD BK 20
PU BK 10 for GR I only
LT 90
PU FD 10
PD FD 20
PU BK 40
PD BK 20

	GR I		GR II		GR III	
	Jennifer	Benny	Gregg	Robert	Grace	Jason (from dribble file)
1)	LT 90	LT 90	RT 90	No Record	PD BK 5	PU BK 5
2)	LT 90	LT 90	RT 90		PD BK 20	PD BK 30
3)	PU FD 5	PU FD 20	PD FD 40		RT 90	RT 90
4)	PD FD 10	PD FD 36	RT 90		PU BK 15	PU BK 20
5)	PU FD 4	PU FD 10	PF FD 50		PD BK 20	PU FD 20
6)	RT 90	RT 90	LT 90		PD FD 20	PU FD 20
7)	PU FD 3	PU FD 10	LT 90		PU FD 30	PU FD 20
8)	PD FD 11	PD FD 20	PD FD 100		PD FD 20	PD FD 30
9)	PD BK 11	RT 90				PD BK 30
10)	PU BK 40	RT 90				PU BK 20
11)	PD BK 15	PU FD 20				PU BK 20
12)		PU FD 20				PD BK 30
13)		PU FD 20				

Children's Attempts

All but one child attempted the homework. In one case, Jason, as the paper and pencil record was not available, used the dribble file for reference.

Programming strategies

Two programming strategies can be identified from two examples of the homework. In Benny's case, he has used RT and LT combined with PU FD and PD FD. As a result of not using BK he is forced to turn the turtle three times; twice through 180 and once through 90 It takes Benny a total of 13 commands to do the task. Grace, on the other hand, uses a combination of FD and BK with PU and PD and turns the turtle only once through 90 degrees It takes Grace a total of 8 commands to complete the task. The difference in the total number of commands required to complete the tasks between Benny and Grace is 5. They can be explained by the following

1 Grace uses the command BK where Benny uses the combination of commands RT/LT 90, RT/LT 90, FD on two occassions. This accounts for four of Benny's extra commands

2 The fifth extra command is due to the different diagrams given to GR I and GR II and III see structure of tasks

The other children used either one of these strategies or a combination of the two

Mathematical Strategies

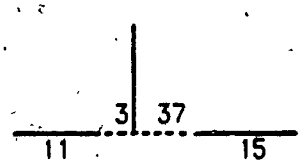
Out of the five submissions, for all but one case symmetry about the vertical line was present One child's program (Jennifer's) did not produce a symmetrical drawing about the vertical line. And another child Gregg, even though he redesigned the task, he did preserve the symmetry

Using the same notation as in figure (c) the following strategies were observed

Jason	Benny & Grace
B	B
A	2A
A	B
B	

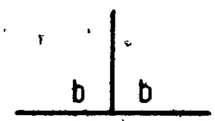
Jennifer did the following for the bottom line

From the center facing left· PU FD 3
PD FD 11
PU BK 11
PU KB 40
PD BK 15



The PU FD 3 and PU BK 40 do not correspond to the symmetry required by the task. Also we can note that in Jennifer's case she gave the solid lines different lengths.

A special case was that in which the task was redesigned by the child (Gregg). For the new design, the child just simply filled the spaces in the diagram for the task to become the following.

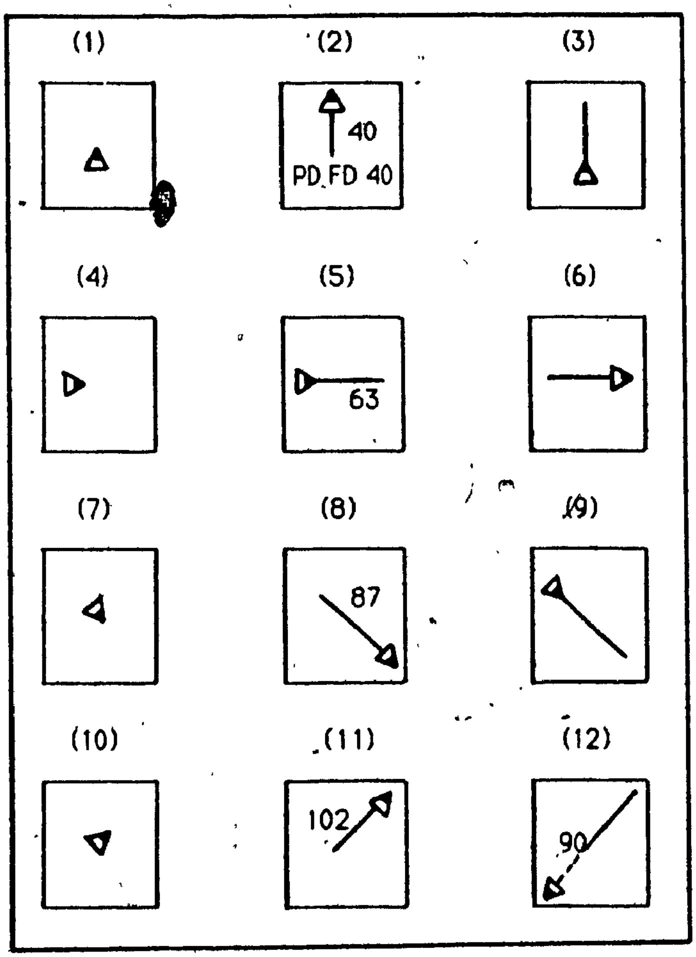


Nonetheless, the child applied symmetry using the strategy of $\left\{\begin{matrix} \text{FD}\ b \\ \text{BK}\ 2b \end{matrix}\right\}$ for inputs

Session 5 - Worksheet

Nature: A worksheet containing 4 excercises was given to each child to work on individually. The worksheet contained 12 drawings in all, three for each exercise. The three drawings were to be read as a sequence going from left to right. In the third drawing there was a blank line where the children were to write the required command for the turtle to follow the sequence.

Structure.



Explicit: The first drawing for each sequence showed the turtle in the same position but with a different heading as seen in figures (1), (4), (7) and (10).

The second drawing for each sequence showed a change by a solid line and a number representing the length of the line in turtle steps. See figures (2), (5), (8) and (11).

For the first exercise the command that was used to create the change is given as an example. The third drawing for the first three exercises showed the turtle returned back to its original position and heading as in the first drawing. See figures (3), (6), (9), (12). The length of the solid line segments is the same for both the 2nd & 3rd columns. The third drawing for the fourth exercise was different than for the first three. In this drawing, the turtle goes beyond the original position that is indicated by a broken line and the heading is changed by 180 degrees. See figure (12).

Implicit The turtle headings in the first-two exercises have already been seen by the children. Whereas the headings in exercises 3 and 4 showing RT 135 and RT 45 have, up until now, not been seen in this environment.

The change in the turtle position as seen in the second column of the worksheet is a results from using the commands PD FD or PD BK with the corresponding varying inputs (40, 63, 87, 102).

The third column for the first three exercises is a result of using the inverse of the command used in the second column. This is also true for the fourth exercise but the turtle is moved beyond it's original position by 90 turtle steps and its heading is changed by 180 degrees.

Task requirements

Explicit A precise solution for each exercise requires:

1. Writing the command in the third column which is the inverse of that depicted in the second column.
2. PU or PD could be used in the commands for the solutions of the first three exercises.

3. PU or a combination of PU and PD are required for the solution of the fourth exercise

4. Turning the turtle through 180 degrees is required in the fourth exercise.

Implicit: The task requires:

a) Knowledge that the commands PD FD and PD BK do the following 1) draw a line when the turtle moves 2) change the turtles position 3) do not change the turtles heading

b) That the children can interpret the sequence. This requires

1) That ability to identify the command used to go from the first diagram to the second

2) And then identify the command used to go from the second to the third

c) That the children use the inverse of the command that was used to go from the first diagram to the second for the command in the third.

d) Use of relative measure of length as no length is provided in the third column of the exercise.

Successful Solution: The commands required in the third box for each of the four exercises are as follows:

1. PU/PD BK 40
2. PU/PD FD 63
3. PU/PD BK 87

	(A)	(D)	(E)
4.	PU/PD BK 102 PU BK 90	PU BK 192 RT 180 RT/LT 180	RT 180 PU FD 192

(B)	(C)
RT/LT 180 PU/PD FD 102 PU FD 90	PU/PD BK 180 RT/LT 180 PU FD 90

Selected Teacher Interventions

The following is a sample of a verbal instruction given with the worksheet. It is an excerpt from the tape with group I.

"The first block is where the turtle starts This is what the turtle does and number 3 is what you have to do to get the turtle where it is"

Children's Attempts

Sample correct solutions	Jason	Jennifer	Grace	Robert	Benny	Gregg
			Worksheet Errors			
1) PU BK 40	✓	✓	✓	✓	FD	FD
2) PU FD 63	✓	✓	60	BK	✓	BK
3) PU BK 87	✓	✓	FD	✓	✓	FD
4) PU BK 192 RT 180	✓	heading	heading	✓	BK 90 heading	✓

✓ - indicates a correct solution.

In the first exercise the type of error observed is that of using the incorrect command Two of the children (Benny & Grace) used FD instead of the required BK. They did however use the appropriate input (40) for their choice of length.

In exercise two, we observe two different types of errors. The first, that as seen in exercise one, using the incorrect command. Two of the children (Robert & Gregg) used BK instead of FD But of these two children only one of them (Gregg) is the same as in exercise one. The second type of error is that of using the incorrect input for the choice of length. In this case, Grace used a correct sequence of commands but chose 60 instead of the correct 63 as her input.

For the fourth exercise which required moving the turtle an additional 90 steps for a total of

192 and changing the turtle heading by 180 degrees, two types of errors are observed as well as different strategies. Two children (Jennifer & Grace) moved the turtle the correct 192 turtle steps but did not change the turtle heading in any way Another child (Benny) did not change the turtle heading in any way but he also only moved the turtle 90 steps (the broken line section) The following is a summary of the successful strategies used by the children in exercise 4

1) Change turtle heading and move turtle the total distance

   (Jason) RT 90 RT 90
   PU FD 192

2) Move turtle the total distance and change its heading

   (Gregg) PU BK 192
   LT 90 LT 90

3) Move the turtle with its pen down over the solid line, then move the turtle with the pen up over the dotted line and change the turtle's heading

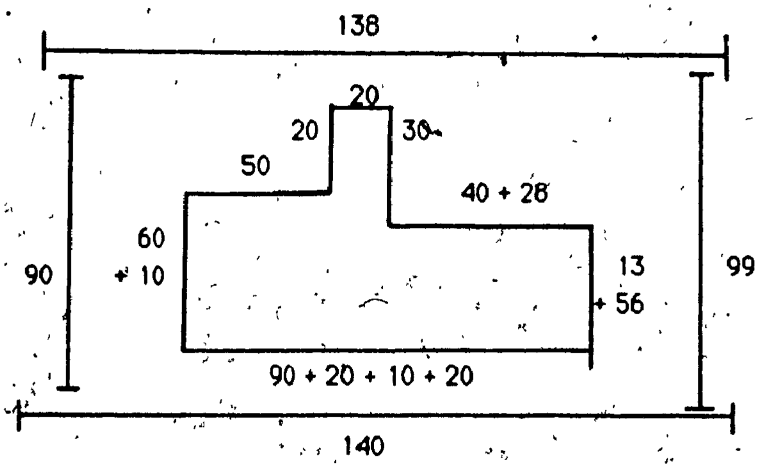
   (Robert) PD BK 102
   PU BK 90
   LT 90 LT 90

Due to the children's inconsistencies in the errors a summative summary is difficult The most common error in the first three exercises is that of using the incorrect command Only one child out of the total four who made this type of error consistently used the wrong command

Session 5

GR I - Unplanned activity

With five minutes remaining in the session the researcher asked the children if they wanted to do another task Benny replied "Can we draw a pumpkin " The researcher replied "yes" and the children proceeded in their choice of direct mode at the computer. The following is a reconstruction from the dribble file of what they did



PD FD 13
PD FD 56
LT 90
PD FD 40
PD FD 28
LT 90
RT 90
RT 90
PD FD 30
LT 90
PD FD 20
LT 90

PD FD 20
RT 90
PD FD 50
LT 90
PD FD 60
PD FD 10
LT 90
PD FD 90
PD FD 20
PD FD 10
PD FD 20

An examination of the final product indicates that the total horizontal and vertical lengths are not far off from each other i e. The total vertical length on the right is 99 whereas the total vertical length on the left is 90 A difference of 9 turtle steps. A similar comparison can be made with the total horizontal lengths on the top and bottom which have an overall difference of 2 turtle steps. Only the difference in the vertical length is really noticeable on the screen. Neither of the children had written down any input information nor was the full screen option ever used to display previous inputs. From the homework given at the end of session 4 we just observed that in Benny's case he was successful in reproducing symmetry in a program. If we were to judge Benny's application of symmetry from this construction one might conclude an absence of this ability.

General Observations

Session 5 consisted of checking a homework assignment that was given at the end of session 4 and working individually on a worksheet. The observations from these activities focused on 1) general programming strategies 2) strategies for the calculation of symmetry and 3) programming and math strategies used for changing the turtle heading and moving a composite distance

General Programming Strategies

The major distinguishing factor in programming strategies is the use of the series of three commands (RT/LT 90, RT/LT 90, FD) by some children for the same effect as using the single command BK by others Some children were found to consistently use one or the other while others used a combination of the two

Calculation of Symmetry

The two strategies used for the symmetrical effect in the program were a) step-by-step and b) composite The step-by-step strategy involved moving the turtle along the horizontal line section by section with the pen appropriately up or down. Where B is a length and A a distance the strategy was B, A, A, B. The composite strategy combined the two distances A, A into one move: B, 2A, B.

SESSION 6

Overall Description

The overall objective of session 6 was to review procedures (their syntax and use) and reinforce the task planning strategy. The session consisted of two questions, each asking that a specific procedure be defined, followed by three tasks which required the use of the procedures.

To enforce the planning strategy the children were reminded to write in their workbooks the choice of path (when required), choice of measurements, their strategy, i.e. S for start and E for end and their program. The three tasks were designed with the following underlying strategy

Task I: Similar to the tasks in session 4, required to move the turtle and draw a line using only one procedure

Task II: Required to move the turtle and draw two lines joined at a right angle. This was the first task requiring that a procedure be interfaced with another.

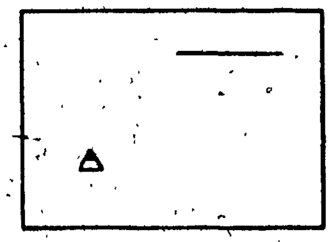
Task III: Required only drawing with the turtle using two procedures. This was the first task which constructed an open geometric shape beginning at the origin

This session is to be followed in session 7 with the introduction to state stransparent procedures and angles other than 90 degrees. A detailed description of each task and the children's attempts at doing them is provided below

Session 6 - Task 1

Nature: The set of tasks for session 6 begin with the children writing and entering into the computer two procedures: LINE25 and LINE50. Task number 1 is the first task on the page in the children's workbooks. The printed instructions read: Use your procedures to do the following. A verbal instruction is also given to "draw in your path, put Start and End, fill in the choice of inputs and then write the program."

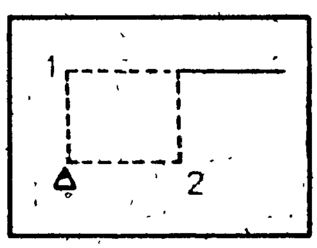
Structure:



Explicit: The task is a horizontal solid line located a vertical and horizontal distance from the turtle. As seen in the diagram, no path is provided between the turtle and the line. Also excluded from the diagram are any measurements.

Implicit: The structure is designed such that the vertical distance, horizontal distance and line segment are all the same length. The planning sequence is an important part of the task.

Task Requirements



Explicit: A precise solution for this task requires:

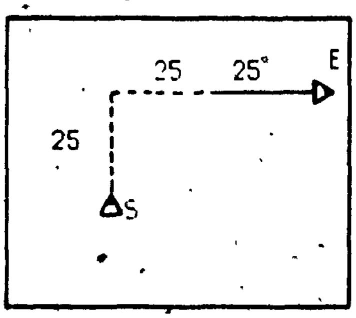
1. Moving the turtle an equal horizontal and vertical distance i.e. 25 or 50 turtle steps.

2 . Depending on the choice in 1 using LINE25 or LINE50 to draw the solid line

Implicit: 1. Planning strategy: Choosing an appropriate path, where the turtle will start and where it will end; choice of inputs, writing the program

2 The correct heading for the turtle is necessary for a successful interface with a procedure

Successful Solution: The solution requires that the diagram be labelled with the following: a drawn path, S for start and E for end, choice of inputs and the written program



1	PU FD 25/50 RT 90 PU FD 25/50 LINE 25/50	2	RT 90 PU FD 25/50 LT 90 PU FD 25/50 RT 90 LINE 25/50

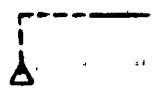
Selected Teacher Interventions:

"Fill in the drawing before you write your program."

"Use your procedures and not PD for drawing."

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C (taken from video tape)	PP	C (taken from video tape)
1)	PU FD 50	PU FD 50	PU FD 40	PU FD 40	PU FD 25	PU FD 25
2)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
3)	PU FD 50	PU FD 50	PU FD 70	PU FD 70	PU FD 25	PU FD 25
4)	LINE50	LINE50	LINE50	LINE50	LINE25	LINE25

All three groups chose the first path i.e. 

GR I correctly used 50 turtle steps for all the measurements (50, 50, 50), made no programming errors, and correctly used a procedure

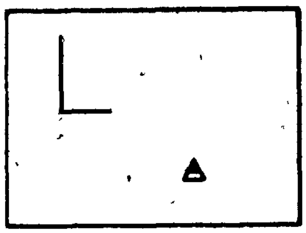
GR II used a different length for each input (40, 70, 50) They had no programming errors and correctly used a procedure

GR III correctly used 25 turtle steps for all the measurements (25, 25, 25), made no programming errors and correctly used a procedure

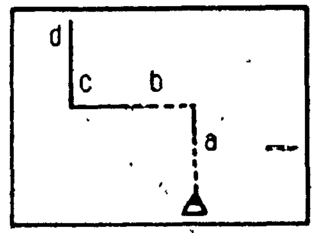
Session 6 - Task 2

Nature: This task is the second task on the page used in session 6. It is presented as two solid lines joined at a right angle a vertical and horizontal distance from the turtle. The task is located in the upper left hand quadrant. The printed instructions read: Use your procedures to do the following. A verbal instruction is also given to "draw in your path, put Start and End, fill in the numbers and then write the program."

Structure:



(a)

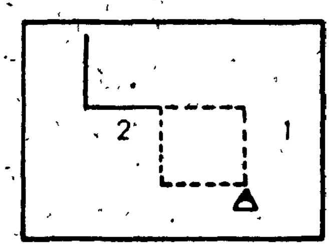


(b)

Explicit: The task is a horizontal and vertical solid line joined at a right angle. The lines are approximately a 1:2 proportion. As seen in the diagram (a) no path is provided between the turtle and the drawing. Also excluded from the diagram are any measurements.

Implicit: The diagram is constructed so that the vertical distance (a) between the turtle and the drawing is equivalent to the vertical line (d) in the drawing, i.e. (a = d). The same is true for the horizontal distance (b) and the horizontal solid line segment (c) i.e. (b = c).

Task requirements:



(c)

Explicit: A precise solution for this task requires:

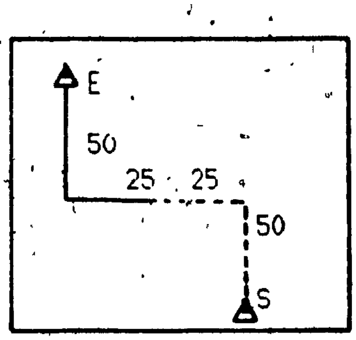
1 Moving the turtle horizontally 25 turtle steps and vertically 50 turtle steps

2 Using LINE25 and LINE50 interfaced with RT 90 to draw the figure.

Implicit: 1 Planning strategy Choosing an appropriate path; where the turtle will start and where it will end, choice of inputs; writing the program

2 The correct heading for the turtle is necessary for a successful interface with a procedure

Successful Solution: The solution requires that the diagram be labelled with the following; a drawn path, S for start and E for end, choice of inputs and the written program This should look as follows:



PROGRAM

```
PU FD 50
LT 90
PU FD 25
LINE 25
RT 90
LINE50
```

Selected Teacher Interventions:

The two children in group II began a discussion on whether it was faster to correct a lateralization error by continuing the turn through 180 degrees in the same or opposite direction. The researcher intervened and asked: "Why is it faster?" (see details under children's attempts.)

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C (taken from video tape)	PP	C (taken from video tape)
1)	PU FD 50	PU FD 50	PU FD 60	PU FD 60	PU FD 25	PU FD 25
2)	LT 90	LT 90	RT 90	RT 90	LT 90	LT 90
3)	PU FD 25	PU FD 25	PU FD 30	RT 90	PU FD 20	PU FD 20
4)	LINE25	LINE25	LINE25	RT 90	LINE25	LINE25
5)	RT 90	RT 90	LT 90	PU FD 30	RT 90	RT 90
6)	LINE50	LINE50	LINE50	LINE25	LINE50	LINE50
7)				LT 90		
8)				RT 90		
9)				RT 90		
10)				LINE50		

All three groups of children met the requirements for labelling the diagram, i.e. choice of path, choice of inputs, start and end, and a written program. GR I. chose the correct (50, 25, 25, 50) inputs for the task and the most direct possible path. They had no error in their program. GR II chose proportionately correct inputs (60, 30, 25, 50) and also the most direct possible path. Their program however, contained two lateralization errors (the only two possible) GR III labelled their diagram correctly and had no errors in their program Their choice for inputs were (25, 20, 25 ,50). The first input (25) and the last input (50) should have, based on the structure of the diagram, been the same.

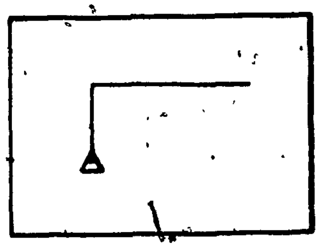
Group II used two different strategies for correcting a lateralization error. The first (GR II, C: lines 2, 3, 4) was to turn the turtle 90 degrees in the same direction twice. The second (GR II, C: lines 7, 8, 9) was to turn the turtle 90 degrees in the opposite direction twice. The following is an excerpt from the videotape of the children discussing the advantages related to the use of these two strategies. During the discussion the researcher is acting as a provoker. It begins at GR II, C: line 7, when Gregg notices that they have once again made an incorrect turn

Gregg:	"Oh no, we strike again!"
Robert:	"Mmm - LT 90."
Gregg:	"RT 90, it's faster if you do RT."
Robert:	"RT 90 RT 90." (typing)
Researcher:	"Why is it faster?"
Gregg:	"Because, if you like this it will have to go ahh!"
Robert:	"RT 90 RT 90 twice."
Gregg:	"No, LT 90 LT 90 - Well, it looks faster on the screen. I guess because of the line."
Researcher:	"It looked faster?"
Robert:	"Yes! cause if you did LT 90 it went 1 - 2 - 3."
Gregg:	"No. If your turtle is like this ng ng and same ng ng (mumble)."
Researcher:	"So is it the same or is one faster?"
Gregg:	"Its the same. I just thought it would be faster."
Robert:	"O.K. LINE50."

Session 6 - Task 3

Nature: The task is the third task on the page used for session 6. It is presented as two solid lines joined at a right angle with the turtle indicated at one end. The task is located in the upper right hand quadrant. The instructions read. "Use your procedures to do the following."

Structure:



Explicit: The task consists of a vertical and horizontal line joined at a right angle. The lines are approximately in a 1:2 proportion. This task requires only drawing with the turtle. i e there is no path provided or required.

Implicit: The task is designed so that the vertical line is equivalent to approximately twice the horizontal line

Task Requirements:

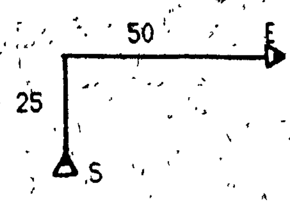
Explicit: A precise solution for this task requires:

1. Using LINE25 and LINE50 interfaced with RT 90 to draw the figure.

Implicit: The task requires only drawing with the turtle using procedures.

Successful solution:

The solution requires that the diagram be labelled with the following. S and E, choice of lengths and the written program. An example is given below.



PROGRAM

LINE 25
RT 90
LINE50

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LINE25	LINE25	LINE25	LINE25	LINE 25	LINE25
2)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
3)	LINE50	LINE50	LINE50	LINE50	LINE50	LINE50

As the above table demonstrates, all three groups successfully completed the task on their first attempt

General Observations:

The session reviewed procedures and moving and drawing with the turtle. The children were asked to define two procedures and then use them in a series of three tasks. While attempting the tasks, planning was emphasized.

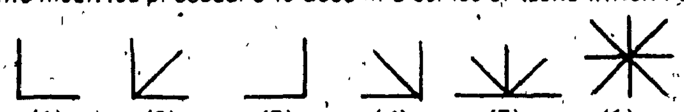
In general the children were able to define the two procedures LINE25 and LINE50. Guidance was required for some regarding procedure syntax. All three tasks were successfully completed with relative ease

SESSION 7

Overall Description

The overall objective in this session was to introduce the children to a turn other than 90 degrees. A state transpaent procedure was defined and used in the tasks In order to emphasize the turtle's rotation, the session was made-up of five tasks and one homework assignment. Together, these six tasks ended in a completed (360 degree) rotation about the origin

A very specific hierarchy was used in the design of the tasks and their sequence The session begins by defining a line procedure which is then made into a state transparent line procedure This modified procedure is used in a series of tasks which require the child to draw the following



(1) (2) (3) (4) (5) (6)

The underlying strategy for each task is described below

Task 1 Is the first task for which the children are to use a state-transparent procedure to draw it The isolation of the turn about the origin emphasizes the effect of RT 90

Task 2 Is a situation in which the turtle must be turned other than 90 degrees. Again, the emphasis is on the rotation permitting the children to observe the effect of RT 90 and their choice for the second required turn

Task 3 Similar to task 1 only this time emphasizes the effect of LT 90

Task 4 Similar to task 2 having the same requirements but with a left turn

Task 5: Structurally the task is task 2 and 4 combined. From a geometric point of view it divides the upper two quadrants into 4 equal parts (of 45 degree each) which could be solved by rotating the turtle through only 45 degree turns

Task 6. This task was designed essentially as a backup for task 5. The ideal programming strategy for the task is to use continuous 45 degree rotations. It implicitly demonstrates a complete rotation about the origin.

A detailed description of each task and the children's attempts is described on the following pages.

Session 7 - Task 1

Nature: The session begins with the first task which consists of two parts. The task involves writing a procedure to meet specified objectives and then modifying this procedure to meet an additional objective. The first procdure is a non-state transparent line procedure. The second procedure is the same line procedure modified to be state transparent Task 1 is presented in the workbooks on a new page for session 7 and includes questions 1) and 2)

Structure:

Explicit: Questions 1) and 2) are given as written instructions without any diagrams They read as follows

1) Write a procedure to draw a LINE50 turtle steps long
2) Write a procedure to draw a LINE50 turtle steps long, only this time return the turtle to where it started

Implicit: Question 1 is the LINE50 procedure used in session 6 It is a non-state transparent procedure. Question 2 requires that LINE50 be made into a state transparent procedure. The LOGO editor was used for quesiton 2

Task requirements:

Explicit: A precise solution for each question in the task requires

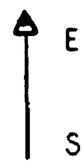
1) Using the correct syntax for a procedure.
2) Naming the procedure

3) For question 1) drawing a LINE50 turtle steps long and for questions 2) moving the turtle back 50 turtle steps.

Implicit: Question 2), making the procedure state transparent, requires using the precise inverse of the command used to draw the line for question 1) i.e. the lengths must be identical

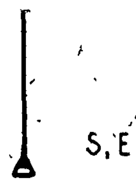
Successful solution: Solution for question 1)

```
TO LINE50
PD FD 50
END
```



Solution for question 2)

```
TO LINE50
PD FD 50
PU/PD BK 50
END
```



Children's Attempts:

	GR I PP (1)	GR I PP (2)	GR II PP (1)	GR II PP (2)	GR III PP (1)	GR III PP (2)
1)	"Procedure	PD FD 50	TO	TO	TO LINE50	TO LINE50
2)	is on disk"	PU BK 50	LINE50	LINE50	PU FD 50	PD FD 50
3)		END	PD FD 50	PD FD 50	END	PU BK 50
4)			END	PU BK 50		END
5)				END		

The children's responses to question one were varied. Group I's response that "the procedure is on disk" is quite correct as it had been saved in session 6. This response was unexpected by the researcher at that particular time but was used as an opportunity to work with the LOAD command.

Group II which separated the command TO from the procedure name are showing some difficulty with the recall of the syntax. Group III successfully completed the task.

For question 2) All the children used PU BK 50 correctly as the inverse for PD FD 50 used in question 1). The computer part of the acitvity was ~~guided~~ by the researcher who demonstrated using the LOGO editor i.e. The LINE50 procedure from question 1) was edited adding to it the line PU BK 50 in the proper sequence.

Session 7 - Task 2

Nature: Task 2 is given as a written instruction with a diagram in the workbook. It is question 3) which follows immediately after questions 1) & 2) from task 1 of session 7

Structure:

Explicit: The written instructions for the task read "Use LINE50 to draw." The diagram is a solid vertical and horizontal line of equal lengths joined at a right angle and opening towards the right. The diagram has no labels regarding length or where the turtle is

Implicit: The solid lines represent LINE50. Because LINE50 is now state transparent the choice of the starting point is crucial

Task requirements:

Explicit: A precise solution requires

1. The use of the now state transparent procedure LINE50.
2. Choosing an appropriate starting point given that LINE50 is state transparent.
3. Turning the turtle through 90 degrees

Implicit: Moving the turtle back 50 turtle steps to draw the second line is not required as LINE50, which is state transparent, already does this.

Selected Teacher Intervention: The teacher refrained from intervening when the children wrote LINE50 followed by PU BK 50. However the children were guided on where to begin the task.

Successful solution:

LINE50
RT 90
LINE50

Children's Attempts:

	GR I PP	GR I C	GR II PP	GR II C	GR III PP	GR III C
1)	LINE50	LINE 50	LINE50	LINE50	LINE50	LINE50
2)	PU BK 50	RT 90	PU BK 50	PU BK 50	RT 90	RT 90
3)	RT 90	LINE50	RT 90	**CS**	LINE50	LINE50
4)	LINE50		LINE50	LINE50		
5)				RT 90		
6)				LINE50		

Group I corrected their error before typing in the incorrect command PU BK 50. It would seem that the visual clue from the screen helped them to modify their program before it was fully executed. Group II, on the other hand, actually typed in the command PU BK 50 before realizing an error. Although they did not act upon the first visual clue as GR I did, they were still successful at identifying what their error was. This can be seen by their use of a correct program in their second attempt. GR III did not encounter any problems.

Note: Although the children were successful in correcting their error, perhaps some of the confusion regarding what LINE50 actually did could have been avoided had a different name such as RLINE50 been used for the modified LINE50.

Session 7 - Task 3

Nature: Task 3 is given as a written instruction with a diagram. In the workbook it is question 4 and is located directly to the right of question 3. The written part of the task has been written in such a way so as to start a dicussion. This task is the first task which requires the use of angles other than 90 degrees.

Structure:

Explicit: The written instructions for the task are "Do you think that you could teach the turtle to draw this?" The diagram is identical to the diagram described in task 2 except that in addition it has a third solid line drawn at a 45 degree angle. The diagram has no labels regarding length, angles or where the turtle is.

Implicit: The solid lines represent LINE50. The task is intended to be drawn using a state transparent procedure so that the focus of the task is on the interface. i.e. the turn.

Task requirements:

Explicit: A precise solution requires

1) The use of the state transparent procedure LINE50.
2) Choosing an appropriate starting point given that LINE50 is state transparent.
3) Turning the turtle through 90 degrees and 45 degrees.

Implicit: The task requires a turn 90 degrees RT or LT 90. Calculation of 1/2 of 90.

Successful Solution:

LINE50 RT 90 LINE50 LT 45 LINE50	or	LINE50 RT 45 LINE50 RT 45 LINE50

Selected Teacher Interventions:

"What did you do to get it to go all the way?"

"What is half of ninety?"

"The turtle isn't very good at math so you have to tell it what half of ninety is."

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LINE50	LINE50	LINE50	LINE50	LINE50	LINE50
2)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
3)	LINE50	LINE50	LINE50	LINE50	LINE50	LINE50
4)	LT 45	LT 45	LT 45	LT 45	RT 45	RT 45
5)	LINE50	LINE50	LINE	LINE50		LT 45
						LT 45
						LINE50

The mathematics

The task began with a discussion around the manipulations using popsicle sticks to represent the diagram and a toy turtle to represent the turtle. Under the guidance of the researcher, each group began attempting the task orally. Each group's first attempt to draw a line at a 45 degree angle was the following

GR I. "Half right turn 90"

GR II. "Half right turn"

GR III. "Left turn a half"

The design of the task assumed that the children would know what should be halved i.e. the input 90. It seemed to be obvious and consistent with what they had done so many times when changing inputs for commands FD and BK. The children, however, revealed another interpretation. They saw the task requiring one half of the whole command RT 90. Although this is consistent to some extent in a programming sense, it is not consistent in a mathematical sense. We note in particular that the use of "half right turn 90" suggests that the command RT with the input 90 is seen by the children all as one unit 'RT 90' Up until now the children have not attempted to change or alter the input section of the RT or ~~LT~~ commands

The discussion was then led by the researcher asking each group, "What is half of 90?" Below are excerpts from the tape of the discussion with each group

GR I	Researcher:	"What is half of ninety?"
	Benny	"45"
	Researcher	"How did you get 45?"
	Benny	"50 + 50 is 100 45 + 45 is 90"
GR II	Researcher:	"What if half of ninety?"
	Gregg	"No half, cause its an odd number cause it won't come out even."
	Researcher	"Are you sure What is half of 100"
	Gregg	"50"
	Researcher	"What is half of 90"
	Gregg	"40 or 50"
	Researcher.	"What is half of 80"
	Gregg	"40"
	Researcher	"half of 100"
	Gregg:	"50"
	Researcher	"half of 90"
	Robert:	"30"

Researcher:	"What is 30 + 30"
Robert:	"60"
Gregg:	"There isn't an equal half."
Researcher:	"What if I tell you there is. What is half of 70?"
Gregg:	"3 + 4 = 7, 30 + 40 = 70"
Researcher:	"Is that a half? What does a half mean?"
Gregg:	"Two equal parts"
Researcher:	"Is 30 and 40 a half"
Gregg:	"No"
Researcher:	"Why?"
Gregg:	"Cause one is 10 more than the other"
Researcher:	"What is half of 20?"
Gregg:	"10"
Researcher:	"Half of 30?"
Gregg:	"10"
Researcher:	"10? Whats half of 10?"
Gregg:	"5"
Researcher:	"Half of 20?"
Gregg:	"10"
Researcher:	"Half of 30?"
Robert:	"15"
Gregg:	"15 + 15 makes 30, we weren't thinking"
Researcher:	"What is half of 90"
Gregg:	(Silence)

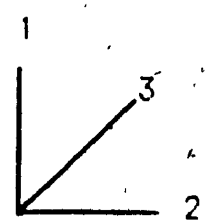
	Researcher:	"What is half of 80?"
	Gregg:	"40"
	Researcher:	"Half of 100?"
	Gregg:	"50"
	Researcher:	"Half of 90?"
	Gregg:	"Oh, ahh - 35"
	Researcher:	"What is 35 + 35?"
	Gregg:	"60"
	Robert:	"Do you have any more paper?"
	Gregg	"70"
	Researcher	"Half of 90?"
	Gregg	"5 + 4 = 9 and I think I have the answer - (silence) - 45"
GR III.	Researcher	"What is half of 90?"
	Jennifer	"What is half of 90?"
	Researcher	"Half of 10?"
	Jennifer	"5"
	Researcher	"Half of 4?"
	Jennifer	"2"
	Researcher:	"Half of 90?"
	Jennifer:	"45"

GR I was able to answer 45 without any help. GR II and III however were guided by the researcher in finding half on ninety. GR II took a very long time and was principally attempted by one member in the group, Gregg. Gregg's algorithm for finding 1/2 of a two digit number involves taking the first digit, finding the half of it and then adding a zero. This is seen in the following excerpts.

	Researcher:	"What is 1/2 of 70?"
	Gregg	"3 + 4 = 7 , 30 + 40 = 70"
and	Researcher:	"What is 1/2 of 90?"
	Gregg	"5 + 4 = 9 and"

This lengthy conversation with the children was my attempt to see if they knew what one half of ninety is. The concept of one half as two equal parts seemed quite sound. It is clear that the limitation is in the arithmatic. It is therefore important to note that arithmatic can be limiting to the implicit mathematics of a task.

The programming:



LINE50
RT90
LINE50
LT 45

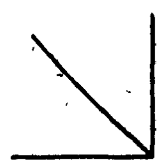
The programming strategy used for the task was the same for all three groups. The strategy draws the vertical and horizontal line first (1, 2) and the slanted line last (3). One might conjecture that the children do choose a strategy by first doing what they know how to do in the task and then include the parts that they are less sure of.

Note: In objective of this session 7 and session 8 is to work enough with LT/RT 45 that the children feel confident to change their strategy to a more optimum programming one. i.e. move in one direction; clockwise or counterclockwise.

Session 7 - Task 4

Nature: The nature of task 4 is somewhat different than the nature of previous tasks in that a visual guide (exercise 5) was provided to the left of it on the worksheet page. The children were not asked to attempt exercise 5 but to skip it and go directly to exercise 6. However, exercise 5 did provide a visual clue to the construction of exercise 6. Note that exercises 5 and 6 are identical to exercises 3 and 4 of the session except that they open to the left. This task is given as a written instruction and a diagram.

Structure:



Explicit: The written instructions for the task are: "Write a program to draw:" The diagram consists of three solid lines of equal length. One vertical, one horizontal and one at a 45 degree angle between the two. The diagram opens to the left. There are no labels regarding length, angles or where the turtle is.

Implicit: The diagram is identical to the one in the previous task only towards the left. The task is intended to be drawn with a state transparent procedure so that the focus of the task is on the interface i.e. the turn.

Task requirements:

Explicit: A precise solution requires:

1. Use of a state transparent procedure LINE50.
2. Choosing an appropriate starting point given that LINE50 is state transparent.
3. Turning the turtle through 90 degrees and 45 degrees.

Implicit: The task requires an input other than 90 for LT or RT

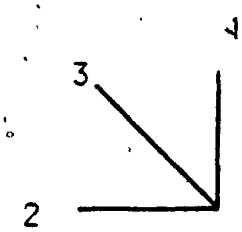
Successful solution: There are two possible successful solutions.

1	2
LINE50	LINE50
LT 90	LT 45
LINE50	LINE50
RT45	LT45
LINE50	LINE50

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LINE50	LINE50	LINE50	LINE50	LINE50	LINE50
2)	LT 90	LT 90	LT 90	LT 90	RT 90	RT 90
3)	LINE50	LINE50	LINE50	LINE50	LINE50	LT 90
4)	RT 45	RT 45	RT 45	RT 45	LT 45	LT 90
5)	LINE50	LINE50	LINE50	LINE50	LINE50	LINE50
6)						LT 45
7)						RT 90
8)						LINE50

Programming Strategies



All three groups followed the same strategy that they used in task 3. That is, they drew the vertical and horizontal lines first (1 , 2) and then drew the slanted line (3) Groups I & II had no errors in either their paper and pencil or computer activities. GR III had

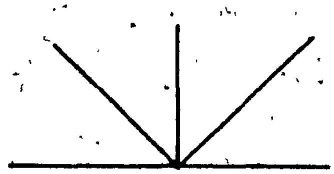
Two lateralization errors in their paper and pencil activity It is interesting to note how they corrected their lateralization errors at the computer (GR III, C: 2, 3, 4, 6, 7) The first RT 90 is corrected with LT 90 LT 90 The second LT 45 is corrected with RT 90. In the first case the additive property of angles is not used Therefore, for the second case because of inconsistency at least three possibilities exist

1) They used the additive property of angles. i.e. 45 + 45 = 90
2) They perceived visually that a correction of 90 degrees was required
3) They guessed

Session 7 - Task 5

Nature: Task 5 is exercise 7 in the workbook. It is given as a written instruction with a diagram. It followed immediately after exercise 6.

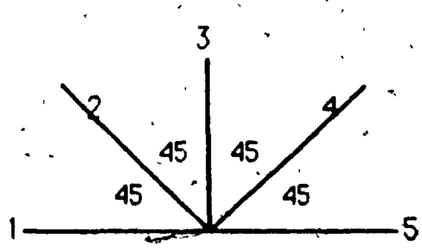
Structure:



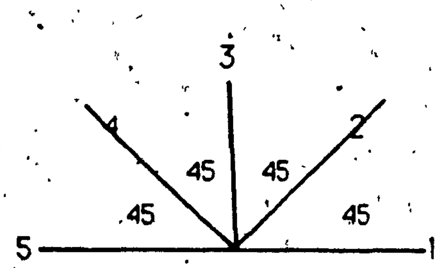
Explicit: The written instructions for the task are "Write a program using LINE50 to draw." The diagram is actually a composition of the diagrams fo Task 3 and task 4. It is made up of one vertical line, two horizontal lines and two slanted lines each at 45 degree angles from the vertical and horizontal lines. As with all the tasks for session 7, the diagram is not labelled.

Implicit: The task is intended to be drawn with a state transparent procedure so that the focus of the task is on the interface i.e. the turn. The task is somewhat more complicated than the previous two tasks in terms of keeping track of where the turtle is and where it has not yet gone. This is intentional to encourage a sequenced strategy to using 45 degree turns only.

Task requirements:



(b)



(c)

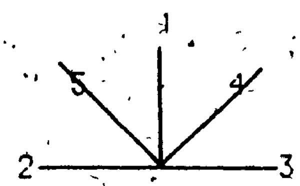
Explicit: A precise solution requires

1. Use of a state transparent procedure, LINE50
2. Choosing an appropriate starting point
3. Turning the turtle through 90 + 45 degrees

Implicit: The task does not require but does create an opportunity for a strategy that would turn the turtle clockwise or counterclockwise through 45 degrees (see figures (b), (c) above).

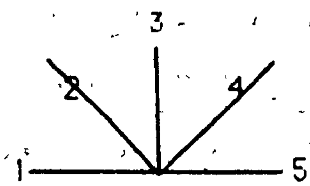
Successful Solution: The solution is dependent on the strategy used. Two samples of successful solutions each demonstrating the use of a different strategy are given.

1




```
LINE50
LT 90
LINE50
RT 180
LINE50
LT 45
LINE50
LT 90
LINE50
```

2

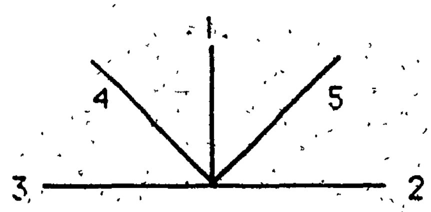



```
LT 90
LINE50
RT 45
LINE50
RT 45
LINE50
RT45
LINE50
RT 45
LINE50
```

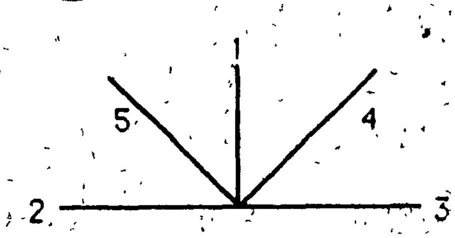
Children's Attempts:

	GR I PP	GR I C	GR II PP	GR II C	GR III PP	GR III C
1)	LINE50	LINE50	Did not attempt task		LINE50	LINE50
2)	RT 90	RT 90			LT 90	LT 90
3)	LINE50	LINE50			LINE50	LINE50
4)	LT 90	LT 90			LT 270	LT 270
5)	LT 90	LT 90			LINE50	RT 90
6)	LINE50	LINE50			RT 45	LINE50
7)	RT 45	RT 45			LINE50	RT 45
8)	LINE50	LINE50			RT 180	LT 45
9)	RT 45	RT45			LINE50	LT 45
10)	RT 45	RT 45				LINE50
11)	LINE50	LINE50				RT 180
						LT 45
						RT 135
						LINE50

Group II did not attempt this task as they had run out of time during the session. The observations are therefore from groups II and III only. Group I used a very safe and cautious strategy. In contrast, Group III used a strategy involving angles other than 90 and 45 which up until now they had not previously done. In examining each group separately the following is observed:



GRI

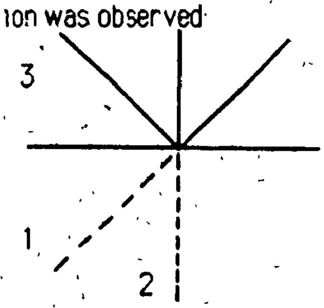


GR III

(construction of path from the computer activity)

Group I used a programming strategy consistent with that used for tasks 3 and 4 They drew the lines at 90 degree angles first (1,2,3) followed by the two lines at 45 degree angles (4,5). A rotation through 180 degrees was done by using the combination of LT 90, LT 90 The combination RT 45, RT 45 was used to go from 4 to 5 in the diagram Group I seems to have adopted the same approach for using RT/LT 45 as that used with RT/LT 90 i e the whole command seen as a unit They have not yet discovered the additive nature of angles

Group III used angles other than 45 and 90 In their paper and pencil activity they used 270 and 180 (GR III, pp. 4,8). In their computer activity they also used 135 (GR III, C:B) due to the corrections required by the errors in their paper and pencil work Although 270 and 180 did not give the desired results they do demonstrate the use of the additive property of angles. In the computer activity the overestimate of LT 270 was corrected with RT 90 and the resulting over-estimate of 180 was corrected with LT 90 From this we can see that the children have added angle inputs and have good turtle control. But further in the computer activity the following use of angle addition was observed



The turtle is facing the direction of 1, the children need it to be facing 3. The command LT 45 is typed moving the turtle to 2. From 2 the command RT 135 is typed followed by LINE 50

This was the first time that 135 was used and due to the video tape running out just prior to this any comments or discussion that may have been present are not available

General Observations

Session 7 had two main objectives and two underlying objectives. The main objectives were to introduce and use 1) a 45 degree turn and 2) a state transparent procedure. The underlying objectives were to provoke 1) the idea of the summative nature of angles and 2) a different programming strategy The main objectives were explicit while the underlying objectives were implicit

Aside from the arithmetic difficulties the children had in determining 1/2 of 90, two behaviours were observed in the children's use of RT/LT 45

1. Use RT/LT 45 the same way as RT/LT 90 e g correct an error RT 45 with LT 45 LT 45 (command as a unit concept).
2. Combine RT/LT 45 with RT/LT 90 to form RT/LT 135. The group which used this also used other summative angle inputs such as 270 and 180 (Discovered the summative nature of angle inputs)

Once introduced, the use of a state transparent procedure was easily adopted A future design feature however would be to give a state-transparent procedure a distinguishing name from a non-state transparent procedure which produced the same thing. e.g LINE50 and LINE50

The sequence of the tasks were very carefully designed The sequence had a built-in hierarchy which allowed the students to first work with a 45 degree angle on the right and then on the left and then combine both. The more complicated task of combining both the left and right 45 degree angles was designed to provoke the situation in which a change of strategy would be provoked e g Use only 45 degree turns. The session concluded with a homework assignment This homework assignment was a still more complicated task to construct the complete figure of 8 lines joined at 45 degree angles ()

SESSION 8

Overall Description

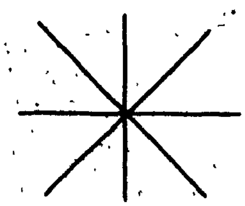
Session 8 concentrated on the homework task that was given to the children at the end of session 7 i.e  Each child had the opportunity to check his or her work on the computer A principal objective of the session was for the child to see (in operation) a strategy different from her/his own including a strategy demonstrated by the "teacher"

The objectives of the task itself involved using a state-transparent procedure and angles other than 90 degrees The task required writing a program that was a minimum of 16 lines long. So far, it is the longest program that has been assigned to them The choice of strategy determined the level of difficulty for successfully completing the task An underlying goal in the task was for the child to choose a strategy appropriate to the task The session ended with the researcher demonstrating the use of 45 degrees and LINE50 in a continuous sequence to produce the design of the task () This strategy was emphasized as a preparatory step for the use and understanding of the REPEAT command

Session 8 - Homework

Nature: All of session 8 concentrated on the homework task given at the end of session 7. The task was a continuation of a design/pattern which had been started in session 7. It asked the children to use the same procedure (LINE50) to draw, this time, the pattern completed about 360 degrees. Each child in the group had the opportunity to check their paper and pencil work on the computer. The homework was written in their homework books.

Structure:



Explicit: The written instructions for the task read: "Write a program using LINE50 to draw": As the diagram shows the task consists of 8 solid lines of equal length all meeting at a point. The lines are evenly spaced at 45 degree angles.

Implicit: As the procedure LINE50 is state transparent the focus of the task is on the rotation of the turtle through 45 degrees and multiples of 45 degrees.

Task requirements:

Explicit: A precise solution requires

1. Use of a state-transparent procedure LINE50.
2. Knowledge that the lines are of equal length and correspond to LINE50.
3. Choosing an appropriate starting point.
4. Turning the turtle through 45 degrees or multiples of 45 degrees.

Implicit: 1 The task does not require but does create a situation in which 45 degree turns can be used in a continuous clockwise or counterclockwise motion

2. The task has two simultaneous demands It requires that the children keep track of

1. What the turtle just drew

2. What the turtle needs to draw

Successful solution: There are many possible solutions an example by the researchers of one is as follows

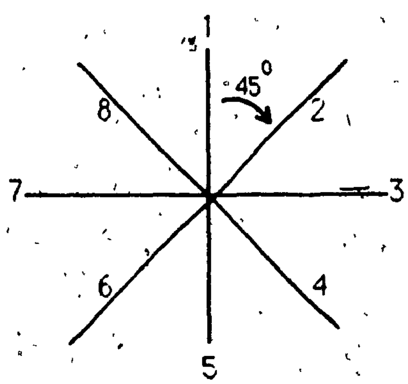


figure b

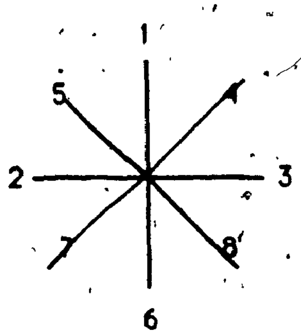
```
LINE50
RT 45
LINE50
RT 45
LINE50
RT 45
LINE50
RT 45
LINE50
RT 45
LINE50
RT 45
LINE50
RT 45
LINE50
```

Selected Teacher Interventions: With each group, following the checking and debugging of their homework, at the computer, the strategy of using only 45 degree turns in a continuous pattern (figure(b)) was discussed and demonstrated.

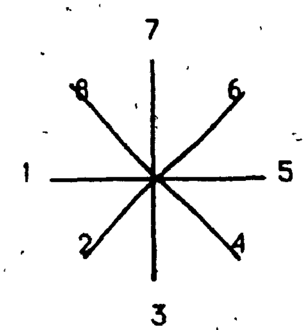
Children's Attempts:

	Benny (GR I) PP	Benny (GR I) C	Jennifer (GR I) PP	Jennifer (GR I) C (from video tape)
1)	LINE50	LINE50	LT 90	LT 90
2)	LT 90	LT 90	LINE50	LINE50
3)	LINE50	LINE50	PU BK 50	LT 45
4)	LT 45	RT 90	LT 45	LINE50
5)	RT 90	RT 45	LINE50	LT 45
6)	LINE50	LT 45	PU BK 50	LINE50
7)	LT 45	LT 45	LT 45	LT 45
8)	LINE50	LINE50	LINE50	LINE50
9)	LT 45	LT 45	PU BK 50	LT 45
10)	LT 45	LINE50	LT 45	LINE50
11)	LINE50	RT 90	LINE50	RT 45
12)	LT 45	RT 90	PU BK 50	LINE50
13)	LT 90	LINE50	LT 45	LT 45
14)	LINE50	LT 45	LINE50	LT 45
15)	RT 45	**CS**	PU BK 50	LINE50
16)	LINE50	LINE50	LT(X)RT 45	LT 45
17)	LT 45	LT 90	LINE50	LINE50
18)	LT 45	LINE50	PU BK 50	LT 45
19)	LINE50	RT 90	LT(X) RT 45	LINE50
20)		RT 90	LINE50	LINE50
21)		LINE50	PU BK 50	
22)		LT 45	LT(X)RT 45	
23)		LINE50	LINE50	
24)		LT 45	PU BK 50	
25)		LT 45	LT(X) RT 45	
26)		LINE50	LINE50	
27)		LT 45	PU BK 50	
28)		LT 90	RT 45	
29)		LINE50	LINE50	
30)		RT 45	PU BK 50	
31)		LINE50	RT 45	
32)		LT 45	LINE50	
33)		LT 45	PU BK 50	
34)		LINE50		

Strategy (Benny)



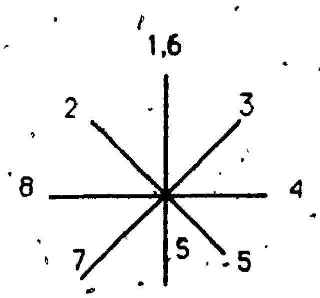
Strategy (Jennifer)



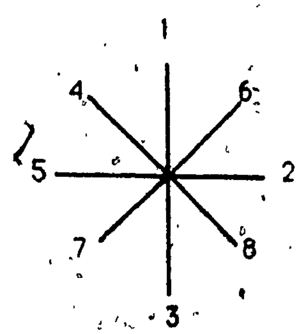
(X) Indicates the child's correction.

	Gregg (GR II) PP	Gregg (GR II) C (from video tape)	Grace (GR III) PP	Grace (GR III) C
1)	LINE50	LINE50	LINE50	LINE50
2)	PU BK 25	PU BK 25	RT 90	RT 90
3)	LT 45	LT 45	LINE50	LINE50
4)	LINE50	LINE50	RT 90	RT 90
5)	PU BK 50	PU BK 50	LINE50	LINE50
6)	RT 90	RT 90	LT 180	LT 180
7)	RT 45	LINE50	LINE50	LT 45
8)	LINE50	PU BK 50	RT 45	LINE50
9)	PU BK 50	RT 90	LINE50	RT 45
10)	RT 90	LT 45	LT 180	LT 90
11)	PD FD 50	PD FD 50	LINE50	LINE50
12)	PU BK 50	PU BK 50	RT 180	LT 180
13)	RT 45	RT 45	LINE50	LT 45
14)	LINE50	LINE50	RT 180	LINE50
15)	PU BK 50	PU BK 50	LINE50	RT 180
16)	LT 90	LT 90	LT 180	LINE50
17)	LT 45	LT 45	LINE50	RT 180
18)	LINE50	LINE50		RT 90
19)	PU BK 50	PU BK 25		LINE50
20)	LT 90	PU BK 15		
21)	LINE50	PU BK 10		
22)		LT 45		
23)		LT 90		
24)		LINE50		
25)		PU BK 50		
26)		LT 45		
27)		RT 90		
28)		LINE50		
29)				
30)				
31)				
32)				
33)				
34)				

Strategy



Strategy

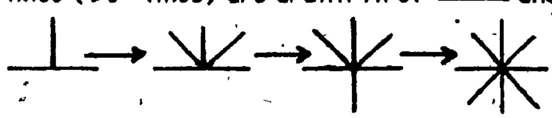


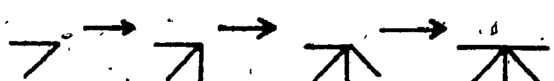
The homework was attempted by four children. Two children, one in group II and one in group III, were absent. The computer activity was used as a guide to identifying each child's strategy. This was necessary as once an error was encountered in the paper and pencil section it was very difficult for the researcher to determine the intended path. The researcher also emphasized that the child follow his/her written program as there was a tendency, once at the computer, to work in direct mode. (This will be commented on later in the analysis).

What was observed:

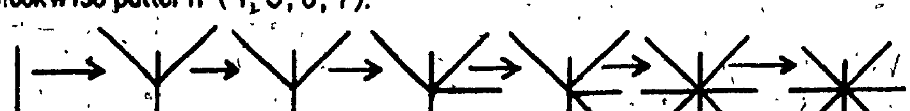
Programming

All four children used a different strategy for their programming sequence. They were:

Strategy 1 (Benny) - Begin at the center, do the upper half first then the lower half. The vertical and horizontal lines (90^0 lines) are drawn first  and then filled in with the slanted lines. 

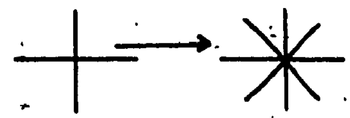
Strategy 2 (Jennifer) - Begin at the center, do the bottom half first then the upper half. The bottom half is constructed in a counterclockwise continuous sequence using 45 degree turns:  The upper half continues using the same pattern 

Strategy 3 (Gregg) - Begin at the bottom of the vertical line and move the turtle backwards halfway to the center  . Fill in the remaining 6 lines so they eventually take on a clockwise pattern (4, 5, 6, 7).



(1) (2) (3) (4) (5) (6) (7)

Strategy 4 (Grace) - Start in the center, do all 90 degree turns and then do all the slanted lines. Perceives diagram as a "cross and an x".



Paper and Pencil vs Direct Mode

The researcher observed that once an error was encountered by the children in their written program, they had a tendency to want to complete the task by disregarding the written part and using only direct mode. This seems to indicate that the task would be easier for the children to do using only the visual clues from the screen. This is probably quite true, but solving the task in this manner takes away from it the implicit dynamism present in writing and debugging the program and keeping track of where the turtle has gone and where it needs to go. The researcher felt this to be a very important aspect of the learning experience.

Mathematics - Use of angles

Three different types of uses of angles are observed in the childrens work. Each is described below.

1. Use of angle as a unit

This type of use of angle is characterized by the child using the command RT/LT "input" all as one unit. Examples of this type of usage include the following:

a) correction of lateralization error as follows:

(Benny)	RT 45 LT 45 LT 45

b) to reverse the direction of the turtle

(Benny)	RT 90 RT 90

2. Using the summative nature of angles

This type of use of angles is characterized by two strategies: i) the child combining angle inputs and ii) the child using one angle input to get to the desired heading. Examples of each strategy are:

a) correcting a lateralization error as follows:

(Gregg) LT 45
RT 90

b) to turn the turtle 135 degrees the child would use RT 135 instead of RT 90
RT 45

(Group III)

3. Misuse of an angle input

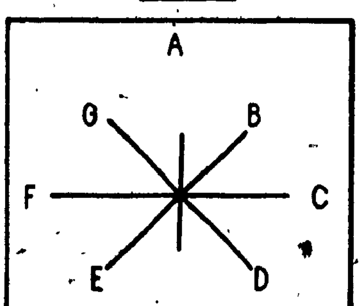
In this case a child uses an angle input but seems unaware of the product of that input. An example from Grace's homework book clearly shows this:

Last ten lines of her program:		
	LINE 50	RT 180
	LT 180	LINE50
	LINE 50	LT 180
	RT 180	LINE50
	LINE50	

A mathematical discussion

Gregg and the researcher had the following discussion afeter he completed his homework task on the screen.

SCREEN



Gregg: "That LINE50 is pretty short (referring to the vertical line). I think that that should have been LINE50 and all of those LINE25. I think."

Researcher: "But I wanted you to use LINE50. (Hoping to provoke a change in his strategy).

Gregg: "Well, I'll make that one (A) LINE100 and all those LINE50."

Gregg has demonstrated here that he is aware of the length error in his original product, i.e. that the vertical line is not long enough. His strategy to solve it is to shorten all the other lines to LINE25. Note: that the proportion is accurate with the product. The researcher, hoping to change his strategy to start the task at the center of the screen, reminds Gregg of the restriction of using LINE50. Gregg, replies, maintaining his original strategy, that he would use LINE100 and LINE50. (Also proportionately accurate).

Gregg was able to relate the mathematics used in his programming strategy to the final product on the screen and mentally make the mathematical adjustments to correct it. We find in general that the children were able to reason quite easily when it came to lengths, distance and proportion, but not in connection with angles.

This excerpt demonstrates Gregg's implicit use of mathematics in a programming environment. It also demonstrates the difference between what the researcher interpreted the task to be and how the child interpreted the task. Although the final product is achieved, the strategy used was unanticipated by the researcher.

General Observations

Session 8 focused on working with the children's homework given to them in session 7. This homework task was a continuation of a series of tasks which began in that session. The task involved the use of a state transparent procedure and 45 degree turns.

The task was a structured task in that the children were asked to reproduce what was in the diagram using a specific procedure (LINE50). It was an unstructured task in that no strategy was specified. The strategy was dependent on the choice of multiples of 45 degrees used. What we observed from this type of task was that the four children who did the task used four different strategies to do it. One of which was totally unanticipated by the researcher (strategy 3). But all of which (with the exception of a few minor programming errors) were successful.

An underlying objective of the researcher was for the children to see the task as a series of eight equal continuous rotations through 45 degrees. This was to lead the children to the beginning of a sequential programming strategy required when using REPEAT. Having each child verify their program on the computer allowed them to relive their original strategy. This was then followed by the researcher demonstrating and discussing "her strategy". The aim of this task was not to restrict the child's strategy but rather to demonstrate another strategy which they could compare with their own.

This session is followed up in session 11 where the children are asked to build a set of ten stairs. After the task is completed the researcher uses it to demonstrate the use of repeat.

SESSION 9

Overall Description

In session 9 rigid transformations of open geometric shapes are introduced The session begins by introducing an open geometric shape as a LOGO procedure which is then used in tasks requiring transformations of that procedure Manipulative representations of the procedure to be transformed are constructed as aids for the successful completion of the tasks

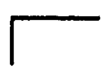
The session has three main objectives These are

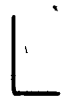
1 Review functional naming

2 Construct and use a manipulative representation of a LOGO procedure.

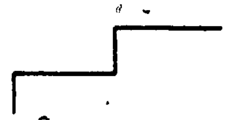
3 Provide tasks involving rigid transformations of a LOGO procedure

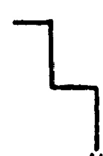
It is made up of five tasks The first task which consists of four questions involves the children writing a program for a LOGO procedure already defined on the computer The children are provided with its name only and are required to interpret it in order to be able to successfully write the procedure definition The four tasks which follow involve simple transformations of this same procedure The hierarchieal strategy underlying the order of the sequence of the tasks is the following

Task 1 define the procedure. 

Task 2 interface (90^0) + procedure 

Task 3 interface (180^0) + procedure

Task 4. procedure + interface (90^0) + procedure 

Task 5. interface (90^0) + procedure + interface (90^0) + procedure. 

Each task and the children's attempts are described below. Please note, however, that due to the similarities in the structure and requirements of the tasks involving a rigid transformation one general description is provided for all four tasks.

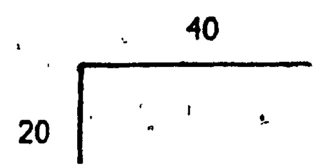
Session 9 - Task 1

Nature: The first task of session 9 has two objectives:

1) To introduce the children to the procedure EL2040 (EL pronounced as "the letter L) which is to be used in all of the tasks in session 9.

2) To review functional naming by examining on the computer a given procedure called EL2040 and then writing the program to draw it.

Structure:



EL2040

Explicit: There are four questions in the workbooks given as written instructions without any diagrams. They are as follows:

1) Type EL2040 and watch what the turtle draws.

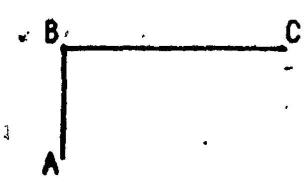
2) Draw what you see.

3) Write down the procedure EL2040.

4) Check your procedure.

Implicit: The procedure EL2040 is a vertical line 20 turtle steps long joined at a 90 degree angle with a horizontal line 40 turtle steps long.

Task requirements:



Explicit. A precise solution for the task requires.

1) Correctly typing the procedure name into the computer
2) Drawing a diagram into a workbook of what is on the screen.
3) Writing the procedure required to produce EL2040
4) Typing that procedure into the computer to verify that it is correct.

Implicit A precise solution of the task requires

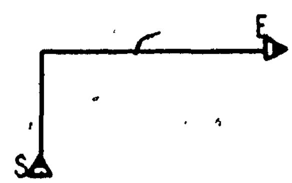
1) The interpretation of the procedure name EL2040 i e that it is an "el" shape with the measurements 20 and 40
2) How the turtle draws the procedure. The turtle draws AB, turns, and then draws BC (see figure above)

Successful Solution

The procedure

```
TO EL2040
PD FD 20
RT 90
PD FD 40
END
```

The diagram



Selected Teacher Intervention

"Why do you think that it is called EL2040?"

Children's Attempts

	GR I PP	GR II PP	GR III PP
	1st attempt	1st attempt	1st attempt
1)	TO PD FD 20	LINE25	PD FD 15
2)	RT 90	RT 90	RT 90
3)	PD FD 40	LINE25	PD FD 30
4)	END	LINE25	
		2nd attempt	2nd attempt
5)		LINE20	no record
6)		RT 90	
7)		LINE40	

All three groups were able to successfully type in the procedure and draw the product (Questions 1 and 2). For question 3 where the children were asked to write down the program for the procedure EL2040, all three groups had difficulty in writing a procedure using the correct syntax (see line 1 for GR I, II and III). Group I descussed the procedure name on their own initiative and were able to get the precise measurements Groups II and III required a second attempt for which at the beginning the researcher asked "Why do you thing that it is called EL2040 ?" The children were then able to complete the task as: e.g. LINE20, RT 90, LINE40.

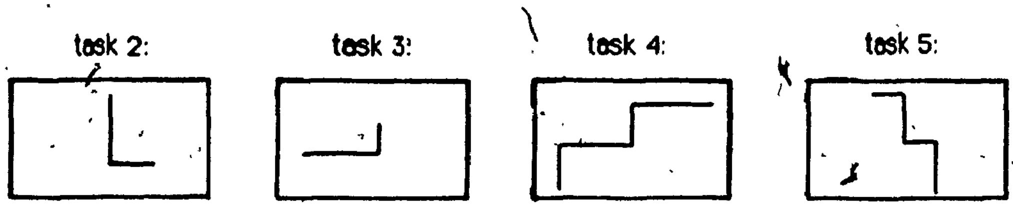
Construction of manipulatives

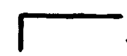
Up until now the only manipulatives being used were the toy screen and turtle and various full-size and half-size popsicle sticks. For this session the children were asked to make an EL2040 procedure out of 2 popsicle sticks - one long, one short - and glue them together. They were then asked to colour, using felt tip pens, a green tip to represent where the turtle starts and a red tip to represent where the turtle ends. Where green is for GO and red is for STOP as in the street light application for colour. These manipulatives representing the EL2040 procedure ⌈, the toy screen and toy turtle were then used for the remaining tasks of the session

Session 9 - General Description for tasks 2-3-4 & 5

Nature: The four tasks are presented to the children in their workbooks all on the same page. Each task is given as a written instruction with a diagram.

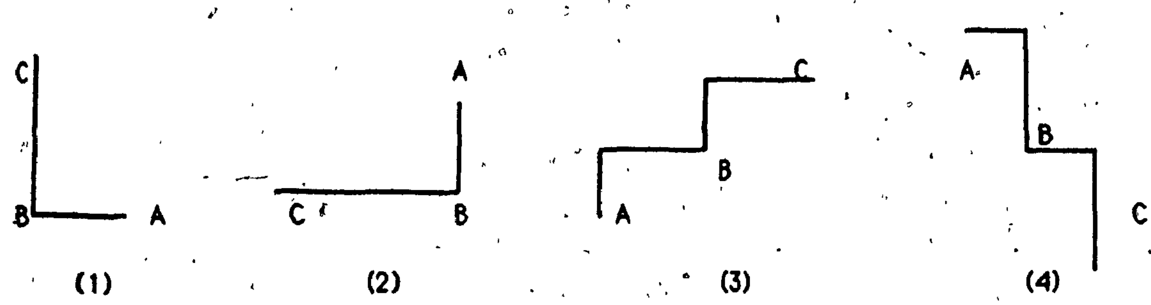
Structure:



Explicit: The written instructions for the task read: "Use EL2040 to draw." The diagrams are rigid transformations of the EL2040 procedure which draws . No other information is given.

Implicit: The figures are all made using the EL2040 procedure (once in tasks 1 and 2, twice in tasks 3 and 4) and some interface which rigidly transforms it.

Task Requirements:



Explicit: A Precise Solution requires

1. Indentifying EL2040 in the diagram.
2. Knowing which line the turtle draws first. i.e. short or long and choosing the

starting point A (see figures (1), (2), (3), and (4) above).

3 Turning the turtle to face AB

4. Use the procedure

Implicit. The task demonstrates

1 Rotation of a rigid figure

2 That a change in orientation does not change the shape of the figure.

Selected Teacher Interventions

Before starting each task the children were asked to place the EL2040 stick they had made (i.e. ⎾ ⏋) on the toy screen to represent the figure in the workbook for the appropriate task.

Successful solutions: A precise solution for each task was required They are the following

Task 2	Task 3	Task 4	Task 5
LT	RT/LT 180	EL2040	RT 90
EL2040	EL2040	LT 90	EL2040
		EL2040	LT 90
			EL2040

Children's Attempts for Task 2

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LT 90	LT 90	LT 90	LT 90	LT 90	LT 90
2)	EL2040	EL2040	LINE20	EL2040	PD FD 10	PD FD 10
3)			RT 90		EL2040	EL2040
4)			LINE40		PD FD 20	PD FD 20

All three groups were able to replicate the figure that was in their workbook. However, different interpretations of the task were observed with Groups II and III. During the paper and pencil activity, Group II used LINE20 and LINE40 instead of the requested EL2040. In examining the program that Group III wrote, it seems that the group interpreted the diagram as having the dimensions of 30 and 50. This may have been a result of their particular choice of scale for the graph paper in their workbook.

Children's Attempts for Task 3

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	RT 90	RT 90	LT 180	LT 180
2)	RT 90	RT 90	EL2040	EL2040	EL2040	EL2040
3)	EL2040	EL2040				
			2nd attempt	2nd attempt		
4)			LT 90	LT 90		
5)			LT 90	LT 90		
6)			EL2040	EL2040		

Each group had used the manipulatives while attempting the task. Groups I and III were successful upon their first attempt (GR, III, pp 1-3). Group II required a second attempt to make the necessary adjustment (GR II, pp. 4-6).

It is interesting to note here that Group III used 180 degrees as opposed to turning the turtle through 90 degrees twice.

Children's Attempts for Task 4

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	EL2040	EL2040	EL2040	EL2040	LT 90	LT 90
2)	LT 90 (erased)	EL2040	EL2040 LT 90	EL2040	EL2040	EL2040
3)	EL2040				LT90	
4)					EL2040	
		2nd attempt		2nd attempt		2nd attempt
5)		EL2040		EL2040		LT 90
6)		LT 90		LT 90		RT 90
7)		EL2040		EL2040		LT 180
8)						EL2040
9)						LT 90
10)						EL2040

A second attempt was required by each group to complete the task successfully Groups I and II made the same error on their first attempt by omitting the required interface (LT 90) for joining the two procedures.

Children's Attempts for Task 5

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	RT 90	RT 90	(not attempted)	
2)	EL2040	EL2040	EL2040	EL2040		
3)	LR 90	LT 90	RT 90	RT 90		
4)	EL2040	EL2040	EL2040	LT 90		
5)				LT 90		
6)				EL2040		

Group I succeeded on their first attempt. Group II had a lateralization error in the paper and pencil activity but spotted and corrected it (Group II, C: 4,5) on the computer before typing in the second EL2040. From the above, it is interesting to note that Group II seemed aware of the turtle state and the desired heading required for the correct interface to occur. Group III did not attempt the task as they were out of time.

General Description and Observations

In this session functional naming was seen from a different point of view. The children were given a procedure name which they were required to "decode" in order to be able to write the program This allowed the children an opportunity to view a procedure name from the perspective of its functionality. Aside from the errors in using the LOGO procedure syntax, it seems that in general the children were able to use the information given in the name to define the procedure.

Rigid transformations were encountered for the first time in this session. The concrete manipulatives played an important role in the presentation and attempt of a task. An objective of the rigid transformational tasks was for the children to use the concrete manipulatives to represent the task in order to facilitate both the understanding of the task requirements and the finding of a solution For each task the children were asked to replicate the figure with the manipulative(s) prior to writing down their attempt(s). The children were able to complete the tasks successfully and it appeared that the concrete manipulatives played a significant role in the process.

SESSION 10

Overall Description

Session 10 is designed as a continuation of session 9. It focused on functional naming, concrete manipulatives and rigid transformations. It is made up of a total of five task. The first three tasks are very similar in structure to those encountered in session 9. The difference is in the procedure to be transformed. In session 9 the procedure was EL2040 (┌──) and this session uses EL4020 (┌). The objective underlying the use of the similar EL4020 was to focus the attention on its related process and possibly sabotage any algorithms carried over from session 9.

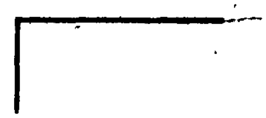
The last two tasks of the session (tasks 4 and 5) introduce a third procedure EL1030. This procedure differs from the previous two in that it begins with a clockwise turn through 90 degrees. Each task and the children's attempts at doing them is described below.

Session 10 - Task 1

Nature: The session begins with the first question on the workbook page for session 10. The task is to type the given name of a procedure into the computer and make a drawing of the product into the workbook. Each group is then asked to make a representation of the procedure with popsicle sticks and glue which is to be used as a manipulative for tasks 2 and 3.

Structure:

EL4020



EL2040

Explicit: The written instruction in the workbook is:

'Type EL4020 and draw what you see.'

The procedure EL4020 draws a vertical line 40 turtle steps long joined at a right angle with a horizontal line 20 turtle steps long.

Implicit: The procedure EL4020 begins with drawing a long vertical line. This is the inverse of the procedure EL2040 used in session 9 which draws a short vertical line first.

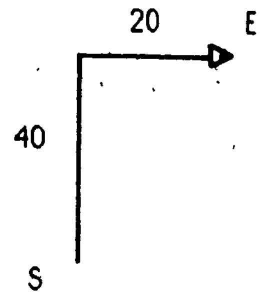
Task requirements:

Explicit: A precise solution for the task requires:

1. Typing the procedure name EL4020 into the computer.
2. Drawing a diagram of what is on the screen into the workbook.
3. Label the drawing.

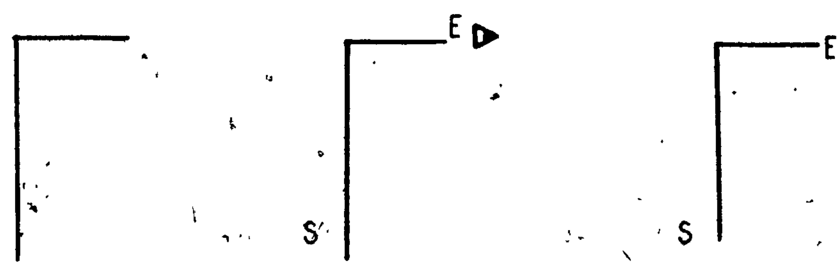
Implicit: To be able to correctly label the dimensions for the diagram the task requires interpretation of the procedure

Successful Solution



Children's Attempts

GR I GR II GR III



All the task requirements were successfully completed by each group.

Session 10 - General Descriptions for tasks 2 and 3

Nature: Tasks 2 and 3 correspond to exercises 2 and 3 in the children's workbooks on the page for session 10. Both tasks are given as a written instruction with a diagram.

Structure:

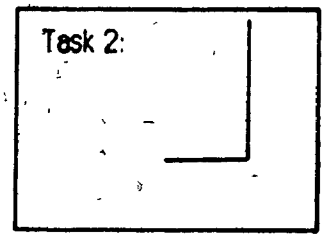


figure (a)

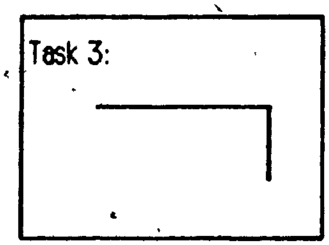
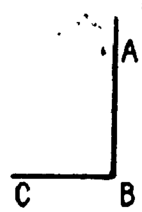


figure (b)

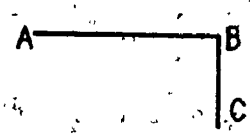
Explicit: The written instructions read: "Use EL4020 to draw:" The diagrams each represent a rigid transformation of the EL4020 procedure drawn as in figures (a) and (b). The diagrams have no labels.

Implicit: Figure (a) is drawn by turning the turtle through 180 degrees and figure (b) is drawn by turning the turtle clockwise through 90 degrees.

Task Requirements:



(task 2)



(task 3)

Explicit: A precise solution requires:

1. Identify EL4020 in the diagram.
2. Knowledge of which line the turtle draws first, i.e. short or long.
3. Choose the starting point A.

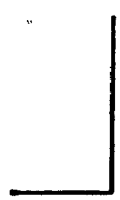
4. Rotate the turtle heading to face AB.

5. Use the procedure

Implicit The task demonstrates

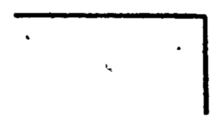
- rotation of a rigid shape
- that a change in orientation does not change the shape

Successful solution A precise solution for each task was required. They are the following:



Task 2

RT/LT 180
EL4020



Task 3

RT 90
EL4020

Selected Teacher Interventions

"How does the turtle draw EL4020?"

"Is there a faster way that you could do it?"

Children's Attempts for Task 2

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	LT 90	LT 90	LT 90	LT 90
2)	EL4020	EL4020	LT 90	LT 90	PD FD 30	PD FD 30
3)	2nd attempt	**CS**	EL4020	EL4020	RT 180	RT 180
4)	RT 90	RT 90			EL4020	EL 4020
5)	RT 90	RT 90				**CS**
6)	EL4020	EL2040				EL4020
7)		**CS**				**CS**
8)		RT 90				RT 90
9)		RT 90				**CS**
10)		EL4020				RT 180
						EL4020

In solving this task all three groups chose a different starting point resulting in different attempted strategies. Group I in their first attempt chose point C (see figure (a)) as their starting point for the task. This was incorrect as the procedure EL4020 begins with drawing the long line segment (40 turtle steps). In their second attempt (GR I, PP: 3-5) Benny suggested: "start with the long one" which leads to the correct solution. It is interesting to note that Benny was apparently able to focus on the process of the procedure in order to solve the task. Group II chose part A (see figure (a)) as their starting point and solved the task on their first attempt. Group III chose as their starting point the point B (see figure (a)) and attempted to solve the task using four commands (see GR III: PP: 1-4) which included the process of retracing a segment of the figure and using the PD FD combination.

Children's Attempts for Task 3:

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	RT 90	EL4020	LT 90	LT 90
2)	EL4020	EL4020	EL4020	CS	PD FD 40	PD FD 40
3)				ST	RT 180	RT 180
4)				RT 90	EL4020	EL4020
5)				EL4020		CS
6)						RT 90
7)						EL4020

The choice of the starting point for solving the task continued to affect the strategies and solutions of each group. Groups I and II were able to solve the task with relative ease. Group III however chose point B (see figure (b)) the center of the figure as their starting point. Although they were able to solve the task successfully (see GR III: PP : 1-4), in order to emphasize the choice of the starting point the researcher asked the group if there was a faster way to do it. The following is an excerpt of the discussion that followed:

Researcher:	"Is that the fastest way you could have done it?"
Jason:	"Ya, I guess so. Why, is there an easier way?"
Researcher:	"I don't know."
Jason:	"Well, I guess I think it's the fastest. I only used 1 - 2 - 3 4 programs .... (muttered)."
Researcher:	"Well, I can do it in (pause) 2."
Grace:	"I think I can do it in 2."
Researcher:	"Tell me how, Grace."
Grace:	"RT 90, EL4020"
Researcher:	"Right."
Jason:	(Types it into the computer) "Ya, it's right."
Researcher:	"How come that works?"
Jason:	"I didn't know that we could start here."

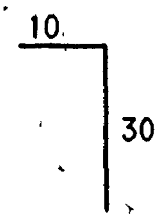
In this situation a challenge ("I can do it in 2 steps") was used to get the children to rethink their strategy. Grace gives us the answer, RT 90 EL4020 as Jason, after checking on the computer, exclaims "I didn't know that we could start here". This seems to tell us that both children understand the new strategy. And, that the strategy used in their first attempt, although it was correct, was chosen based on their perception of the task ,which was different from the researcher's perception of the task.

The above discussion demonstrates the importance of the role of the teacher in this design as a provoker and participator. This strategy helped to reveal a serious misconception about the choice of starting point which Jason had acquired. It also permitted the opportunity for the new strategy to actually be tested by the children themselves.

Session 10 - Task 4

Nature: This task is similar to task 1 of this session. As a method of introducing a new procedure the children are asked to type the procedure name into the computer and draw what they see. This new procedure is different from the previous (EI2040, EL4020) procedures in that it begins with a turn.

Structure:



Explicit: The written instruction in the workbook is

'Type EL1030 and draw what you see.'

The procedure EL1030 draws a horizontal line 10 turtle steps long joined at a right angle with a vertical line 30 turtle steps long.

Implicit: The procedure EL1030 begins with the turtle turning clockwise through 90 degrees.

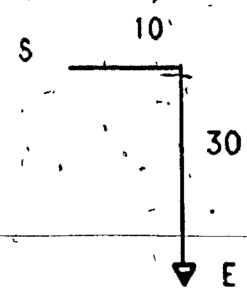
Task requirements:

Explicit: A precise solution for the task requires:

1. Typing the procedure name EL1030 into the computer.
2. Drawing a diagram of what is on the screen into the workbook.
3. Label the drawing.

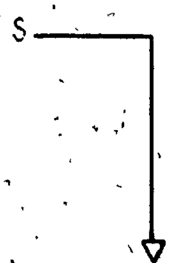
Implicit: To be able to correctly label the dimensions for the diagram the task requires interpretation of the procedure name.

Succesful solution

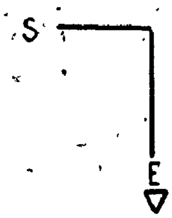


Children's Attempts

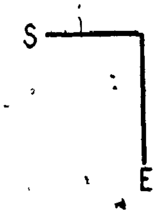
Gr I



GR II



GR III



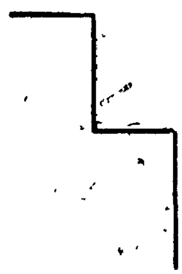
All the task requirements were successfully completed by each group

Note to the reader This LOGO procedure was quite different from the other procedures previously encountered in the environment as it began with a turn. It will be shown later that an additional task requirement should have been to write the program for the EL1030 procedure

Session 10 - Task 5

Nature: Task 5 is exercise 5 in the workbook. It follows immediately after exercise 4. It is given as a written instruction with a diagram.

Structure:



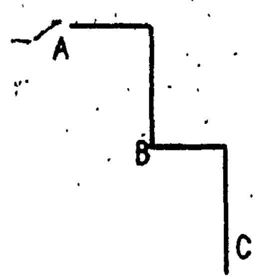
Explicit: The written instructions are:

'Use EL1030 to draw:'

The diagram is contructed with the E11030 procedure used twice. The diagram has no labels.

Implicit: The interface between the two procedures requires a rotation through 180 degrees.

Task requirements:



Explicit: A precise solution for the task requires:

1. Identifying that the original procedure is used twice.
2. Choose the starting point A.
3. Use the procedure.
4. Rotate the turtle at B through 180 degrees.
5. Use the procedure.

Implicit The task requires an interface at B This interface has to take into account that the EL1030 procedure begins with a turn

Successful Solution

EL1030
RT/LT 180
EL1030

Selected Teacher Intervention

"What is the first command in the EL1030 procedure?"

Children's Attempts

	Gr I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	RT 90	RT 90	RT 90	RT 90
2)	EL1030	EL1030	EL1030	EL1030	EL1030	EL1030
3)	LT 90	CS	LT 90	CS	LT 90	CS
4)	LT 90	EL1030	EL1030	RT 90	EL1030	EL1030
5)	EL1030	EL1030		LINE 10		RT 90
6)		CS		RT 90		RT 180
7)		EL1030		RT 90		EL1030
8)		LT 90		LINE 30		CS
9)		EL1030		CS		RT 90
10)		CS		RT 90		EL1030
11)		EL1030		LINE 10		CS
12)		RT 90		PD FD 10		LT 90
13)		EL1030		~~RT 90~~		EL1030
14)		CS		PD FD 30		CS
15)		RT 90		CS		RT 90
16)		EL1030		EL1030		EL1030
17)		CS		RT 90		CS
18)		EL1030		LT 90		EL1030
19)		LT 90		LT 90		EL1030
20)		EL1030		EL1030		CS
21)		CS		CS		EL1030
22)		EL1030		EL1030		LT 90
23)		EL1030		EL1030		PD FD 10
24)		CS		CS		RT 90
25)		EL1030		EL1030		PD FD 30
26)		LT 90		LT 90		CS
27)		LT 90		EL1030		EL1030
28)		EL1030				PU BK 30

29) RT 90
30) PU FD 10
31) CS
32) EL1030
33) RT 180
34) EL1030

The difficulty designed into this task was that the procedure EL1030 began with a clockwise turn through 90 degrees. In order to complete the task successfully, an interface joining the procedure to itself was required. This interface however needed to take the initial turn within the procedure into account. Hence, a turn through a total 180 degrees would result in the desired turtle heading to correctly interface the procedure with itself to obtain the given figure.

Groups I and III were able to do the task after 8 and 9 attempts respectively (see GR I and GR III: C : 1-34). Group II ran out of time and were unsuccessful after 8 attempts (see GR II: C : 1-27). It is interesting to note that all three groups on their first attempt began the task with a clockwise turn through 90 degrees. This turn was already present in the EL1030 procedure. This led the researcher to question if actually writing the program for the EL1030 procedure before using it for rigid transformations would have been a better intermediary step in the series of tasks. A comment from Benny, after his fourth attempt, of "I quit" may well represent how the children felt while attempting this task.

<u>Note to the reader</u>: This task, although upon initial examination it seems relatively straightforward, contains an implicit element embedded in the particular use of a specifically designed foundation procedure, i.e. interfacing a procedure that begins with a turn with itself.

General Observations:

The rigid transformations in this session were similar to those encountered in session 9. The exception was the last task using the EL1030 procedure which began with a turn. In general the children were able to successfully complete the tasks. Concrete manipulatives continued to be used throughout the session and were always available to the children. To overcome the problem of representing the initial turn in the EL1030 procedure as a concrete manipulative, a turtle was glued on at one end to indicate the turn.

Although the program for the EL4020 procedure introduced in this session was not actually written down, the children seemed to be able to distinguish it from the EL2040 procedure and use it appropriatley in the tasks. Skipping this step became a problem in the introduction to the EL1030 procedure which contained the added feature of it beginning with the turtle turning. It is perhaps difficult to judge what the children actually understood after completing the task with 8 or 9 attempts.

SESSION 11

General Descriptions

Session 11 introduces the REPEAT command. Structurally it is similar to and is a continuation of Session 8. It is centered on a task which uses a procedure as a building block to create a set of stairs As with the structure of the star (session 8) which can be viewed as a repeating series of a line procedure with a turn through 45 degrees, the structure of the stairs can also be viewed as a repeating series of commands.

The stair task is attempted by each child as a homework assignment from the previous week. Only after each child in the pair has verified and modified, when necessary, each of their programs is the REPEAT command introduced using the set of stairs as the pilot example. The children's reactions to seeing the effects of the REPEAT command are described in detail at the end of the session.

Session 11 - Task 1 : Homework from Session 10

Nature: Task 1 is centered on checking at the computer the homework assignment given to each child at the end of session 10. This assignment asked them to write a procedure and then a program using the procedure to draw a set of ten stairs. It was given to them on a separate sheet of paper.

Structure:

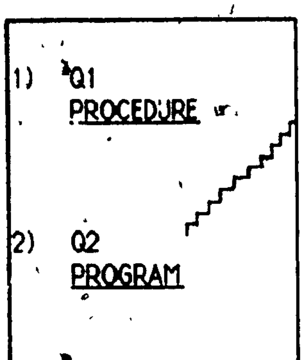


figure (A)

Explicit: The homework has two questions and a diagram set up on the sheet as seen in figure (A). The first question has written instructions, the word PROCEDURE underlined below it and a diagram. The written instructions are:

Q 1 - "Write a procedure that will help you to draw a set of ten stairs."

The diagram consists of horizontal and vertical lines of equal lengths joined at right angles to make 10 steps.

The second question has written instructions and the word PROGRAM underlined below it. The question reads:

Q 2 - "Write a program using your procedure to draw a set of 10 stairs."

Implicit: Unlike in the previous tasks, in this task the child must begin by choosing an appropriate procedure.

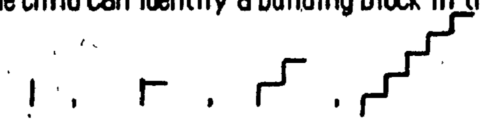
Task Requirements:

Explicit: A precise solution for the task requires:

1. Knowledge of what a procedure is and its corresponding LOGO syntax.
2. Choice of a procedure that can be used to construct the diagram e.g. LINEX (|), ELXX ( ), or multiples of ELXX ( ).
3. The use of a procedure with the correct interface to draw the set of 10 stairs.

Implicit: The task requires

1. That the child distinguish a procedure from a task.
2. That the child can identify a building block in the diagram.

   e.g. 

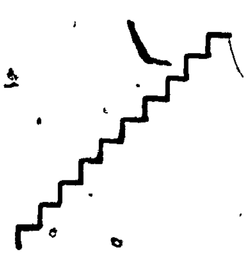
3. That the child can give the procedure a functional name.
4. That the child can use the building block to produce the set of 10 stairs.
5. That the child can identify the appropriate interface required to make the set of 10 stairs for his/her building block.

Successful Solution: There are many possible solutions. An example using as a building block is given below:

```
Q1:  TO EL1010
     PD FD 10
     RT 90
     PD FD 10
     END
```

```
Q2:  EL1010
     LT 90
     EL1010
     .
     .
     .
     LT 90
     EL1010
```

10 stairs



Selected Teacher Intervention: None as the computer provided the children with the necessary feedback.

Children's Attempts:

	GR I PP	GR I C	GR II PP	GR II C	GR III PP	GR III C
			(Gregg)		(Grace)	
1)	Q1-EL1010	TO EL1010	Q1-LINE30	LINE50	Q1-TO 10 STAIRS	TO STAIRS10
2)	LT 90	PD FD 10	RT 90	TO LINE50	PD FD 5	EL5X5
3)	EL1010	RT 90	LT 90	LINE50	RT 90	LT 90
4)	.	PD FD 10	LINE30	LINE30	PD FD 5	EL5X5
5)	.	END	RT 90	TO LINE30	LT 90	.
6)	.	CS	LT 90	LINE30	PD FD 5	.
7)	(10 times)	ST	LINE30	RT 90	.	.
8)		EL1010	RT 90	LINE30	.	END
9)		LT 90	LINE30	RT 90	.	STAIRS10
10)		EL1010	LT 90	LT 90	(9 times)	TO EL5X5
11)		LT 90	LINE30	LT 90	END	PD FD 5
12)		.		LINE30		LT 90
13)		.	Q2-LINE50	.	Q2-TO 10STAIRS	PD FD 5
14)		.	RT 90	.	EL5X5	END
15)		.	LINE50	.	LT 90	EL5X5
16)		(9 times)	LT 90	EL2040	EL5X5	CS
17)			LINE50	TO EL2040	LT 90	STAIRS10
18)			RT 90	CS	.	
19)			.	EL2020	.	
20)			.	TO EL2020	.	
21)			.	PD FD 20	(10 times)	
22)			(7 times)	RT 90	END	
23)				PD FD 20		
24)			(Robert)	END		
25)			Q1-PD FD 10	EL2020		
26)			RT 90	LT 90		
27)			PD FD 10			
28)			RT 90			
29)			PD FD 10			
30)			RT 90			
31)			.			
32)			.			
33)			.			
34)			(18 times)			
35)						
36)			Q2-not attempted			

- Please note that due to the length of the computer work done in this task only parts are reported on this table. For a complete description please refer to the dribble files in the Appendix.

Up until this session, for tasks involving the use of a procedure the procedure to be used had been provided. This was the first time that the children were asked to choose and define their own procedure (questions 1) to be used as the "foundation procedure" in the program of a specific task (question 2). The researcher assumed that the children were by now able to distinguish a procedure from a program and that the structuring of the questions in terms of their order, and careful use of the words PROCEDURE and PROGRAM respectively written below each one, would be a hint. None of the children correctly answered either question (see table above). Under question 1, only Grace wrote an actual procedure whilst the others wrote programs. Under question 2, Jennifer, Benny and Grace wrote procedures, Gregg wrote a program and Robert left the question unanswered. We can see from the way the children answered each question that they neither understood exactly what each question was asking nor were the words PROCEDURE and PROGRAM very effective hints.

Despite this confusion in the homework it was interesting to observe that once at the computer each group of children was able to successfully complete the task. For example, Grace, from group III, began her computer work writing her procedure to STAIRS10 which used the subprocedure EL5X5 (GR III, C:1-4). In her case, the subprocedure EL5X5 had not been defined previously although this had been the intention within the design of the task. Grace, however, was able to complete the task successfully using the information provided in the error messages. The role of the computer during this activity became one of a "feedback provider" both at a visual and an organizational level. This feedback enabled the children to define their procedures and thereafter to revise their programs.

Another form of feedback was also observed. That which came from the interaction between the children themselves. It was observed with group II that the interaction between the two children was sufficient to eliminate the step-by-step approach that had been adopted by the one child (Robert). As a result of this dynamism between the children, their written work and the computer, and between the children themselves, the researcher's role became that of an observer.

Introducing the REPEAT Command

In order to focus on the processes corresponding to Turtle Geometry activities designed for this learning environment, the command REPEAT was intentionally omitted up until now. The introduction to this command has been carefully embedded within the design of the sessions. Preparation for its introduction consistent with the approach used for other programming concepts in the environment began in session 8 and has continued in this session.

The homework activity tackled in session 8(x), for each group, concluded with the researcher demonstrating solving the task using 45 degree turns in a continuous clockwise motion. i.e. LINE50, RT 45, LINE50, RT45. The objective underlying the demonstration of this strategy was to view the task as a patterned series of commands. This strategy was again embedded in Session 11 in task 1, drawing a set of 10 stairs. Each group had the opportunity (either self-achieved or demonstrated) to view the task as a series of the procedure "STAIR" with an interface. This was followed with a demonstration by the researcher of the REPEAT command for completing the same task: REPEAT 10 [EL1010 LT 90].

The following are excerpts from each group during this activity.

GR I:

Researcher: "We type repeat space 10 times square bracket EL1010 LT 90 square bracket other side." (REPEAT 10 [EL1010 LT 90])

Jennifer & Benny: (Both children laugh after watching the turtle draw the ten stairs consecutively).

Researcher: "What do you think?"

Benny: "It's like it gone crazy !"

Researcher: "How did the turtle do it?"

Benny: "It went zzzzzzz." (Imitating the movement of the turtle with his hand.)

OR II:

Researcher: "What is it we want to do 10 times in order to draw the stairs?"

Gregg: "EL1010 and ... "

Researcher: "And?"

Gregg: "RT 90"

Researcher: "There is a command in LOGO that goes, REPEAT space, how many times do we want to repeat?"

Gregg: "10 times"

Researcher: "(while typing) 10. Open square bracket."

Gregg: "What do we want to repeat 10 times, EL1010 LT 90?"

Researcher: "Close square brackets. (REPEAT [ ]) What do you think the turtle is going to do?"

Gregg: "Ah - like this (ie) 10 times, except really fast."

Researcher: "OK, let's watch."

Gregg & Robert: "Oh yes!" (The children laughed and laughed in excitement)

Researcher: "Bobby didn't see that because he is too tired today, he said he didn't want to do computer work."

Robert: "Since I saw that trick I'm still alive!"

GR III:

Researcher: "Which one did you like doing better?"

Grace: "This one."

Researcher: "Why?"

Grace: "'Cause it's shorter."

Researcher: "Do you want to see another shorter way?"

Grace: "Yes."

Researcher: "There is a command in LOGO called REPEAT (typing). Now we have to tell it how many times we want it to repeat if - 10 - use square bracket and put in EL5X5 LT90 and square bracket. (After the turtle draws).

Grace: (Laughs with excitement.)

Researcher: "Is there another way that you could do the stairs?"

The common response among all the children when watching the turtle do REPEAT 10 [EL1010 Lt 90] was to become very excited and laugh outloud. They all seemed amused by what the turtle did. Benny comments that "it's like its gone crazy" and Bobby who had been losing interest in the session responds with, "since I saw that trick, I'm still alive". This sheer excitement and amazement had not been expected to such an extent by the researcher. In this particular situation the product (the ten stairs) was assumed anticipated by the children. What seemed to become the point of focus was the actual turtle's process in producing the stairs.

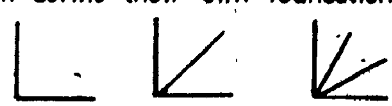
SESSION 12

General Description

Session 12 was designed to meet two objectives. For the purpose of informal evaluation by the researcher the first objective was to design tasks for which the requirements would review programming and mathematical concepts previously encountered in the environment. The second objective was to provide for the first item a situation which required the use of angles other than multiples of 45 degrees. The session was designed with a minimum amount of structure required to meet the above set-out objectives. The reason for this was to be able to observe the children's particular strategies while attempting the tasks.

The session consisted of a series of four tasks designed with a very specific hierarchy. It is as follows:

Task 1: Is a semi-structured task in which the children define their own foundation procedure (a line) to be used in the proceding three tasks.



(2) (3) (4)

Task 2, 3, 4: The strategy behind this series of tasks is the same that was used in session 7 when introducing a 45 degree angle except that it is continued one step further by dividing the quadrant into three equal parts. Tasks 2 and 3 are present for the purpose of recall and task 4 requires the use of angles other than multiples of 45 degrees.

It should be noted here that the difference in tasks 2 and 3 in this esssion to those given in session 7 lies in the structure of the tasks. In session 7 the foundation procedure is given as a state-transparent procedure. In this session the type of foundation procedure is determined by the choices made in task 1. The task requirements are dependent on the procedure type chosen. Each task and the children's attempts are described below.

Session 12 - Task 1

Nature: This is the first task on the workbook page for session 12. It asks the children to write and draw a line procedure of the length of their choice. This line procedure is then used as the foundation procedure for the session.

Structure

> 1) Write a procedure to draw a line any size you want.
>
> DRAWING PROCEDURE

Explicit: A written instruction and two column headings are provided in the area of the workbook designated for task 1 (figure x). The written instruction is: "Write a procedure to draw a line any size you want". The two column headings are: DRAWING AND PROCEDURE.

Implicit: This is the first of a series of four hierarchical tasks. The restriction of writing a procedure is to define a "foundation procedure" which can be used in the remaining tasks.

Task requirements:

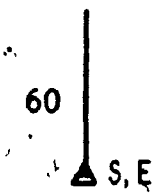
Explicit: A precise solution for the task requires:

1. That the children choose the size of line they wish to produce.
2. Write the procedure that will produce that line (using correct LOGO syntax).
3. Draw the line.

Note: For this task steps 2 and 3 can be done in reverse order.

Implicit: The task demonstrates defining a "foundation procedure" before using it.

Successful Solution: There are many possible solutions. An example is:



```
TO LINE60
PD FD 60
PU BK 60
END
```

Selected Teacher Interventions:

Used with GR III – to focus on the task requirements.

"Is that a procedure?"

Children's Attempts:

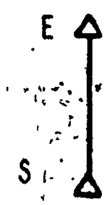
GR I

```
TO LINE60
PD FD 60
END
```

GR II

```
LINE60
```

GR III



```
PD FD 100
TO LINE100
PD FD 100
END
```

The following table summarizes the children's Pencil and Paper responses to the question: "Write a procedure to draw a line any size you want."

GR I was the only group to meet the task requirements as intended by the researcher on the first attempt, i.e. write the instructions for a procedure to draw a straight line. In the case of GR II, they used a procedure that had been previously defined in another session. This may be the result of the question being unclear in stating the task requirements. However, once the group was at the computer, they were required to define the procedure, regardless, as it was not available in memory. In this particular case the computer aided in directing the children to meet the task requirements. GR III in writing "PD FD 100" for their first attempt, required the teacher's intervention of "Is that a procedure?" to focus their attention on the task requirements.

<u>Note</u>: It is interesting to note here that none of the groups wrote a state-transparent procedure.

Session 12 - Task 2

Nature: This task is the second task in the series of four for session 12. It is similar in structure to that given in session 7, task 2, but differs in its requirements because of the "foundation procedure" used for doing the task.

Structure:

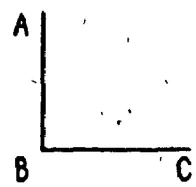


figure A

Explicit: The task consists of written instructions and a diagram. The written instructions read: Use the procedure to draw. The diagram is a solid vertical and horizontal line joined at a right angle and opening to the right. The diagram has no labels or indication of where the turtle is.

Implicit: The solid line represents the length chosen by each group in task 1. The two lines (AB and BC) are of equal length.

Task Requirements:

Explicit: The task requires:

1. The use of the procedure as determined by the choice made in task 1.
2. Choosing an appropriate starting point given the structure of the procedure defined in task 1.
3. Turning the turtle through 90 degrees.

Implicit: The choice of the starting point will determine the ease or complexity of the program to be written for the task, i.e. if the procedure being used to do the task is non-state transparent then C is an optimum starting point. The points A, B will require extra programming steps.

Successful Solution: There are many possible solutions. An example is

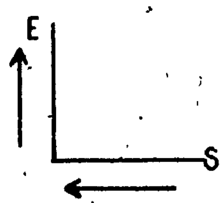
LT 90
LINE60
RT 90
LINE60

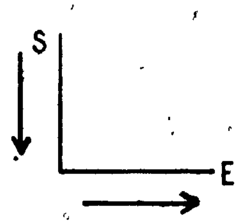
Selected Teacher Interventions:

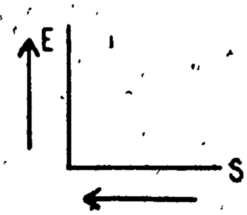
The computer was the principal source for feedback. The researcher did not intervene.

Children's Attempts:

	GR I		GR II		GR III	
	PP	C	PP	C	PP	C
1)	LT 90	LT 90	LINE60	LINE60	LT 90	LT 90
2)	LINE60	LINE60	RT 90	RT 90	LINE100	LINE100
3)	RT 90	RT 90	LINE60	RT 90	RT 90	RT 90
4)	LINE60	LINE60		PD FD 60	LINE100	LINE100
5)				RT 90		
6)				LT 90		
7)				LT 90		
8)				LINE60		







Both Groups I and II were successful on their first attempts. Each of these groups chose the starting point C (in figure A), the optimum starting point given each of their defined non-state transparent procedures. Group II originally chose the point A (in figure A) as the starting point and typed the lengthy program required by this choice using direct mode.

Two things are interesting to note here. The first is that all of the groups in their initial attempts seemed to be aware of the nature of their foundation procedure, i.e. none of them wrote a program assuming that the program was state transparent (LINE60, RT 90; LINE60). The second note is that GR II working in direct mode at the computer demonstrated a non-optimal strategy. It is unclear how much was really "planning" and how much was just consequential due to using direct mode on their part.

Session 12 - Task 3

Nature: This task is the third task in the series of four for session 12. It is similar in structure to that given in session 7 - task 3 differs in its requirements because of the "foundation procedure" used for doing the task.

Structure:

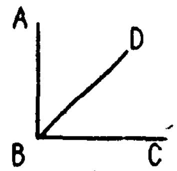


figure b

Explicit: The task consists of written instructions and a diagram. The written instructions given are "Write a program to draw:" The diagram is identical to that in task 2 except that addition there is a third solid line drawn at a 45 degree angle. The diagram has no labels.

Implicit: The solid lines are not of equal length, i.e. line BD is longer than line BA and BC. Because the use of a procedure is not specified in the written instruction, the task requirements will be partially determined by the choice of building blocks used to write the program. The emphasis in this task is not on the lengths assigned to each line as visually the differences are very subtle.

Task Requirements:

Explicit: A correct solution requires

1. That the three solid lines be drawn.
2. That line AB and line BC be at a 90 degree angle from each other.
3. That the line BD be at a 45 degree angle from the other two lines.

Implicit: The ease or difficulty of the task is determined in part by the strategy used to solve it.

i.e. use of a procedure, choice of starting point, etc.

Successful Solution: There are many possible solutions. An example is:

LT 90
LINE60
RT 90
LINE60
PU BK 60
RT 45
LINE60

Children's Attempts

	OR I		OR II		OR III	
	PP	C	PP	C	PP	C
1)	RT 90	RT 90	EL4040	EL4040	LT 90	LT 90
2)	LT 90	LT 90	PU BK 40	CS	LINE100	LINE100
3)	LINE60	PD FD 50	LT 45	TO EL4040	RT 90	RT 90
4)	LT 90	CS	LINE50	CS	LINE100	LINE100
5)	PD FD 50	LINE60		TO LINE40	PD BK 100	PD BK 00
6)	PU BK 50	LINE60		TO LINE50	LT 45	LT 45
7)	RT 45	CS		EL4040	LINE100	RT 90
8)	PD FD 50	LINE60		PU BK 50		LINE100
9)		BK LINE60		LT 40		
10)		CS		LINE50		
11)		LINE60				
12)		LT 45				
13)		CS				
14)		RT 90				
15)		RT 90				
16)		LINE60				
17)		LT 45				
18)		LT 45				
19)		LT 45				
20)		LINE60				
21)		PU BK 60				
22)		RT 45				
23)		LINE60				

GR I: Jennifer and Benny decided between themselves that Jennifer would work on the Pencil and Paper part of task 3 alone. The program which she wrote contains 2 lateralization errors (see GR I, PP : 1, 2, 7) and uses both a procedure and a command for drawing (see GR I, PP : 3, 5, 8). It appears that Jennifer perceived the three line segments to not all be of the same length. During the actual computer activity, Benny participated in the task by helping Jennifer correct her errors. e.g. "NO, that should be LINE60." During this time the researcher acted as an observer.

GR II: This group took the strategy of using a procedure called EL4040. Depending on the process given to the EL4040 procedure, the Pencil and Paper part of the activity could be correct. This group used 40/40/50 for the lengths of the line segments with 50 being the 45 degree line. What was observed with this group was that once at the computer they discovered that EL4040 and the LINE40 procedure needed to be defined. This became a lengthier process than what was originally intended for the task (see GR II, C : 3 - 6)

GR III: Used the same program strategy to draw the horizontal and vertical lines as they had used in task 2. In adding the third 45 degree line they made a lateralization error using LT 45 instead of RT 45. At the computer LT 45 was corrected with RT 90 (see GR III, C: 6,7). This group made all line segments equal length.

<u>Note</u>: Given that the structure of task 3 was identical to task 2 with the exception of an additional 45 degree line segment, it is interesting to note that only GR III used the same programming strategy in both tasks. GR I changed the starting point and GR II used a whole new procedure (EL4040).

Session 12 - Task 4

Nature: This task is the last task of a series of 4 in the session. Although it appears similar in structure to the other tasks for this session, it differs substantially in that a successful solution requires for the first time the use of a 30 degree angle.

Structure:

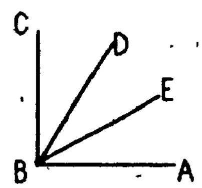


figure (A)

Explicit The task consists of a written instruction and a diagram. The written instruction is: "Write a program to draw:" The diagram consists of four straight lines" one horizontal, one vertical, and two at 30 degree angles from each other. The lines are not of equal length, i.e. lines BD and BE are longer than lines BC and BA.

Implicit. The quadrant is divided into three equal parts of 30 degrees each.

Task Requirements

Explict: A correct solution requires:

1. That four solid lines be drawn.
2. That line BA and BC be at a 90 degree angle from each other, one being vertical and the other horizontal
3. That the lines BD and BE be 30 degrees apart.

Implicit: The task requires a turn other than RT/LT 180, 90 or 45.

Successful solution: There are many possible solution depending on the choice of programming strategy. An example (assuming LINE60 is state-transparent) is:

LINE60
RT 30
LINE60
RT 30
LINE60
RT 30
LINE60

Selected Teacher Interventions

In order to facilitate the programming process associated with the children attempting various angle inputs, the researcher provided each group with a state transparent procedure towards the end of the session when time was becoming of the essence.

Children's Attempts

GR I	GR II	GR III
PP	PP	PP
LINE60	EL4040	LT 90
PU BK 60	PU BK 40	LINE100
RT 40	LT 45	RT 35
LINE60	LINE50	PD FD 100
PU BK 60	PU BK 50	PU BK 100
LT 40	LT 40	LT 45
LINE60	LINE50	PD FD 100
PU BK 60		PD BK 100
RT 40		LT 45
LINE60		PD FD 100

Choice of Angles (GR I)

1	2	3	4	5
40	40	20	30	20
40	40	20	30	20
40	20	30	LINE30	30

6	7	8
20	25	25
20	25	25
40	25	20

Choice of Angles (GR II)

1	2	3
EL4040	EL4040	EL4040
LT 5	LT 5	LT 45
RT 5	RT 20	RT 30

4
LT 45
RT 30
RT 90

Choice of Angles (GR III)

1	2	3	4
35	90	20	90
45	45	6	30
45	25	10	40
		15	5

5	6
90	90
10	22
	22
	66
	45

Each group used a different strategy in writing the program for the task. GR I started at point B and used a procedure called LINE60. GR II started at point C and used two procedures; EL4040 and LINE50. GR III started at point A and used a procedure called LINE100. All of the procedures used for the task were non-state transparent. The Paper and Pencil work suggests that the children are not having any difficulty in programming the turtle to draw the four solid lines

The initial choice of inputs for the turns are for GR I (40, 40, 40), GR II (45, 40) and GR III (35, 45, 45). For the first time the children used inputs for angles other than multiples of 45 degrees The difficulty in this task seems to lie in the choice of inputs for the turns which for the first time involved angles other than 45 and 90. The inputs chosen by the children however, indicate some awareness that

A) The rotation of the turtle determines the position of the line.

B) Number inputs other than 90 are required.

C) That the turns are less than 45.

General Observations

This session was the last session in the series of twelve. The two main objectives were to observe a) the children's programming strategies in a semi-structured task and b) how the children would handle a drawing that explicitly requires a 30 degree turn.

It was observed that in general the children had very little difficulty in the programming aspects of the tasks. Despite the odd lateralization error, controlling the turtle seems to pose no problem for the children. In fact, the open structure for the solutions of tasks 2, 3 and 4 resulted in the children using programming strategies which were not anticipated by the researcher. e.g. EL4040.

The aim of this session was to build on the children's knowledge about 90 and 45 degrees in order to introduce 30 degrees. This was done by assuming the hierarchy ($\llcorner \rightarrow \perp \rightarrow \angle$) used in the series of tasks would help the children to recall what was believed to be known of 45 degrees relative to 90 degrees. i.e. "1/2 RT 90". The researcher expected the concept of 1/3 to surface and come under discussion. However, this was not the case. The children never mentioned a fraction in the <u>whole</u> session. What they did do as a result of the task was to use angles other then multiples of 45. This was not an original objective for the session but was an original objective of the overall learning environment, which despite the efforts in session 11 finally occurred. The weakness here was the assumption made by the researcher regarding the children's perception of 90 and 45 degrees and perhaps their knowledge of fractions.

CHAPTER 5

THE CONCLUSION

Overview

Significance of the Study

The study provides

a) A frame of reference of how to improve LOGO in the classroom.

b) A working model for others to develop further.

c) Concrete suggestions for teachers and researchers.

Limitations fo the Study

The following are the limitations of the study:

a) The study took place outside of the actual classroom.

b) A limited number of children (6) worked in the environment.

c) Limited timeframe (12 sessions / 1 hour a week).

THE ENVIRONMENT

In this section, the various components of this 'Procedure-Based learning Environment' are examined with respect to how they evolved in the actual experiment. The purpose of this examination is to link what was discussed from a more theoretical point of view in the methodolgy with how it was actually implemented in the study. The aim here is to provide concrete examples to both clarify and demonstrate each component as it has been defined in the overall environment.

The Role of LOGO

The role of LOGO in this environment is one in which the LOGO programming process is itself the learning activity while very carefully designed products are provided as the children's objectives. That is, actual programming in LOGO is done by the children as in a project-oriented approach but, projects are replaced by tasks which have been designed to meet selected programming and mathematical objectives. In order to create tasks which meet these objectives, certain restrictions have been intentionally placed on some of the LOGO features (e.g. having to use a procedure instead of PEN DOWN for drawing) and availability of certain primitives (e.g. omission of the HOME command).

Role of the Teacher

The teacher's roles are very specific, distinct and strategic to the learning environment. The aim is for the teacher to be used at an optimum level whild the child is learning. The fact that the roles are pre-determined in the design of the environment acts as a guide for the teacher during the actual sessions. The following roles were observed in the twelve-session period: guide, demonstrator, provoker, facilitator and participating observer Each role is examined with examples from the experiment in order to identify and clarify how they evolved

Guide: The teacher's role as a guide involves providing instructions and steering the children on how to operate in the environment with respect to the use of the learning materials (paper and pencil, concrete manipulatives and the computer). Examples of this role include reminding the children to write down their solutions before going to the computer or within the paper and pencil stage, indicating where the turtle is going to start (S) and end (E). As this was a new environment for the children, in the early sessions a fair amount of guidance was necessary. However, it did diminish as the children became more familiar with the environment.

Demonstrator: The teacher's role as a demonstrator involves using elements (e.g. a task) already present in the learning environment to explicitly demonstrate a specific idea or concept. Although at times this role may take the form of a spontaneous action during a session (e.g. demonstrating how to use a manipulative) certain tasks are actually designed so they can be used by the teacher to demonstrate a specific concept or strategy. An example of such a task is seen in Session 8 which required the children to draw a star (✳). This task was used to demonstrate to the children how it could be solved using a 'continuous programming flow' of a repeating sequence of a 45 degree turn and a LINE procedure. The objective was to demonstrate a solution strategy consistent with the process logic of the REPEAT command. The role of the teacher as a demonstrator was a very distinct and strategic role in the environment

Provoker: The teacher's role as a provoker is a spontaneous role. It is found to be especially usefull and strategic for situations in which the provocation accentuates an underlying objective of the environment or of a specific task For example, as a stimulus for improving estimation skills, during the maze task in session 3 the teacher challenged the children to not only get the turtle through the maze but to do it in the least number of moves. Another example is taken from session 10 in which the children found a successfull solution for the required rigid transformation but in an attempt to stimulate a more optimal one, a challenge was presented by the teacher declaring that the task could be solved using only two commands. These provocations were an immediate response to the children working in the envrionment. They were possible because overall and specific objectives were known to the teacher at the beginning of the task allowing the teacher to complement the actual contribution of the task

Facilitator: The teacher's role as a facilitator is one in which the teacher provides some form of aid to the children facing a difficult situation. It is a reserved role since an objective of the learning environment is to observe what the children are capable of doing. The aim is to facilitate a situation and not to provide a solution. For example, while attempting a rigid transformation task, a new procedure for which the process began with a rotation was posing a problem for the children (Session 10, task 5). The teacher acting as a facilitator tried to focus the children's attention on the procedure's process by asking them what was the first command in the procedure. Another exmaple was one in which the teacher suggested the use of a state-transparent procedure for a task in which the children were having difficulty in determining the correct rotation (session 12, task 4). This allowed them to focus on the turn, as with a state-tranparent procedure the turtle would automatically return to the required position. In both these examples the teacher attempted to facilitate the situation but <u>did not provide the solutions for a task.</u>

<u>Participating Observer:</u> During the time that the teacher is not playing one of the above roles, the teacher becomes a participating observer. This allows the children to work independently and the teacher to observe them. This combination permits an ongoing analysis of the children's behaviour to take place providing an opportunity for the teacher to evaluate any possible requirements that may be necessary.

<u>Teacher Intervention</u>

The strategies used for teacher intervention in this study are parallel to the teacher's roles, i.e. intervention is used to guide, demonstrate to, provoke and facilitate for, the children. As all the components (teacher, child, learning materials and LOGO) in this learning environment are given specific and shared roles, intervention itself is very strategic but does not carry the weight that has been observed in other studies (Brookline, Chiltern). In this study every effort has been made to include in the descriptions of the children's behaviours the interventions which were present. For examples see "Selected Teacher Interventions" in Chapter 4. In general, interventions were short and to the point. Some examples taken from the tape are:

"How far have you gone from here to here (pointing on the screen)"

"Remember, you want to do this in the least number of moves."

Overall it was found throughout the experiment that having specific objectives to be met allowed for constructive and spontaneous interventions to take place.

Child Role

In general, the child played the role of an experimentor, and, exceptionally, the role of a participating observer during a demonstration. In the context of this learning environment the children experimented on their own, tasks being provided to steer the experimentation, i.e. the children worked in pairs quite independently from the teacher (see teacher roles/ intervention) but the tasks implicitly provided the contents which were to be explored. Again, as with what was observed with respect to teacher role/intervention, having distinct roles for the various components in the learning environment seems to have facilitated as well as supported this role of the child.

Teaching Strategies

The teaching strategy in this learning environment has been to present both programming and mathematical concepts in a very progressive and steady manner. Tasks are designed to present these concepts very gradually and manipulatives were available as support for the tasks. Both the programming and mathematical concepts are developed thoroughly. This is done by presenting several similar tasks requiring the use of the same concepts. The overall aim is for the children to work with LOGO features which they can understand or to build up gradually to more powerful programming processes (e.g. see session 8 and 11 for the introduction of the REPEAT command). The emphasis was on providing a learning environment which would foster the learning of both concepts and skills.

Tasks

The children's solutions to the tasks designed for this learning environment seem to suggest that they were appropriate for the age level. In general, a solution was found within the first two to three attempts. Occasionally, though, solutions were found on the first attempt or not at all. Although each task was carefully designed and analysed with respect to the mathematical and programming concepts required to successfully do it, occasionally unexpected interpretations and solution strategies were observed. For example, in a task in which the children were asked to use LINE60 to draw a figure, on group decided during the paper and pencil stage that the length was 70 so they defined and used a procedure called LINE70. This was not at all expected as a solution strategy (Session 4, task 2). A second example demonstrated an unexpected interpretation of the task. It was a task in which the children were asked to draw a star () with eight equal spikes. One child perceived the task as () with the center line being different in length from the others (see session 8, homework task). It was not always obvious how to present and write unambiguous instructions for a task

Different features arose in the experiment with respect to **structured** and **semi-structured** tasks. **Structured tasks**, those for which a single solution exists, were extremely useful for demonstrating a particular programming or mathematical concept. For example, a task which required a 90 degree turn interfaced with a procedure demonstrating a rigid transformation (see session 9, task 2). **Semi-structured** tasks, those for which a number of possible solutions exist, were very useful for observing children's strategies and acquired understandings. For example, the last task of the experiment (session 12, task 4) was presented to the children without any programming restrictions (e.g. use a procedure, use a state-transparent procedure, etc.) allowing for any strategy to be applied. This open structure created a situation in which the children's own strategies and choices could be observed.

OBERSERVATIONS

Because each task is analysed with respect to both the explicit and implicit programming and mathematical concepts required to do them, the children's behaviours in learning and using them can be more precisely analysed. The following is a summary of the programming and mathematical behaviours of the children observed over the twelve session period.

PROGRAMMING BEHAVIOURS

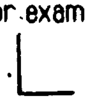
Programming Strategies

Various programming strategies are emphasized within the design of the learning environment. The children's behaviours working with these strategies are discussed below.

i) Planning a Strategy Choice of Start (S) and End (E)

In order to emphasize the idea of planning a programming strategy, as part of the paper and pencil activity the children were always asked to indicate on the diagram where the turtle was going to start (S) and where and in what position it was going to end (E). This allowed the children to examine the task globally and to choose a strategy that would then be used for writing the program. In general it was observed that the children had no difficulties in meeting this requirement (see for example session 6, task 2). They would indicate their choices and then proceed to write the program.

It was especially interesting to observe the children's strategy choice as they became more familiar with the environment and worked with both non-state and state transparent procedures. For example, at different times in the learning environment the children were given the figure



to draw. For one task the foundation procedure was state-transparent (case 1) and for another task it was non-state transparent (case 2). A consequence of the process difference in these two procedure types is the different optimum strategies associated for solving each case. The optimum strategy with a state-tranparent procedure is to start at B and the optimum strategy with a non-state-transparent procedure is to start at C. The results of the children's attempts with respect to these two situations were, in case 1, all the children chose B as their starting point (see session 7, task 2) and in case 2 the children chose either A or C as the starting point (see session 12, task 2). As A or C were never chosen as a starting point in case 1 and similarly B was never chosen in case 2, it suggests that the children were aware of the process logic with respect to each procedure and able to take this into consideration in choosing their programming strategy.

ii) <u>The importance of seeing various strategies</u>

The learning environment stressed the importance of the children seeing various programming strategies which resulted in the same end-product. In general this was done by verifying together the children's programs that had been written individually. Occasionally different strategies were discussed between the children during the actual planning stage. One session in particular, session 8, had as one of its objectives to use the homework task to explicitly demonstrate a very specific programming strategy. This strategy was a preparation for the introduction of the REPEAT command and involved solving the task using a continuous sequence of a turn with a procedure that draws a line (e.g. RT 45 LINE50 RT 45 ...). In such a short period (12 sessions) with so many new elements, it is difficult to judge the overall effect of the presence of this element in the learning environment. In general, the children did seem open to the idea that there was more than one way to solve some of the tasks.

iii) <u>Observed strategies</u>

The star (✳) homework task in Session 8 was one of the longest unstructured tasks given to the children. Each child used a different strategy to solve the task, e.g. 1) construct upper half first using 90 then 45 degree turns 2) do all 90 degree turns then 45 degree turns 3) construct lower half first using a sequence of 45 degree turns (see session 8 for more details). The observed various strategies seem to suggest that at this particular stage in the learning environment the chidren's strategies are defined by what they know best (i.e. feel most comfortable with) <u>and</u> by their perception of the task. Optimality does not appear to be a consideration at this stage.

Inconsistency in strategy was also observed. For example in Session 12 two consecutive tasks () were given to the children. Although the second task was very similar to the first, the only addition being a 45 degree line, two of the three groups used a new strategy for writing the second program (see Session 12, tasks 2 and 3). Again, this seems to suggest the importance at this stage of the child's perception of the task in determining their programming strategy vs the optimum choice.

iv) Inverse of a command (BK x vs RT/LT 180 FD x)

An inconsistent use of BK and RT/LT 180 FD as the inverse of FD was observed. Some children used a combination of the two possibilities while others were observed to use one or the other consistently. It is not clear from these 12 sessions the reasons which may underlie these inconsistencies. What was observed however was the choice of programming strategies which did not necessitate the use of the inverse of a command (retracing). Inverses tended to be used in situations which required the correction of a programming error. The inverse concept was stressed however in the environment with the introduction and writing of state-transparent procedures.

Functional Naming

Functional naming in this environment was viewed from two perspectives. The first is giving a functional name to a procedure. This involves the usual discussion about practical names for a procedure. As a means of enforcing this idea, functional naming was also viewed from a second perspective, that of 'decoding' a procedure name. This involves, given a procedure name (and its geometric product on the screen), writing the instructions for that procedure. This requires the children to analyse the given name for information about the procedure (decoding). The children did have difficulty decoding their first procedure name (see Session 9, task 1).

However, in a second similar task given in Sesion 10 (task 4) no difficulties were observed.

Commands and Syntax

In this learning environment the basic commands (FD, BK, RT, LT) were introduced in the first two sessions and the syntax for writing a procedure in Session 4. In general, no difficulties were observed with respect to working with the formality of the language. In one instance, in addition to a set of procedures provided, one group defined and used simple procedures as they required them (see Session 4, General Observations). The children seemed comfortable with the actual structure and syntax of the LOGO features introduced during the twelve sessions.

Procedures

The use of procedures from their programming perspectives i.e. **internal** and **external components** was emphasized in the environment. The **internal component** (once defined, a procdure will always do the same thing) was emphasized by using the same procedure in various tasks as well as in different sessions. A behaviour observed even in the last session with respect to a procedure's internal compenent was the occasional attempt to use the procedure's product as an input, e.g. BK LINE60 (see Session 12, task 3, group 1). This seems to indicate a possible confusion with respect to the procedure's internal and external component. The **external component** (once defined a procedure is used as a command) was emphasized by the requirement of writing programs to solve tasks for which one or several procedures were used in the solution. In the early sessions, when procedures were introduced, the children did have difficulty with the external component. They would define a procedure but when asked to verify its product they did not know how to use it as a command.

Program Length

As this learning environment was introductory and designed for 9-10 year olds, program length was not an immediate issue. However, it was observed with the star task (✳) of Session

8 that the errors in the children's paper and pencil work seemed to be related to keeping track of what had been drawn and what needed to be drawn. An incorrect assumption on their part resulted in a programming error. These errors seem to suggest that the difficulty was not related to the use of commands and procedures but rather to the length of the program required to complete the task. An optimum number of instructions with respect to an age group may be a factor to consider for future designs.

Errors and Misconceptions

The children's errors in this environment were related directly to the programming and mathematical requirements of a task. Each task and the children's behaviours while attempting the tasks have been carefully documented in Chapter 4. Of these errors, lateralisation was a dominant one. Observed strategies for correcting a wrong turn include a) using the opposite turn twice (RT 90 ⟶ LT 90 LT 90) and b) continuing the same rotation an additional two times (RT 90 RT 90 RT 90). A misconception with respect to rotations and angles was revealed in a discussion between two children about which one of the above described strategies was faster (see Session 6, task 2). Each child believed that their respective strategy resulted in a faster more direct correction. One child's reasoning was that "it looked faster". With the aid of some provocation on the part of the teacher, and the children using had no gestures to imitate the turtle, they were able to come to an agreement that the speeds were in fact the same. Note that the children were not using analytical skills with respect to the actual angle measures (90 + 90 = 180 ; 180 = 180) but were able to reason and compare the two situations with respect to the equivalence of the rotation (one quarter turn) movement.

State-Transparency

The introduction of the idea of state-transparency has been incorporated into the learning environment by designing tasks which require its use. These tasks begin by implicitly emphasizing the process of a state-transparent procdure by asking the children to re-draw figures with this new procedure type (see Session 7, task 2). The aim here is for the children to experience the different programming strategy associated with this new procedure process which would further be emphasized if an old strategy were attempted. In addition to emphasizing the actual process of a state-transparent procedure, tasks which demonstrated the usefullness of this process were also provided. The tasks chosen for this in this environment were geometric figures centered about the origin (Barfurth, 1986: p. 137). This eliminated the need to return the turtle to the origin and allowed the focus to be on the actual rotation. These tasks were used for introducing new angles (see Session 7 and Session 12).

In children's first attempts at using a state-transparent procedure for solving a task all three groups started their program at the origin (Session 7, task 2). The confusion that seemed present was with respect to using the BK command to return the turtle to the origin. Some children included this extra (redundant) step in their program. This was eliminated by the following task (task 3). It was extremely interesting to note that much later in the study (in session 12) the children, again presented with the same figure () but who had themselves chosen a non-state transparent procdure for drawing it, did not chose the origin as their starting point which was, in this case, not the optimum choice.

Interfacing

In order to facilitate the learning of interfacing, the turtle's state (position and heading) was emphasized throughout this study. This was done by requiring the children from the onset to indicate during the paper and pencil activity the turtle's state both at the beginning and the end of each task. Determining the appropriate lengths and rotations was also simplified by the fact that the children were always asked to label the diagrams with this information before writing the program. In general, difficulties with respect to interfacing were not observed. The exception was with respect to a situation in which the interface involved a procedure which began with a turn. This situation requires that the beginning turn be taken into account in the calculation of the rotation for the interface (see Session 10, task 5).

Modularity

In this environment, the concept of modularity is first introduced as a rigid transformation of a procedure's product. The products used were open geometric shapes. They were EL2040 (┌─) EL4020 (┌) and EL1030 (┐) (see Session 9 and 10). The use of very similar procedures was intentional so that 1) the children would have to focus on the process of the procedure and 2) the possible existence of any algorithms would be sabotaged. Manipulatives representing each of these procedures were constructed, labelled and used as aids for solving the related tasks. A built-in hierarchy in the series of tasks demonstrated both simple transformations and combined transformations requiring interfacing.

In general, the children were able to solve the tasks which used the EL2040 and EL4020 procedures. What was observed was the importance of the role of the manipulative in solving the tasks. The children frequently referred to them in the planning and revising stages. The observed problem area with respect to these types of activities was when the children had to interface a particular procedure, which began with a turn, with itself (EL1030) (see interfacing above).

The REPEAT command

As a main objective of this learning environment was to create a LOGO learning environment appropriate for 9-10 year old children the REPEAT command was treated from a different point of view. The approach was to build-up to the REPEAT command (i.e. encountering programming situations which loaned themselves to the repeat process) as opposed to presenting the repeat process and then dissecting its product. The reasoning behind this approach was to emphasize the understanding of the process and avoid the possiblity of the memorization of a command syntax for which the associated process was not understood. A detailed description of how this was done as well as the children's behaviours can be found in Session 11 under the heading 'Introducing the REPEAT Command'.

MATHEMATICAL BEHAVIOURS

This section reviews the mathematical behaviours of the children observed in the learning envirnonment. Each concept is reviewed under a seperate heading.

Estimation of Distance and Length

An implicit requirement of the early tasks was the extimation of distance and length and the calculation of total distance With respect to the estimation of distance and length two strategies were observed. These were 1.) incrementing the second estimation by one half of the value of the first (e.g. FD 30, FD 15) and 2) following a first estimation using increments or decrements of 10 (e.g. FD 100 BK 10 Bk 10) (see Session 3, 'Estimation'). Both these strategies seem to suggest a certain awareness of relative proportion. Despite the possible scale implied by the use of squared paper for the representation of the tasks, in general a visual approach to estimation rather than an analytical approach was observed. Estimation skills appeared to have improved over time if one used the declining number of required estimates to reach a desired point as an indicator (see Session 1, task 2).

The Concept of Total Distance

The concept of total distance was introduced into the environment through a teacher intervention asking how far the turtle had gone between two points. The children were able on their own to define total distance as the sum of the individual distances which they had used to get from one point to the other. Total distance = $\sum$ of inputs. (see Session 1, task 2).

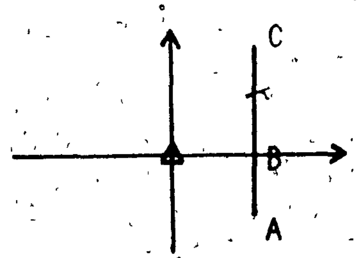
Proportionality

With respect to the geometric tasks given in the environment the children did show evidence of the conservation of the implicit proportions: the longest measurement was given to the longest line and the shortest measurement was given to the shortest line. The resulting assigned measurements were not always in the precise proportion implied by the squared paper. In a task which involved a displacement factor on the same line (see Session 4, task 4) the children again were observed conserving the relative proportion (1/3 to 2/3) of a section of the line with respect to its whole.

In a later session of the study as a result of a different interpretation of a task's structure, an interesting situation was observed with respect to proportionality. In the star task (✳), one child had assigned two line segments to be of length 25 and all of the others to be of length 50. In response to the suggestion that he could use LINE50, the child agreed and made two line segments to be of length 50 and the others of length 100. One might conclude from this that the child's perception of the structure of the task had not changed and at the same time he was very capable of preserving and calculating original proportion (Session 8, Homework task).

Displacement

The concept of displacement is with respect to a displacement of the turtle. A situation which requires this kind of displacement is one in which the turtle must cross below the x-axis in order to be in the correct position to draw a produt. In this kind of situation, the value assigned to the displacement factor (AB) must be proportional to the desired product (AC). See figure below:

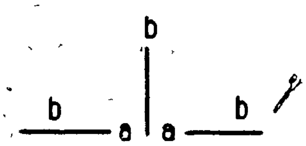


The displacement factor can also be viewed as a <u>negative component</u> since the turtle needs to be moved over the same vertical distance twice; once to position it correctly (BA) and a second time to draw the product (AC = AB + BC).

The children were able to program a successfull solution. All three groups were able to position the turtle in a correct state before interfacing it with the procedure. Two of the three groups actually used the intended 1:3 proportion while the other group assigned a slightly less accurate 40:70 proportion. It was interesting to observe that the displacement factor did not seem to disturb the children in any obvious manner (see Session 4, task 4).

Symmetry

In Session 5 a homework task was given which implicitly required the use of analytical calculations of symmetry. The task was.



where the line segments (b) were all of equal length and the distance between the line segments (a) were of equal length. A successful solution for the task requires that the horizontal lines be symmetrically placed about the vertical line. (For more details on the task requirements please refer to Sesion 5, Homework task.) Two strategies were observed with respect to the calculation of the symmetry requirements. These were 1) step-by-step, which involved moving the turtle along the horizontal line section by section (b,a,a,b) and 2) composite, which combined the two distances (a,a) into one move resulting in (b,2a,b). Of the five children who attempted the homework four correctly preserved the element of symmetry.

Arithmetic Errors

One important factor which was observed in this learning environment was children's arithmetic errors. Calculation errors were observed in various situations. For example, in Session 1 when the children were calculating the total distance, errors such as 90 + 90 = 190 and 90 + 90 = 170 were observed. Another calculation problem was observed in session 7 when the children were trying to determine what one half of ninety was. Responses such as "No half, cause it's an odd number cause it won't come out even" and "There isn't an equal half" were observed.

Arithmetic errors are an important factor to take into consideration when analysing children's behaviours with respect to an understanding of mathematical concepts since what might appear to be a lack in the understeding of a concept may in fact actually be an arithmetic error. Furthermore, it is important to note that arithmetic can be a limiting factor on the implicit mathematics of a task.

Fractions

Children's behaviours with respect to the concept of fraction were observed in two separate situations. The first encounter was in a situation in which the children were trying to calculate one half of ninety (Session 7, task 3). The idea that one half of something resulted in two equal parts appeared to be quite sound. However, in a situation similar to the one which provoked the concept of one half, the concept of one third as dividing something into three equal parts did not emerge (Session 12, task 4). It is not really clear whether the notion of one third was present or not. Perhaps it is something which should be considered in future research.

Angles

i) Rotations and Degrees

In this learning environment angles were examined in terms of turtle rotations. The terminology used was with respect to how much the turtle was to be turned rather than at what angle one wanted the turtle to make. In the second session when the children were asked what they thought ninety meant in the command RT 90 the responses were: "a number", "steps" and "turtle steps". For the remainder of the study, the idea of viewing rotations with respect to degrees was left up to the initiative of the children. The result was that the term 'degrees' was never mentioned.

ii) Angles other than 90

In addition to the use of 90 as an angle input other observed inputs include 180, 270 and after the task which provoked 45, 45 was also used. No other angle inputs (i.e. inputs that were not multiples of 45) were observed in the study until the last session in which a task which was aimed at provoking 30 resulted in angle inputs which were less than 45 (session 12, task 4).

iii) Observed uses of angles

Early uses of angles observed include: 1) correction of lateralisation errors such as RT 90 with LT 90, LT 90 and RT 45 with LT 45 LT 45 and 2) using RT 90 twice to turn the turtle through 180 degrees. The additive property of angles was not discovered by all the children nor was it consistently used. With respect to this property the following behaviours were observed: 1) correction of lateralisation errors by doubling the rotation in the opposite direction e.g. LT 90 corrected with RT 180 2) combining multiples of 90 degree turns e.g. inputs such as 180, 270 3) combining 90 degree turns with 45 degree turns e.g. RT 135.

iv) Emphasis on angles in the environment

State transparent procedures were used as a means of focusing on the turtle's rotation. The observations from the last task of the study seem to suggest that the children were aware that the rotation (heading) of the turtle determined the position of the line (see Session 12, task 4).

Rigid Transformations

Tasks which required the rigid transformations of simple open geometric figures were given in sessions 9 and 10. In the cases of simple procedure processes (e.g. two lines joined at 90 degree angle) the children were able to solve these tasks with the aid of both the concrete manipulatives representing the procedures and the visual feedback from the computer (see Session 9, tasks 2,3,4,5 and Session 10, tasks 2,3). In the case of a slightly more complex procedure process (e.g. an opening turn followed by two lins joined at a right angle) it is difficult to access the children's understanding after 8 and 9 attempts were required and even then not in all cases was the task solved (see session 10, task 5). The additional opening turn seems to have been the stumbling-block for the interface.

Concluding Remarks

It is interesting to note that although this 'procedure-based learning environment' is quite different from other LOGO learning environments, it is nonetheless fully dependent on LOGO and all of its Turtle Geometry features. No other existing programming language could act as a substitute.

Bibliography

Abelson, H. (1982) Apple LOGO N.H. Byte/McGraw-Hill.

Barfurth, M. (1986) State Transpareent and Non-State Transparent Procedures for Learning. The Mathematical Consequences and Design Origins for Each Type. Conference Proceedings LOGO and Math, 1986 - London, England

Bork, A. (1985) Personal Computers for Education. Harper and Row Publisher, N.Y.

Chait, S. (1978) An Analysis of Children's Problem Sovling in a Graphis Oriented Computer Programming Environment. MA Thesis-McGill University

Clements, D.H. (1985) Research on LOGO in education: Is the Turtle slow but Steady, or not even in the Race? Paper presented at LOGO 85, MIT Cambridge, M.A.

Erlwanger, S.H. (1985) Using Procedure - Based Microworlds to teach Mathematics. Unpublished Paper - Concordia University.

Erlwanger, S.H. (1985) Teaching Mathematics in a Procedure - Based LOGO Environment. Unpublished paper - Concordia University

Erlwanger, S., Hillel, J. (1984) An Exploratory Study of Children and LOGO. Unpublished paper - Concordia University.

Ginsburg, H. (1981) The clinical interview in psychological research on mathematical thinking: aims, rationales, techniques. For the learning of Mathematics. vol 1, no. 3.

Ginsburg, H., Opper, S. (1969) Piaget's Theory of Intellectual Development - An Introduction. Prentic-Hall, New Jersey.

Hillel, J (1985) Mathematical and Programming Concepts Acquired by Children, Aged 8-9, in a Restricted LOGO Environment. Unpublished paper, Concordia University

Howe, J.A.M., (1978) Developmental Stages in Learning to Program. DAI Research Paper No. 119. University of Edinburgh.

Howe, J.A.M.; O'Shea, T., Plane, F. (1980) Teachiing Mathematics Through LOGO Programming: An Evaluation Study. DAI Research Paper No. 115 University of Edinburgh.

Hoyles et al (1986): C. H., R. Noss and R. Sutherland (Eds) - Proceedings of the 2nd International Conference on LOGO and Mathematical Education, London Institute of Education, London 1986.

Kantowski, M.G. (1979) In R.B. Davis, T.A. Romberg, S. Rachlin & M.G. Kantowski (Eds), An Analysis of Mathematics Education on the Union of Soviet Socialist Republics. Columbus, OH: ERIC/SMEAC.

Lavoi, M. (1985) An Exploritory LOGO study with Fourth Grade Students. Unpublished paper-Concordia University.

Leron, U. (1985) Some Thoughts in LOGO 85. LOGO 85, Theoretical Papers, MIT Cambridge, Mass.

Moursand, D. "LOGO Frightens Me". The Computing Teacher. Vol 11. no. 5, 1984

Noss, Richard (1985) Creating a Mathematical Environment Through Programming: A Study of Young Children Learning LOGO. University of London Institute of Education.

Noss, Richard (1984) Children Learning LOGO Programming Interim Report No. 2 of the Chiltern LOGO Project.

Papert, S (1980) - 'Mindstorms - Children, Computers, and Powerful Ideas. Basic Books, N.Y.

Papert, S., Watt, D., et al. (1980) Final "Report of the Brookline Project". Part 3. A.I. Memo No. 54, MIT.

Papert, S. (1985) Computer Criticism vs. Technocentric Thinking. LOGO 85 Theoretical Papers - M.I.T.

Pea, R.D., Kurland, D.M. (1984) On the Cognitive Effects of Learning Computers Programming: A Critical Look. (Technical Reprot No. 9) New York: Center for Children and Technology, Bonh Street College.

Piaget, J. (1969). Science of Education and the Psychology of the Child. Grosman Publishers, Viking Press.

Ross, P., Howe, J. (1982) The Design of Edinburgh LOGO DAI Research Paper No. 15. University of Edinburgh.

Solomon, C. (1975) Comments and Advice on Introducing Kids to Turtles and LOGO. LOGO Working Paper 42, M.I.T.

Solomon, C. (1976) Problem-Solving in an Anthropomorphic Computer Culture. Boston University, Master's Thesis.

Solomon, C. (1978) "Teaching Young Children to Program in a LOGO Turtle Computer Culture." ACM SIGGUE Bulletin (July 1978).

APPENDIX I

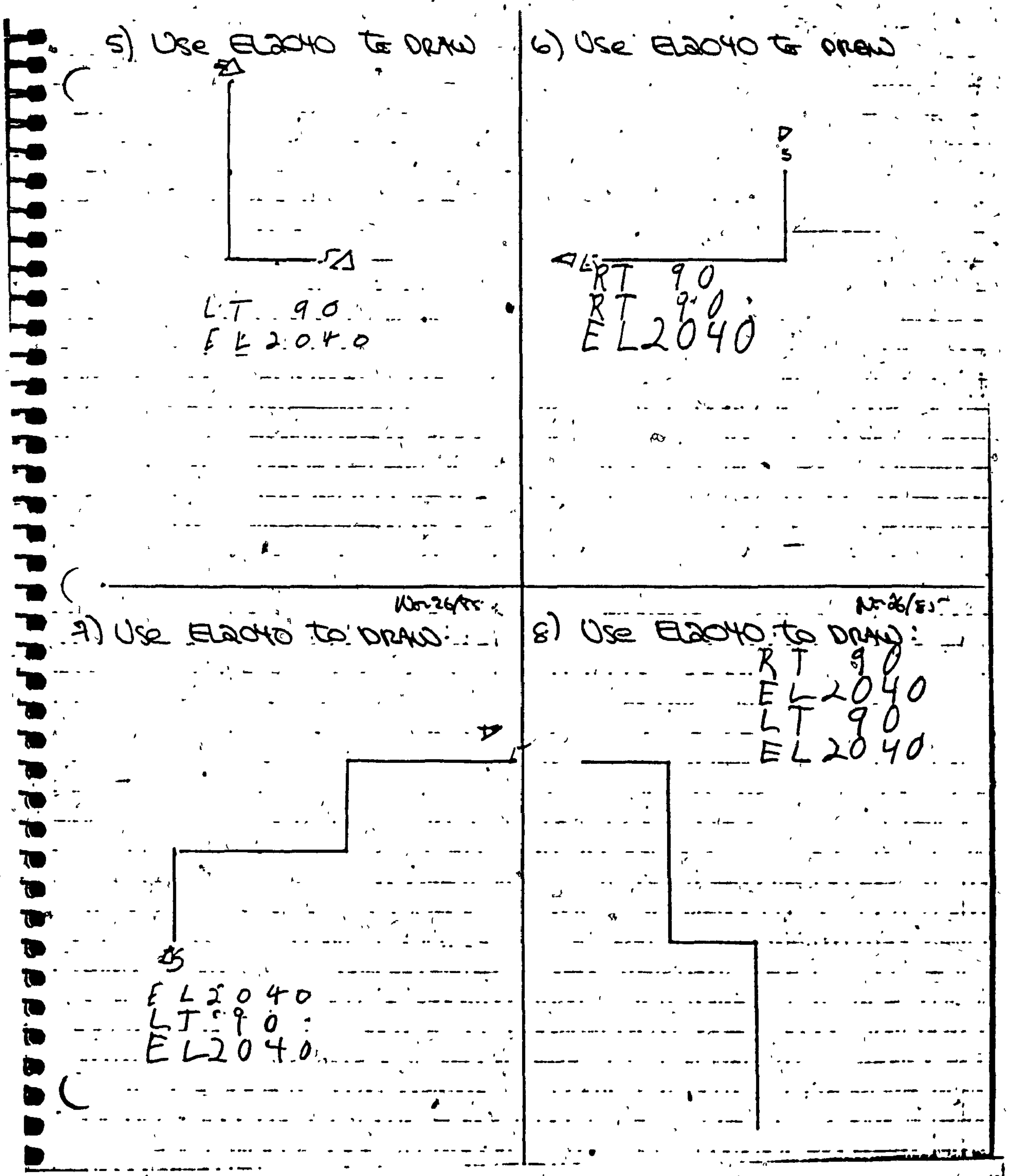
B. Attendence record.

	GR I		GR II		GR III	
	Jennifer	Benny	Greg	Robert	Jason	Grace
Session 1	✓	✓	✓	✓	✓	✓
Session 2	✓	✓	✓	✓	✓	✓
Session 3	✓	✓	✓	✓	✓	✓
Session 4	✓	✓	✓	✓	✓	✓
Session 5	✓	✓	✓	✓	✓	✓
Session 6	✓	✓	✓	✓	✓	✓
Session 7	✓	✓	✓	✓	✓	✓
Session 8	✓	✓	✓	X	X	✓
Session 9	✓	✓	✓	✓	✓	✓
Session 10	✓	✓	✓	✓	✓	✓
Session 11	✓	✓	✓	✓	X	✓
Session 12	✓	✓	✓	✓	✓	✓

APPENDIX II

This appendix contains samples of the learning materials and dribble files used in the study. The complete set of each of these is available upon request directly from the author.

A. Sample page from a workbook - Session 9, Group 1



5) Use EL2040 to DRAW

LT 90
EL2040

6) Use EL2040 to DRAW

RT 90
RT 90
EL2040

Nov 26/85

7) Use EL2040 to DRAW:

EL2040
LT 90
EL2040

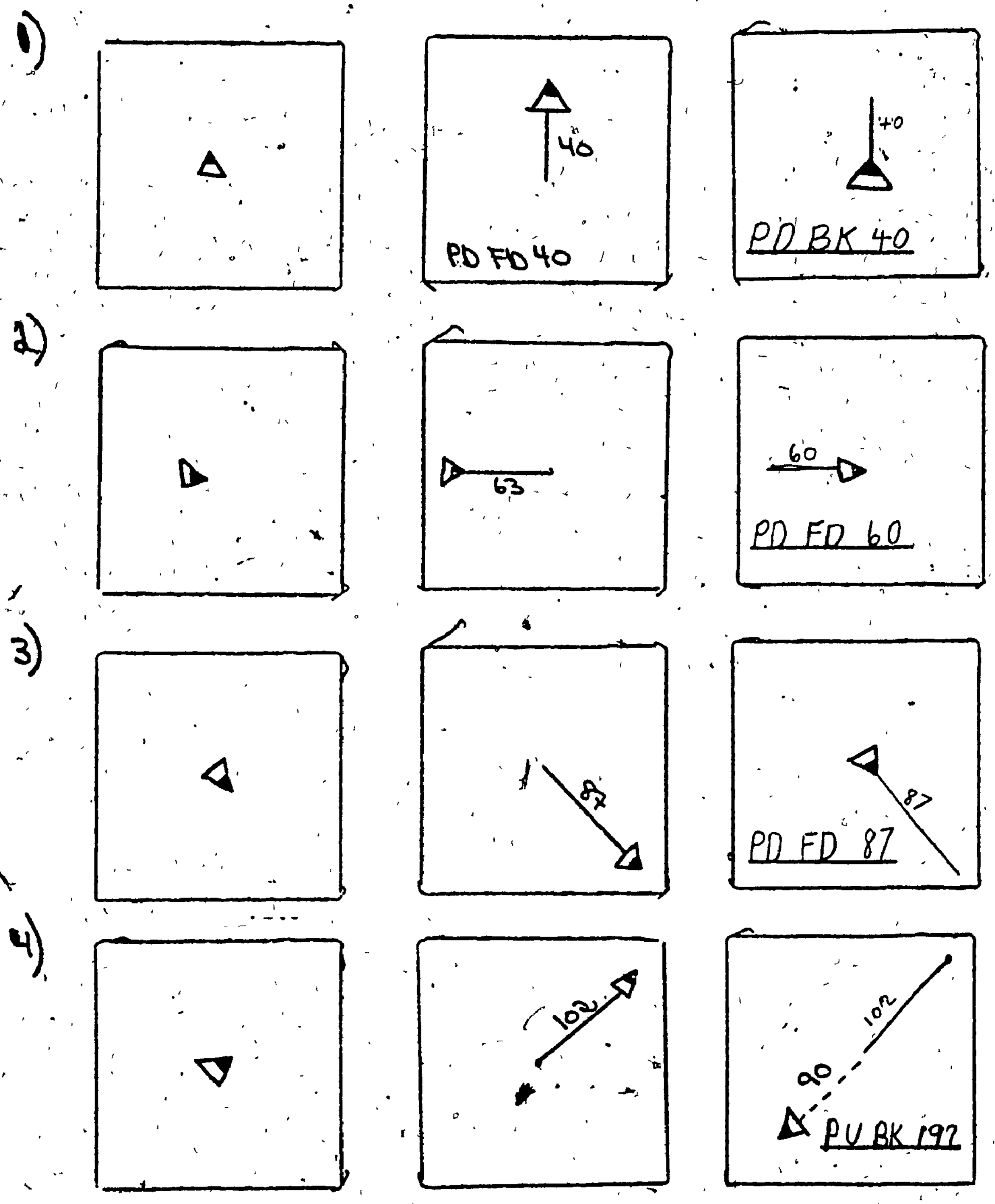
Nov 26/85

8) Use EL2040 to DRAW:

RT 90
EL2040
LT 90
EL2040

B. Sample of a worksheet.

Worksheet NAME: ____________



C. Sample of a dribble file - Session 8, Group 3.

```
?ST
?H T
I DON'T KNOW HOW TO H
?HT
?
?
?
?LINE50
I DON'T KNOW HOW TO LINE50
?CS
?ST
?LINE50
I DON'T KNOW HOW TO LINE50
?TO LINE50
>PD FD 50
>PU BK 50
>END
LINE50 DEFINED
?LINE25
I DON'T KNOW HOW TO LINE25
?LINE50
?RT 90
?LINE50
?RT 90
?LINE50
?LT 180
?LT 45
?LINE 50
I DON'T KNOW HOW TO LINE
?LINE50
?RT 45
?LT 90
?LINE50
?LT 180
?LT 45
?LINE50
?RT 180
?LINE50
?RT 180
?RT 90
?LINE50
?HT
?CS
?LINE50
?ST
?RT 45
?LINE50
?RT 45
?LINE50
?RT 45
?LINE50
?RT 45
?LINE50
?RT 45
?LINE50
?RT 45
?LINE50
?RT 45
?LINTO EL2040
PD FD 20
RT 90
PD FD 40
END
```