The Production and Evaluation of Self-Instructional Computer Courseware to Assist the Teaching of the Written Alphabet

Nicholas Barker

A Thesis

in

The Department

of

Education

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

September 1985

ISBN 0-315-30651-3

ABSTRACT

The Production and Evaluation of
Self-Instructional Computer Courseware to Assist
the Teaching of the Written Alphabet

Nicholas Barker

The purpose of this Thesis-equivalent was to design a self-instructional tool for the elementary school classroom in order to teach the writing of the lowercase alphabet. Computer Assisted Learning (C.A.L.) was chosen as the medium of instruction because it can combine a "dynamic" presentation of the letters to the student and an instant feedback format. Interaction between the computer and the student was achieved through the use of a graphics tablet. Sixteen learning disabled children were tested over an eight week period for their ability to write the alphabet to criterion. For two of the weeks, the children were exposed to the computer courseware. It was found that there was a significant decrease in the number of errors between the pre and post-intervention periods. Despite possible threat to learning due to some aspects of the program design, it was concluded that this courseware was an appropriate and effective teaching tool in a normal classroom situation.

ACKNOWLEDGEMENTS

I would like to thank the following people for their assistance and advice during the completion of this thesis;

My advisor, Mariela Tovar,

Jocelyn Guevremont, Lucien Néron and Julian Daniels for their technical expertise,

Kenneth F. Cassidy (Principal), staff members and students of Terry Fox School, Pierrefonds, for their cooperation during the lengthy evaluation,

Louise Pinsonneault and Claire Néron for their work on the final manuscript,

Johanne Roy and Danielle Constantin for their consistent support, encouragement and constructive criticism,

Jesus Vazquez-Abad and Jonathan Marsh for sharing their knowledge of statistical packages.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

List of Tables

List of Figures

CHAPTER 1

The Problem

The specific skill that was chosen to be remediated via computer courseware was the writing of the lower case alphabet. Special Education teachers experience much frustration in the teaching of this skill to children with learning disabilities or a mental handicap. It requires constant repetition on the part of the student, which of course must be vigilantly monitored by the teacher to ensure that it is the correct letter formation that is being reinforced. If this monitoring process could be achieved through a student-paced and self-instructional format, the teacher would be able to use this time in more constructive ways with his or her students.

Apart from the designing of such courseware, the implementation of Computer Assisted Learning (CAL) in a classroom situation is an additional problem. Teacher acceptance of computers in the classroom does not reflect the enormous amount of research being conducted in the field of CAL. There seems to be three main reasons for this. First, the fierce competition between producers of both computers and software and the attendant problems of non-compatibility; second, teacher apprehension of not being able to manipulate the technology; and third, teacher scepticism that computer programs can really assist in the teaching process.

Recent research (Hedges, 1983; Morrissey, 1982) has pointed out that teachers have good reason to be apprehensive of computer technology and to be critical of its actual use in the classroom. Documentation for both hardware and software operation can often be baffling and discouraging. This leads to a frustration on the part of the user and, especially for the initiate, an angry rejection of the technology. Much of the current software has not lived up to its advertised effectiveness in normal classroom situations and often requires that the teacher be present with the user to read and interpret on-screen directions and to take decisions on the options presented.

This thesis will concern itself with the two problems outlined above: the remediation of handwriting skills using CAL and its practical and effective implementation as a tool in a normal classroom environment.

CHAPTER 2

Review of the Related Literature

Traditional Methods of Teaching Handwriting Skills

There has been much concern in recent years about a possible drop in literacy skills of school-children and about the teaching of these skills in the schools today. The teaching of handwriting has not escaped this criticism. For example, Peck (1980) emphasises that current teaching methods do not seem to be satisfactory considering the importance of these skills in our "literacy-conscious" society. Sassoon (1983) states that "poor handwriting is having a serious effect on the performance and sometimes the potential of children of all ages."

The most common instructional technique for this skill in recent years has been copying. Copying consists of presenting the student with a model, either on a blackboard or in a work-book, and the student copies the image onto a space on a sheet. This procedure is repeated until an acceptable copy of the model has been produced. A variation of this method is faded tracing. Here, the model is presented as a series of dots (or as a broken line) in a work-book. The student connects the dots thus forming the letter. This exercise is repeated on a rote basis. Gradually the dots are faded out and the student is drawing the letter in a blank space. Much research has been directed towards finding the more efficient of these two methods but results have been inconclusive (Peck, 1980).

A major problem connected with copying is that the student cannot receive consistent and immediate feedback for each copy of the model. Charles (1971) attempted to remediate this situation by the use of overlays. The student copies the model and then overlays the attempt with a correct representation of the letter. This introduces the element of feedback and also requires critical analysis on the part of the student. A definite increase in accurate letter formation was reported using this method.

However, even with this method, there still appeared to be little generalisation of handwriting strokes to unfamiliar letters. The letters were still being memorized as discrete "chunks" of information. Gibson (1972) notes that perceptual learning poses a greater problem than the actual motor skill and this is why letters similar in form are often the most difficult to learn. The letters "m" and "n" are examples of this.

Wright and Wright (1980) conducted a study in order to test the hypothesis that learning the different segments that make up the letters is more effective than memorising each letter. They predicted that if a model depicting motion could be developed for individual students, the sensory feedback would be an improvement over the use of the still (overlay) model previously described. They devised a "flip-book" so that the letters could be presented in an animated cartoon style. Thus the student viewed the development of the letter, segment by segment, as the book was rapidly flipped through. The student then put the book down and formed the letter on a sheet with the aid of a still model. This method reported significantly better results. However, correct manipulation of the flipbook was a constant problem and the element of immediate feedback was sacrificed.

Smith and Murphy (1963) studied another important aspect of handwriting that is often overlooked when discussing the learning processes involved. They demonstrated that handwriting is not solely mediated by visual feedback. Their subjects were blind-folded before being asked to write and the researchers concluded that letter formation and accuracy were hardly affected by this adverse condition. It appeared that handwriting concerns both visual and kinaesthetic processes.

It can be concluded from the above research that the following elements should be present when teaching this handwriting skill: copying, immediate and accurate feedback, critical analysis on the part of the student and a knowledge of the various segments that combine to create different letters.

Handwriting Skills and CAL

There has been some research conducted in the use of CAL for the teaching of handwriting skills. Lally (1981) designed a system utilising a monitor that was tilted at an appropriate writing angle and a light pen attached to a computer. His subjects wrote directly on the screen with the pen, following a box-shaped cursor. The cursor left a blinking trail which changed to an unbroken track when followed by the pen. If the subject strayed too far from the trail the blinking trail would stop until it was relocated by the pen.

This research combines the element of dot tracing with immediate and accurate feedback, supplied by the computer. The research indicated that tracing promotes accuracy in the patterns produced, but requires little active decision-making about shapes and stroke sequences.

Lally stated that the element of quick and accurate feedback was of crucial importance in the favourable results achieved using this model. To deliver this feedback is difficult in this situation as has been previously discussed and Lally's study appears to indicate that significant improvement can result from presenting the student with precise and detailed information yet without distracting from the task at hand.

The same instruction model was used by McCleod and Proctor (1979). This research concerned the remediation of signature-writing skills. Their strategy was to present a guideline on the monitor screen (with a blinking dot to indicate where the subject should start). As the guideline was successfully tracked it turned into a solid line behind the light pen. The model of the correct signature was presented to the student segment by segment, thus "each stroke indicated its own dynamic pattern as it was about to be drawn by the subject." Here, a new element, movement, comes into play. Not only is the model being revealed to the student segment by segment but also the segments are presented as dynamically formed entities.

The researchers noted that the addition of this element of movement appeared to enforce stroke sequences and direction as well as supplying the visual feedback. It confirmed to them that handwriting skills should be taught with the emphasis on the dynamic process involved rather than on the product, the finished letter. It was also noted that handwriting skills learned this way generalised to a pen and paper situation.

The research discussed in this chapter indicates that the computer-based model for handwriting instruction can supply consistent and immediate feedback and also provide the student with an exact, dynamically-formed model from which to copy.

Learning Disability as Related to Handwriting Skills.

Children with specific learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written languages (Bartel and Hammill, 1975). Generally, they possess normal intelligence and suffer from no physical or sensory handicap. It is argued that learning-disabled children have an intellectual potential that is normal or better than normal, but because of these specific disorders, they function at a lower level than expected. The possible causes of these disabilities can be neurological disorders (possibly triggered by prenatal problems or mild brain damage at birth) or side-effects from drugs, infections or food additives.

According to Levy (1978), some of the common characteristics (relevant to this thesis) displayed by learning-disabled children are; sloppy writing, letter reversals, mirror writing, short attention span and spelling problems. It must be emphasised that it is children who exhibit a constellation of these symptoms over a period of time who are considered learning disabled, since most children show some of them at different stages of their development.

The education of learning-disabled children is neither quick nor easy. No specific learning program has been successful in all cases. Individual attention and hard work on the part of the student usually result in improvement, yet progress can be agonisingly slow. The literature indicates that adapting materials so as to accomodate special educational needs can result in increased learning. Lauzon (1981) adapted a computer keyboard so that large, coloured letters were displayed to mentally handicapped children and found a significant increase in the learning of sight vocabulary. Special educational measures are applied either in a special class or in a free-flow structure depending on the extent of the difficulties.

The writing of the lowercase alphabet is usually taught in Grades 1 and 2. Prior to this, the emphasis would have been on letter recognition and the writing of the capital letters. It is generally agreed among teachers that the learning of the lowercase alphabet presents two major problems to children with recognised learning disabilities: (a) many letters differ, often quite radically, from the previously learnt capitals, (b) many of the letters are very similar in form, such as "d" and "b", "p" and "q." This phenomenom is a natural consequence of a rapidly written alphabet.

If children begin to struggle with this transition from capitals to lowercase, it could indicate the presence of a learning disability, especially if the difficulty persists into a second year. The problem can be further compounded by the fact that remedial instruction requires a high level of individual assistance which is not always forthcoming. The CAL courseware in this thesis was designed to ease this transition stage. The learning problems of learning-disabled children have been approached from the viewpoint of increasing the involvement of the student in the learning process through a multisensory feedback system embedded in a self-instructional format.

CHAPTER 3

Courseware Design

Objectives

The concept of writing alphabet letters can be defined as an educational, psycho-motor skill "initially processed by perceptual-cognitive functions and carried out through the psycho-motor system as an instrumental behavior, conveying a graphic record as the product of that behavior" (Sovik, 1975).

The educational problem addressed by this thesis is the writing of the lowercase alphabet by means of a self-instructional and user-friendly courseware. This courseware must be able to function as part of a normal elementary classroom routine.

The first requirement in the design of this courseware was to create a program whereby the computer would be able to receive graphic information from the student, compare this information with a model stored in the memory, and then transmit the result of this comparison back to the student for critical analysis. This process would be repeated until the student attempt matched the model. It was predicted that such a program would not only be an effective monitor for the learning of this skill but would also significantly increase the rate of learning. It was also predicted that the new level of learning achieved through using the courseware would be sustained after the program was removed from the teaching situation.

It was then required that the program be adaptable to a normal classroom situation. To achieve this, the following conditions had to be met: (a) the program had to require the minimum of computer experience to operate by both teacher and student, (b) the program had to be truly self-instructional, i.e. it would require no teacher supervision once the student was familiar with it, and (c) the program had to be of proven educational value.

Audience

The potential users of this courseware would be anyone who needs to know how to write the lowercase alphabet. Apart from its use as a remedial tool in the elementary classroom, other potential users are mentally handicapped children and adults, and any young children who are forced by circumstances such as illness to learn in isolation. Courseware such as this could be used in adult literacy classes as well as with immigrants from different alphabetic cultures, such as Arabic.

Description of the CAL Courseware

The hardware used in designing and running this courseware was an Apple 11 computer and a graphics tablet peripheral called a PowerPad (Appendix D). This tablet has recently been put on the market by Chalk Board, based in Atlanta. It does not require a special pen to communicate with the computer, any stylus-like instrument will suffice.

The software that was created for this courseware has two parts. First, there is the "bank" of alphabet letters that are brought to the screen, segment by segment, on the prompting of the student. Second, there is the communication between the computer and the tablet.

All programming was done in BASIC, using high-resolution graphics to create the letters (Appendix C).

The user wrote on pre-programmed sheets, depending on which letters were practised. The sheet of paper was secured on the tablet by way of two small clips. These positioned the paper exactly so that the user's attempt would superimpose over the model in the computer's memory. The flashing dots which appeared on the screen to indicate the beginning of a letter segment coincided with coloured dots on the sheets. The pressure of the user's pencil on the sheet transmitted the attempt to the computer's memory via the PowerPad (Appendix B).

The courseware was designed in such a way that no computer experience was needed to operate it. The user needed only to identify the letters of the alphabet and the spacebar on the Apple keyboard to be able to interact fully with the program. There were no codes or passwords to be remembered or typed in. The pacing of the program was controlled by the user throughout.

Instructional Strategy

The design of the courseware attempted to incorporate the major elements identified by the literature as important for the successful learning of handwriting skills. These are: copying, critical analysis, immediate and accurate feedback and presenting the student with dynamically-formed segments of the letter to copy. Unfortunately, these elements have not yet been combined into one instructional technique. A microcomputer along with a graphics tablet allowed the combination of these elements into the instructional strategy for the courseware.

The sequence of events that takes place when a student interacts with the program is illustrated in the Instructional Strategy Chart (figure 1). Steps three and six require decisions concerning the replication of the prompted letter segment. Step eight requires fast and accurate

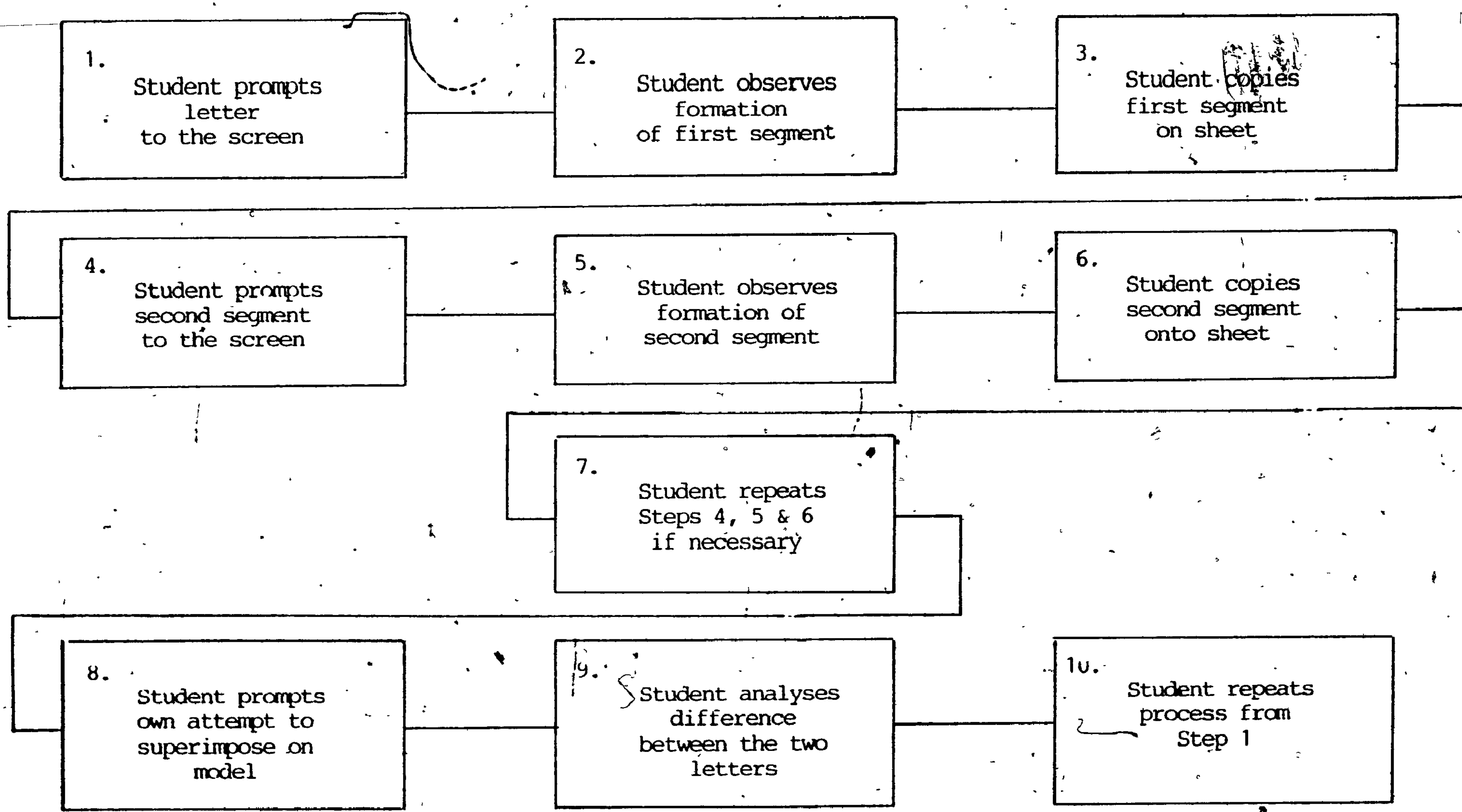

Figure 1. Courseware Instructional Design Chart

feedback from the computer. Finally, step nine requires critical analysis of the superimposed attempt on the model. The student has to discover where the discrepancies are and how to correct them.

The student/program interaction that activates each step on the Instructional Strategy Chart is as follows (a) the student presses the key of the letter that is to be practised, (b) a flashing dot indicates where the segment starts forming on a grid-like background of four horizontal lines, (c) the first segment is created dynamically on the screen. It is drawn slowly, as if drawn by an invisible hand, (d) the student copies this segment on the sheet (on which is drawn the same grid pattern as on the screen) resting on the tablet, (e) when the spacebar is pressed again, the flashing dot indicates where the next segment is going to start, (f) prompted by the student, the next segment appears on the screen and is copied as before on the sheet, (g) prompted by the student, the student attempt is superimposed over the model on the screen and the two letters are examined for discrepancies, (h) by pressing the key of the letter the process starts again.

The element of feedback has been described as the most important. A feedback system was defined as "a kind of reciprocal interaction between two or more events, in which one activity generates a secondary action which in turn redirects the primary actions" (Smith and Smith, 1966). The feedback system comprises of three events which have been built into the instructional design in the following manner; (a) movement generating the system towards a defined path (steps two and three), (b) comparing the responses of this activity with the true path and finding deviations (steps eight and nine), and (c) using the deviation signal for further attempts (steps ten and one).

While designing the strategy described above, several decisions had to be made concerning the most effective way for students to interact successfully with the program. It was decided to create the model letters thicker than the superimposed student attempt. Thus the student did not have to reproduce an exact replica of the model (a difficult enough task even without the added distortion of the monitor). The thicker model letters meant that any attempt which lay within the parameters of the model could be considered as having achieved criterion.

It was considered necessary to indicate the starting point of each segment by a flashing curser as the primary users of the courseware were young children. This flashing curser facilitated the process of viewing each segment as a discrete chunk of information with its own starting and finishing points.

At Step three in the strategy, the student is attempting to replicate the model letter on the paper. It was decided not to have this attempt appear on the screen as it was being formed. Although this might have given immediate feedback to the student as he or she was in the process of creating the letter, as noted by McCleod and Proctor (1979), the actual superimposition process could prove to be distracting. The student would tend to watch the screen rather than concentrating on the physical process of creating the letter on the sheet.

Programming restraints dictated that the student attempt could not superimpose dynamically over the model; an action which would have reinforced further the awareness of the seperate segments in each letter.

Rationale for Using C.A.L.

It was stated in the Instructional Strategy that the elements thought necessary to teach handwriting skills could only be combined using a computer and a graphics tablet. Of these, immediate and accurate feedback is considered the most crucial. There is no other teaching tool generally available that can organize and present this graphic information so accurately as a computer.

Research indicates that children are intrigued with computer technology and enjoy interacting with CAL courseware. Lally and McCleod (1982) have put forward five principles that underly "high-quality interaction" when using a computer in a remedial setting. These are (a) student attention on the task as a whole and on those aspects relevant at each stage, (b) procedures which exercise fine control over the learning process, (c) feedback, both at critical moments and for the overall performance, (d) challenging and enjoyable activities, and (e) reinforcement of success. These principles have been applied to the design of this courseware.

Motivation is an important part of remedial instruction and these aspects of computer-based instruction can help to maintain concentration and motivation. The radically different appearance of CAL from more traditional tools (together with the semi-mystical powers attributed to computers) could give the student an enhanced expectation of success. The self-instructional aspect of effective CAL can be another boost to motivation and self-image. The student-pacing and self-evaluation that are inherent in successful self-instructional courseware can diminish the fear of error, relax the pupil and encourage a more active and critical way of approaching problems.

CHAPTER 4

Method

One to One Evaluation

A formative evaluation was conducted with three, diagnosed learning disabled children. A pre-test was administered whereby the children copied all the letters of the alphabet from a blackboard onto a paper. The number of unrecognizable letters as well as the number of recognizable letters that were not formed to criterion were noted. The children then practised six of these letters using the CAL courseware. Observation of the children, together with the results of discussions with them, were used to assess the ease of use of the instrument. The viability of the self-instructional format was also assessed. Overall comprehension of the goals of the courseware, and the childrens' reaction to it, were used to assess if the instrument was appropriately designed for children of this age and educational level. At the end of the treatment period, a post-test was administered which was exactly the same as the pre-test and the results were compared.

Main Evaluation Questions

The evaluation of the courseware examined the following questions:

Will the use of this courseware in the course of a normal learning routine significantly increase the number of letters written to criterion by learning disabled children?

Will any significant improvememt be sustained over a post-intervention period of three weeks?

Is the courseware an appropriate teaching tool for the remediation of handwriting in a classroom environment? That is to say, is the courseware truly self-instructional?

Sample

The sixteen children involved in this evaluation were chosen from Grades One and Two of the Regular programme in Terry Fox School in Pierrefonds. All the children had been diagnosed as Moderately Learning Disabled (MLD) according to the criteria of the Department of Education (1981). The process of diagnosis is standard throughout the School Board. If a teacher suspects that a child is in need of special help, the child is referred to the Special Education teacher. The child is tested using two instruments, the Slingerland Perceptual Tests and the School Board Manual of Minimum Objectives. The results of this procedure indicate whether the child is at Grade level in respect to eye-hand coordination, fine motor ability, manual dexterity, etc. If the child is found to be two years behind in any of these respects, yet appears to be able to function in a normal classroom situation, then he or she is diagnosed as MLD and attends a number of remedial small-group sessions with the free flow teacher.

All subjects were unable to form ten or more letters of the alphabet to criterion. This criterion was decided by the evaluator and two other teachers. In the case of borderline cases, a majority decision was agreed on.

Eleven of the subjects were from Grade Two and five were from Grade One. The Grade Two subjects were randomly assigned to two groups and then the Grade One subjects were similarly assigned to the two groups. The groups were balanced so that they contained eight subjects each.

Evaluation Design

The design chosen for this evaluation was an adaptation of the multiple time-series design as described by Campbell and Stanley (1963). This design is illustrated in Figure 2. Educational processes can often be considered as trends of gradual learning. It is important, when intervening in such a process, to demonstrate that any significant increase in learning is due to the intervention and is not merely a product of the continuation of the process.

```
O O O O X O O O O
-------------------
O O O O   O O O O
```

Figure 2 Multiple Time-Series Design (Campbell and Stanley)

	1	2	3	4	5	6	7	8	9	10
R	O	O	O	O X	O X	O	O	O		
R			O	O	O	O X	O X	O	O	O

Figure 3 Main Evaluation Design (Staggered Time-Series)

Ideally, the intervention of this courseware should be viewed as significantly accelerating this trend. Thus a time series design is the most efficient way to establish the existence of a true effect by observing the stability of the base-line of pre-intervention learning (the pre-tests) and the stability and strength of the post-intervention learning (the post-tests). The stability of any increase in learning is an important factor. If the test scores increase immediately after the intervention, yet the effect weakens over the complete post-testing period, it would indicate that the increase is due largely to the novelty of the situation (i.e. the presence of computer courseware). To indicate that true learning has taken place, the data would have to indicate long-term stability after the removal of the intervention.

The main evaluation design (figure 3) was a staggered time-series format. Two groups of eight subjects each were pre-tested, given the intervention, and then post-tested. This took place over an eight-week period for both groups. However, Group B were administered the first pre-test as Group A were experiencing the first intervention session. Thus the time-span for the complete evaluation was ten weeks. The advantage of this design was that the two groups could act as control for each other at two critical points, and so keeping the time variable constant.

Terrel and Lynyard (1982) used a similar design when evaluating the SpeakSpell spelling aid. They noted that a particular advantage of such a design is that it is simple and flexible enough to be adapted to the organizational patterns of a school with the minimum of disruption. A design of this kind can be imposed on a normal classroom routine without disturbing the working atmosphere to a possibly significant degree.

From the design described above, two mixed factorial designs were tested. "The mixed factorial is the design of choice when a researcher is studying learning and the processes that influence the speed with which learning takes place." (Keppel, 1980). In both, two independent treatment conditions were present, treatment and testing. The former had two levels (intervention and no intervention), and the latter had two levels (test position). Two comparisons were made using these designs.

1. The results of Group A over the intervention period were compared to the results of Group B over the pre-testing period (figure 4).

	Tests		
	3	4	5
Group A	O	O X	O X
Group B	O	O	O

Figure 4 Evaluation Design for Comparison 1

	Tests		
	3	6	7
Group A	O	O	O
Group B	O	O X	O X

Figure 5 Evaluation Design for Comparison 2

2. Similarly, the results from the intervention period of Group B were compared to the results from Group A over the post-testing period (figure 5).

For comparisons One and Two, the third pre-test for both groups was used as a covariate. This was used to account for individual differences in handwriting ability before the courseware was introduced.

A third comparison was made between the combined pre-tests of both groups and the combined post-tests of both groups. The results of the two groups were collapsed over an eight-week period (figure 6).

Instrumentation and Data to be Gathered.

Each letter of the alphabet was tested and the procedure was consistent throughout. All subjects were tested for their ability to write the letters to criterion. The subjects were tested as a group following a standard procedure and using a standard instrument, a lined sheet of paper (Appendix A). The letter "a" was written on the blackboard and the subjects' were asked to copy it onto their sheets. After a 15-second interval the procedure was repeated for the letter "b", and subsequently for the rest of the alphabet.

Tests

1	2	3	4	5	6	7	8

O O O O X O X O O O

Figure 6 Evaluation Design for Comparison 3 (Collapsed Data)

The sheets were then collected and marked according to the criterion agreed on. The raw data thus comprised of the number of errors in letter formation (out of a total of 26) for each of the subjects over the eight tests.

When the subjects' were experiencing the intervention, they were informally monitored by the evaluator. This data comprised not only the evaluator's observations but also subjects' comments, questions and reactions to the courseware in general as well as to specific components of it (e.g. the self-instructional format). It was considered that this informal data could not only augment the results of the statistical analysis, but also provide information concerning the interaction between CAL courseware and elementary teachers and children.

Procedure

One day before the intervention of the courseware, the subjects participated in a familiarisation session with the computer and the graphics tablet. This was intended to minimize any confusion concerning the manipulation of the courseware during the intervention period, and also to alert the subjects to such practical considerations as not pressing down on the tablet with the free hand.

The evaluation took place in Terry Fox School, Pierrefonds. The classroom used was that of the Grade Two Regular class, comprising 25 students.

A time for the weekly testing was arranged with the classroom teacher. This was when the class attended a regular lesson in the gym and so leaving the room empty. For two weeks Group A followed the testing procedure previously described. At the third test, Group B joined in for the first time. At the fourth, fifth, sixth, seventh and eighth tests both groups were tested together. For tests nine and ten, only Group B was tested.

The intervention of the courseware consisted of ten daily sessions for each subject over a two-week period. Group A worked with the program during weeks four and five and Group B during weeks six and seven. A table was set up in the corner of the room to support the hardware and facing away from the class. A schedule was drawn up so that the subjects could spent 20 minutes a day working with the program without disturbing the rest of the class.

All the Grade Two subjects were members of this class and the Grade One subjects entered the room just for their turn at the computer. Initially, the appearance of the hardware caused some disturbance in the class. This was compounded by the news that only certain class members were to use it. It was arranged that the rest of the class would get some time at the computer on the completion of the evaluation.

For the first two days, the evaluator stayed with each subject at the computer, explaining the program and observing reactions. The explanation followed the same pattern for each subject; first it was stressed that the computer could make any letter the subject wished and make it perfectly each time. After the subjects had experimented with this, it was then explained that the subjects themselves could make letters just as well as the computer and that the computer would help them in this process. The graphics tablet was then reintroduced together with the programmed sheets and the sequence of interactions was explained. Then the subjects operated the program alone, with the evaluator observing, answering questions and clarifying certain concepts when it appeared necessary.

After these two sessions, the evaluator withdrew from the computer and observed from a distance. At the start of each session, the subject would ask the teacher which letters were to be practised, something the teacher and evaluator had arranged in advance. A limit of five letters per session was set. At the end of each session the subjects showed the sheets to the teacher for review and comments.

Data Analysis

The data obtained from the overall ten tests were subject to the following analysis:

1. The means of the scores for Group A and B for the first comparison (for tests four and five, Table 2) were subject to an analysis of covariance for repeated measures. The mean scores for week three acted as the covariate. The results were examined for any significant differences between the two groups.

2. The means of the scores for Group A and Group B for the second comparison (for tests six and seven, Table 3) were also subject to an analysis of covariance for repeated measures. The mean scores for test three acted as the covariate. The results were examined for any significant differences.

3. A one-way analysis of variance for repeated measures was performed on the collapsed group data (comparison three, Table 5). This was to test for significant differences between the eight test means.

4. A post hoc analysis, Tukey's comparison of pairs of means, was performed on the collapsed data to indicate any significant differences between test means.

CHAPTER 5

Results and Discussion

One to One Evaluation

As a result of the one to one evaluation, some potential threats to learning were discovered due to hardware limitations and software design. Due to the nature of the graphics tablet, the whole writing surface was "sensitive" to the touch. Thus if a student touched the surface with the free hand or any part of the writing hand besides the pencil point, this pressure would appear on the screen along with the actual letter formation. Attempts to mask off the unused portion of the surface via a platform for the wrist of the writing hand proved unreliable and too awkward to manipulate. The children were instructed, prior to the introduction of the courseware, to form the letters with just the pencil point touching the surface. This is not a natural writing position and thus posed a potential threat to learning. The students appeared to adapt quickly to this style of writing, especially when the reason for it was clearly demonstrated. The post-test results indicated that transfer of learning to a normal pen and paper situation took place.

During the design of the courseware, it was decided that the model letters had to be between 1" and 2.5" high on the screen to maximize the visual effect of the dynamically created letter segments. However, anything that is drawn on the tablet appears smaller in scale when it is transferred to the screen. If the student attempt was to superimpose exactly over the model letter, it meant that the student had to create letters almost twice the size as the model on the screen. The letters created by the student would have to be between 2.5" and 5" high. This scale of writing was expected to increase the subjects' awareness of the psycho-motor actions that are involved in the formation of each letter, an important aspect of handwriting skills as previously discussed in Chapter Two. However, it did not conform to the fine motor actions used in writing during normal classroom activity or in the testing sessions. The parameters for correct letter formation in the testing situations were between 3/4" and 1.5" (Appendix A). The post-test results indicated this size difference between the intervention and the testing situations did not deter learning.

Another design problem was that the student attempt as written on the sheet did not translate exactly when transferred to the screen. This was due to both a limitation of the graphics tablet in recording exact curvatures and the pixel by pixel reproduction of the monitor. Although the subjects noted these discrepancies (such as slightly flattened curves) they did not appear to detract from critical analysis of the attempt and the model.

The following conclusions were made following the one to one evaluation:

1. The self-instructional format was comprehensible to children of this age after careful explanation and after allowing the children to experiment with the graphics tablet outside of the program.

2. The size and width of the model letters were appropriate.

3. The dynamic letter formation intrigued and delighted the children and prompted an immediate impulse to copy.

4. The comparison between the pre and post-tests indicated learning had taken place.

5. All the children expressed satisfaction using the courseware and indicated a willingness to continue.

Main Evaluation

The means and standard deviations for the number of errors recorded are shown in Table 1. The analysis of variance for the group means of the first comparison (weeks four and five) indicated a significant interaction between the treatment and testing variables ($F_{1,12} = 7.17$, $p = .0201$,

Table 2). This would indicate that the mean number of errors in letter formation for Group A decreased significantly on the introduction of the courseware compared to the Group B results, which indicated a slow decrease in errors over the same period. The Tukey procedure for the comparison of means performed on the data confirmed the above; there was a significant difference between tests four and five for Group A, but not between tests four and five for Group B (Table 4). The Tukey also revealed significant differences between Groups A and B over both tests, thus confirming a significant decrease in errors for Group A during the intervention.

The analysis of variance for the group means of the second comparison (weeks six and seven) indicated a non-significant interaction between the treatment and testing variables. Furthermore, the effects of the two variables were also non-significant (Table 3). The analysis revealed that neither group performed significantly better than the other over the treatment and testing variables. The treatment had the effect of eliminating any differences between the two groups over the testing period. So it can be claimed that the scores of Group B, during the intervention, were maintained over the time of the Group A post-tests.

The mean differences for comparisons one and two are expressed graphically in Figure 7.

The means and standard deviations for the number of errors recorded in the third comparison (the collapsed data) are shown in Table 5. The analysis of variance indicated a significant difference between the means of the test positions ($F_{7,91} = 43.80$, $p = .0000$, Table 6). The Tukey procedure performed on the data revealed a significant difference between weeks three and four. Week four marked the introduction of the courseware. This procedure also indicated no significant differences between the scores of the three pre-tests (the baseline data) and no significant differences between the three post-tests (Table 7). This information is expressed graphically in Figure 8.

Learning Outcomes

The statistical analysis of the data described in the previous section indicates that the intervention of this courseware did increase the number of letters learnt to criterion by the students.

The baseline data for both Groups A and B indicate that the learning of this handwriting skill without using the courseware was progressing at a gradual but statistically

Table 1

Means and Standard Deviations
for the Number of Errors in Letter Formation: Groups A and B

	Tests									
	1	2	3	4	5	6	7	8	9	10
	Means									
Group A	14.85	14.28	14.14	10.42	7.85	7.71	8.42	8.2		
Group B			13.43	12.71	12.2	8.0	7.28	7.14	7.0	7.4
	Standard Deviations									
Group A	3.98	4.68	4.30	4.35	5.05	5.85	5.41	5.45		
Group B			1.81	2.14	1.95	1.91	2.56	2.64	2.67	2.61

Table 2

Analysis of Variance
Comparison 1

Source	SS	df	MS	F	p
Covariate	199.31	1	199.31	20.73	.0008
Treatment	105.56	1	105.56	10.97	.0069
Error	105.83	11	9.62		
Testing	17.28	1	17.28	17.71	.0012
Treat x Test	7.00	1	7.00	7.17	.0201
Error	11.71	12	.98		

Table 3

Analysis of Variance
Comparison 2

Source	SS	df	MS	F	p
Covariate	252.9	1	252.9	16.74	.0018
Treatment	0.52	1	0.52	0.03	.8562
Error	166.23	11	15.11		
Testing	0.00	1	0.00	0.00	1.0000
Treat x Test	3.57	1	3.57	1.83	.2012
Error	23.43	12	1.95		

Table 4

Comparison 1

Ordered Sums Matrix for the Tukey
Comparison of Pairs of Means
(Critical Range 11)

		A5	A4	B5	B4
		55.2	73.0	84.9	88.9
A5	55.2	_	17.9	29.9	33.95
A4	73.0	_	_	11.9	15.9
B5	84.9	_	_	_	3.9
B4	88.9	_	_	_	_

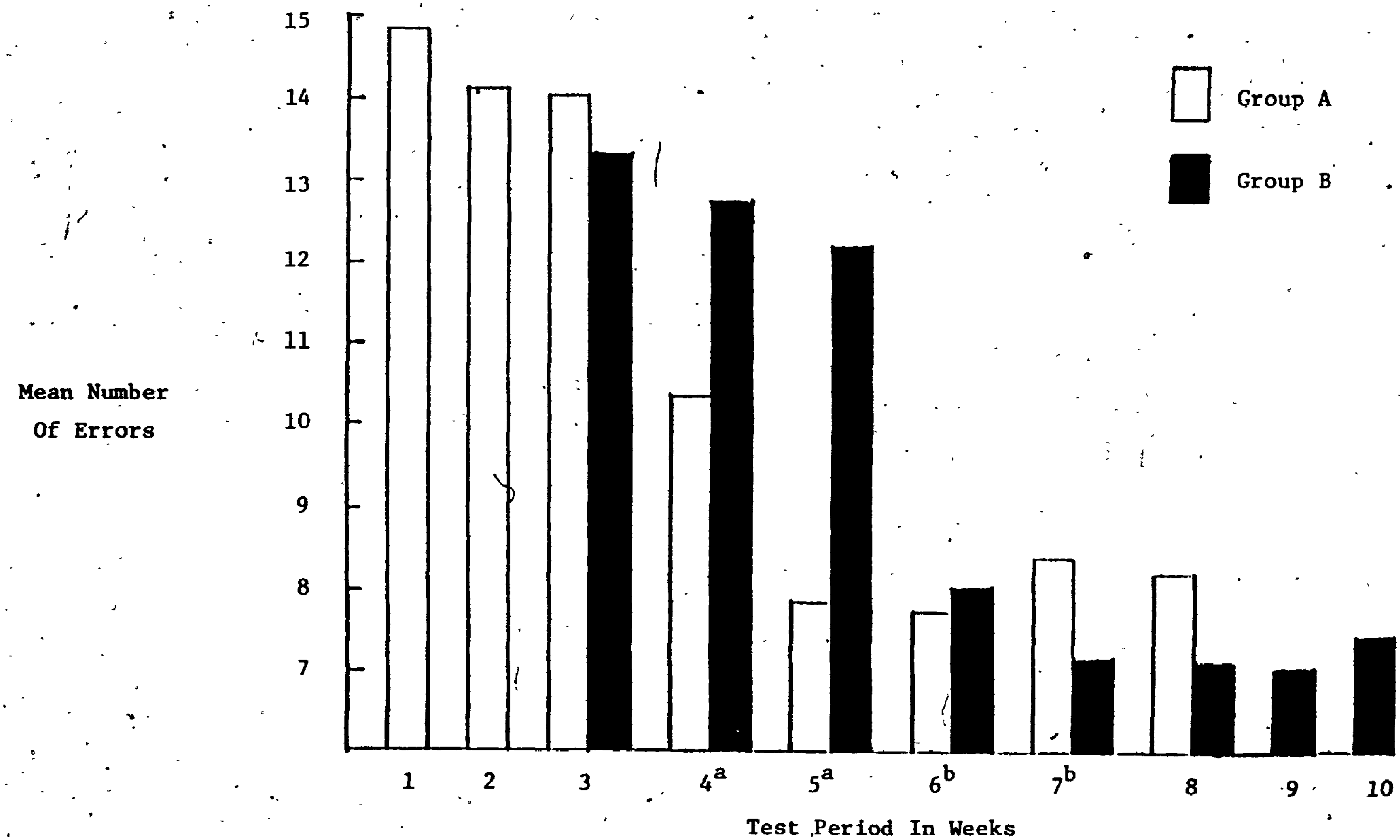

Figure 7. Number of Errors in Letter Formation for Groups A and B

[a] Indicates the introduction of the courseware for Group A.

[b] Indicates the introduction of the courseware for Group B.

Table 5

Cell Means and Standard Deviations
for Number of Errors in Letter Formation: Comparison 3

Tests							
1	2	3	4	5	6	7	8
Cell Means							
14.1	13.5	13.14	9.21	7.57	7.42	7.71	7.21
Standard Deviations							
3.25	3.61	3.37	3.46	3.85	4.43	4.23	4.44

Table 6

Analysis of Variance
Comparison 3

Source	SS	df	MS	F	p
Groups A&B (collapsed)	915.68	7	130.80	43.8	.0000
Error	271.74	91	2.99		

Table 7

Comparison 3

Ordered Sums Matrix for the Tukey Comparison of Pairs of Means (Critical Range 28.6)

		T8	T6	T5	T7	T4	T3	T2	T1
		100.9	104	106	107.9	128.9	184	189	189
T8	100.9	–	3.1	5.1	7	28	83.1	88.1	97.1
T6	104	–	–	2	3.9	24.9	80	85	94
T5	106	–	–	–	1.9	22.9	78	83	92
T7	107.9	–	–	–	–	21	72.1	81.1	90.1
T4	128.9	–	–	–	–	–	55.1	70.1	81.1
T3	184	–	–	–	–	–	–	5	14
T2	189	–	–	–	–	–	–	–	9
T1	189	–	–	–	–	–	–	–	–

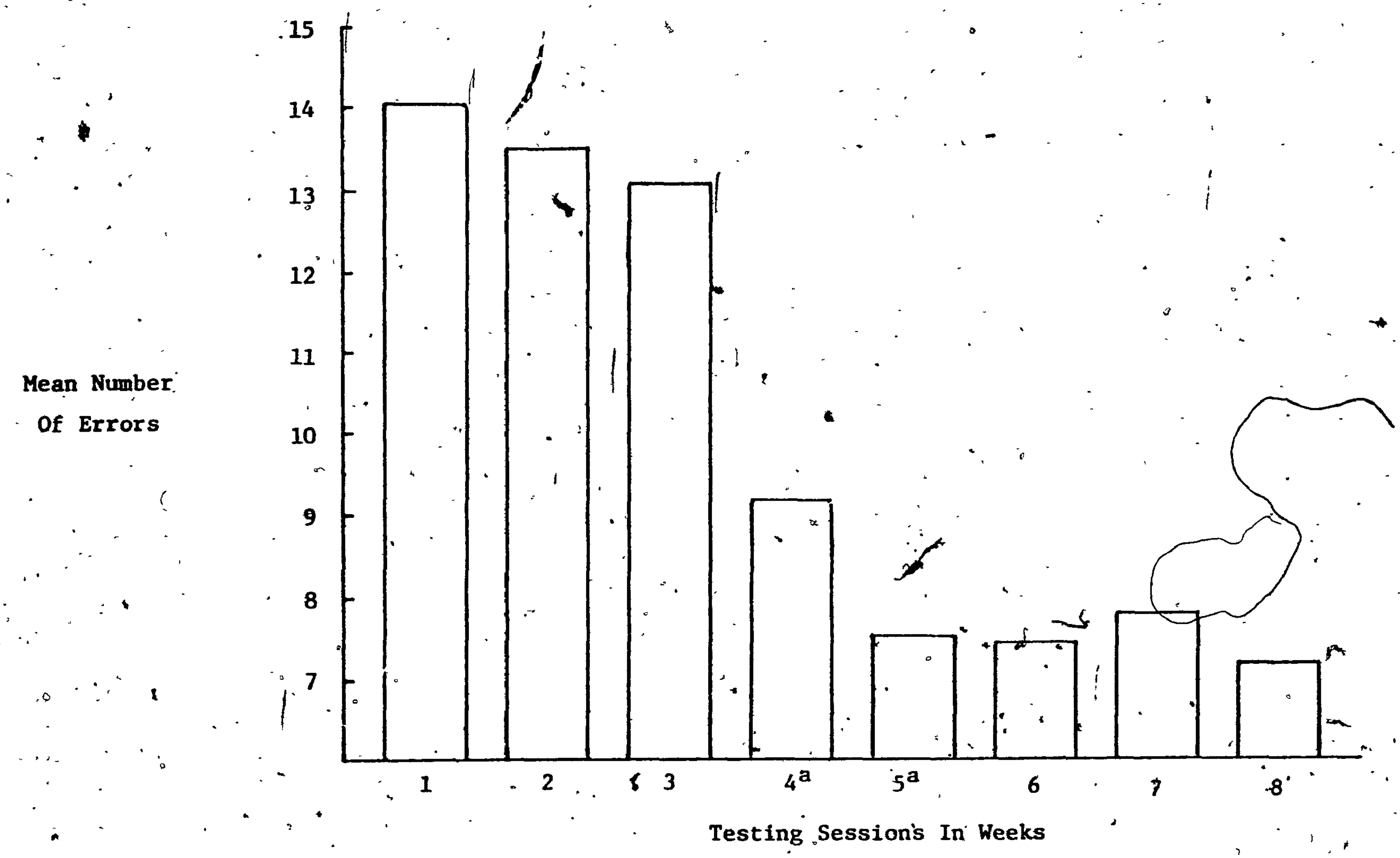

Figure 8. Number of Errors in Letter Formation: Data Collapsed Over 8 Weeks

a Indicates the introduction of the courseware.

insignificant rate. Analysis of both the first and third comparisons indicate that a significant increase in learning took place when the courseware was introduced.

The Tukey procedure indicated that there was no significant decrease in learning over the post-test period. When the courseware was withdrawn and the normal learning routine reestablished, the level of learning achieved by using the courseware was sustained. This demonstrated that true learning did take place and that the increase was not due solely to the introduction of a new and exciting medium of instruction. It could be argued that this level of error-free learning could be eventually reached even if the courseware did not intervene, only that the process would take longer. A further long-term study using a traditional control group design would test this hypothesis. Regardless of the results of such a study, the early intervention of the courseware can be justified in two ways. Firstly, this accelerated learning can only increase the motivation and self-confidence of students already struggling with learning disabilities. Secondly, this learning comes about in a self-instructional format, thus relieving the teacher of a time-consuming and repetitive task.

Another interesting follow-up study would be to continue to use the courseware as described in this thesis until criterion for all 26 letters was reached or until a ceiling for this handwriting skill was reached.

The Self-Instructional Format

The self-instructional format was a critically important aspect of this evaluation for the following reasons. Firstly, previous research indicates that enhanced learning takes place when the learner has some degree of control over the learning process. Secondly, a major objective of this evaluation was to create a teaching tool that would ease some of the teacher's burden of individual instruction in the classroom. Thirdly, according to the literature, self-instruction is one of the advantages that CAL holds over the traditional methods of instruction.

In the case of this evaluation, the self-instructional format demanded more than merely moving the program along by pressing the spacebar.The students used the courseware in a truly self-instructional manner only after they had grasped the relationship between what happened on the screen and what they had created on their sheet. Once this was established, critical analysis of what had occured took place automatically. Any discrepancies in letter formation were pin-pointed and the desire to self-correct was expressed, and the process was repeated.

Two days after the introduction of the courseware, five children (all from Grade One) were still demonstrating difficulty in using the self-instructional format. With these children, the relationship between the superimposed attempt on the screen and the letter formed on the sheet was stressed. After four days, only two children were still experiencing difficulty. These children tended to be passive in front of the computer and made the least improvement in the testing situations. The Grade One teacher singled out these students as probably displaying serious learning and concentration problems. The fact that almost all of the Grade One students experienced some initial difficulty and the Grade Two students did not in manipulating the program perhaps indicates that a certain level of maturity is required to comprehend this interactive process. Equally, the problem could be attributed to a lack of confidence among children in the few months of their first full school year. The program itself could be improved to include more visual or musical cues to prompt the student when specific input is required.

The self-instructional aspect of the program appeared to aid the concentration level of the students during the self-correcting process. Generally, small-step corrections were made to a letter not formed to criterion, but because of the ease and speed of the feedback process, criterion could be quickly reached by many such small steps once the self-instructional aspect had been mastered. This constant repetition and correction not only allowed the student to discover the dynamic process of letter formation but also allowed for drill-and-practise of the skill which was self-directed and self-paced.

Being able to manipulate the courseware alone seemed to instill the confidence to demand more control over the situation. The evaluation had been designed so that the student had to install a fresh sheet of paper on the tablet for each correction attempt. However, many students asked to keep the sheet with the original error for their subsequent attempts, so as to better gauge the small-step corrections. Only when they had reached criterion were they willing to transfer to a fresh sheet. This transition was then undertaken with a sense of expectancy and confidence, an indication that the student now understood how to create an improved letter. Remarks such as "I know how to do it now" and "This time it's going to be easy" often accompanied the transition to a fresh sheet. The number of corrections generally decreased with each fresh sheet, although the rate of decrease varied from child to child.

Dynamic Letter Formation

The model letters stored in the program's memory were made up of one or more of 17 segments. For example, the letter -d- was created by combining the segments -l- and -c-. As the intervention progressed, the students began to comment on these individual segments and the letters they formed. They demonstrated their grasp of the segments concept while watching the segments form the letters. Common remarks were "Oh yes, this bit is the same as in the -a-" (for example) and "That tail is the same as in the -j-" and "If the computer stopped right here it would make an -r-" (as when forming an -a-). Thus the courseware assisted the student in gaining a dynamic, intellectual concept of letter formation as opposed to a mechanistic, rote-learnt concept.

Reversals

The learning disability known as reversals occurs quite frequently with learning disabled children. This disability manifests itself as mirror-image letter formation. For example, the placing of the rounded segment of the letters

-d- and -b- are often confused, or the letter -a- is written as - -. The exact cause of this disability is not known and has proven very difficult to remediate. Of the 14 subjects who took part in this evaluation, seven reversed between three and six letters in the pre-testing situation. An analysis of the post-test results showed only a slight improvement in these letters, although improvement in letters not usually subject to reversal (such as the -m-) was significant in five of the cases. All the subjects consistently corrected their reversals when faced with the graphic feedback on the screen, yet this learning did not appear to carry over to the pen and paper situation.

Motivation

The research seems to indicate (Lally, 1982) that CAL courseware can encourage and sustain student motivation. In the case of special education, lack of motivation is cited as a major stumbling block to learning (Levy, 1973). The level of interest of the children who participated in this evaluation was high. After the first week of using the courseware, the children were asked if they liked working with the program. Besides four subjects, who expressed indifference to the program, all the children were positive and enthusiastic. Many were concerned, when changes in the schedule had to be made, that they would miss a turn. Once they began to manipulate the program alone and the self-correction process began to yield positive results, the confidence level began to rise. The number of letters practised at each session increased until the limit of five was reached. At this point, the students were given the choice of either leaving the program or practising the same letters again. Most preferred the former choice. They were quickly at ease with the program, often displaying such relaxed behavior as pressing the keys with the blunt end of the pencil and talking to the screen.

The courseware was designed to achieve positive results over a short period of time, as this can be a frustrating and exacting skill for these children to learn. The attitude towards discrepancies signalled that this success came early. Initially, discrepancies in letter formation as revealed by the superimposed feedback were viewed as errors. A common response to the feedback was "Oh, I got it wrong there." However, as the self-correctional process began to accelerate, these "errors" were seen more as stepping stones to reach the perfect letter, and the feedback then drew such responses as "It needs a bit more this way" and "It's got to be rounder here."

These manifestations of confidence and motivation can be attributed partly to the ability of the courseware to deliver non-judgemental feedback. The program channelled a student's ability towards a goal and then allowed him or her endless attempts to reach it, all the while demonstrating clearly where corrections should be made.

The Program as a Teaching Tool

One of the objectives of this evaluation was to create a teaching tool that could work efficiently in a non-computer oriented classroom. The courseware had to assist rather than complicate the role of the teacher. The evaluation design dictated who used the courseware and for how long, but the teacher had to decide which letters were to be practised and to continue with the normal routine of the class while each subject took their turn at the computer. This teacher had never experienced a computer in the classroom before. After some initial confusion, the teacher and the evaluation subjects were soon into a smooth running of the schedule. Over the four weeks that the courseware was in operation, the initial skepticism of the teacher was replaced by enthusiasm as the students' acceptance of the program proved lasting and positive educational results began to appear.

On several occasions the teacher spontaneously used the program when working with a student outside of the evaluation to demonstrate a specific point of letter formation.

During the four-week period that the computer was in the classroom, two other teachers expressed an interest in the courseware for some of their own students. Unfortunately, the unavailability of an Apple in the school meant that this interest could not be followed up.

Conclusion

It has been stated that four elements must be present in combination to effectively teach the skill of writing the alphabet. These are copying, instant and accurate feedback, critical analysis and a dynamic presentation of the letters. The results of this evaluation seem to indicate this CAL courseware can successfully provide two of these elements (instant, accurate feedback and dynamic presentation) while at the same time providing an interesting and motivating environment for the remedial student to make critical decisions and to copy consistantly. Therefore the courseware can be justified as a legitimate instructional tool. In fact, the four elements named above cannot be brought together any other way in a self-instructional format.

Reference Notes

1. Lauzon, R-A. An investigation of the effects of using large letter keyboard and large coloured letter displays on the computer assisted learning of vocabulary of mentally handicapped children. Unpublished thesis, Concordia University, 1981.

2. Ministère de l' Education du Québec. Instructions regarding the organisation of educational services for children with difficulties in adaptation and learning. (Document No. AE-15-81-01), Québec, 1981.

References

Bartel, N. & Hammill, D. Teaching children with learning and behavior problems. Boston: Allyn & Bacon, 1975.

Berthold, H. & Sach, R. Education of the minimally brain-damaged child by computer and teacher. Programmed Learning and Educational Technology., 1974, 11, 121-124.

Campbell, D. & Stanley, J. Experimental and quasi-experimental designs for research. Boston: Houghton and Miffin, 1963.

Charles, J. The effect of training, self-recording and group contingencies on immediate grade pupils. Dissertation Abstracts, 1971, 31, 4383-4384.

Drew, c. Introduction to designing and conducting research. St. Louis: Mosby, 1980.

Gibson, E. J. Untutored aquisition of writing skills. Dissertation Abstracts, 1972, 32, 5504.

Gronlund, N.E. Preparing criterion-referenced tests for classroom instruction. New York: McMillan, 1973.

Hasselbring, T. Remediating spelling problems of learning handicapped students through the use of the microcomputer. Computers in Schools, 1982, 7, 231-234.

Hedges, W. D. How to introduce teachers, principals and curriculum personnel to the microcomputer. The Computing Teacher, 1982, 8, 45-48.

Howe, J. Computers can teach where others fail. Technological Horizons in Education, 1981, 8, 44-46.

Lally, M. Computer-assisted handwriting instruction and visual/kinaesthetic feedback processes. Applied Research into Mental Retardation, 1982, 27, 77-82.

Lally, M & McCleod, I. Development of skills through computers. Impact of Science on Society, 1982, 32, 449-459.

Lally, M. & McCleod, I. The effectiveness of computer.

controlled feedback in handwriting instruction. In R. Lewis & E. D. Tagg (Eds.), Computers in education. Amsterdam: North Holland, 1981.

Levy, H. Square pegs, round holes: the learning disabled child in the classroom. Boston: Little & Brown, 1973.

Lewis, R. Education, computers and microelectronics. Technological Horizons in Education, 1981, 8, 47-53.

McCleod, I & Proctor, P. A dynamic approach to teaching handwriting skills. Visible Language, 1979, 13, 29-42.

Morrissey, W. J. Overcoming educators' fear about computers in the classroom. The Computing Teacher, 1981, 6, 50-51.

Peck, M. Another decade of research into handwriting progression in the 80's. Journal of Educational Research, 1980, 73, 283-291.

Popham W. & Sirotnik, K. Educational statistics - use and interpretation. New York: Harper & Row, 1973.

Sassoon, S. Writing wrongs. Times Educational Supplement, September 1983, pp.4-5.

Smith, K. & Smith, M. Cybernetic principles of learning and educational design. New York, Harper & Row, 1966.

Smith, S. & Murphy, L. Psycho-motor principles at work in basic skills. Impact of Science on Society, 1982, 32, 104-109.

Sovik, N. Development cybernetics of handwriting and graphic behavior. Oslo: Universitats Forlaget, 1975.

Stevens, D. How educators perceive computers in the classroom. Association for Educational Data Systems, 1980, 13, 221-227.

Terrel, C. & Lynyard, O. Evaluation of electronic learning aids. International Journal of Man-Machine Studies, 1982, 17, 59-67.

Thomassen, A. J. Computer-aided analysis of handwriting movements. Visible Language, 1979, 13, 56-59.

Watson, P. Using the computer in education. New Jersey: Educational Technology Publications, 1972.

Welford, A. Skilled performances: Perceptual and motor skills. Glenview: Scot, Foresman & Co., 1976.

Wright, C. & Wright, J. Handwriting ; the effect of copying moving and still models. Journal of Educational Research, 1980, 13, 283-285.

APPENDIX A

Instrument for the Testing Sessions

APPENDIX B

Programmed Sheets for Student Copying

APPENDIX C

Software Program (BASIC)

]RUN


```
]LOAD THE PROGRAM! (MACH2)
]LIST

10  TEXT : HOME : PRINT  CHR$ (13
    ) CHR$ (4)"BRUNLOMEM:": &  LOMEM:
    24576
120  HIMEM: 149 * 256: GOSUB 1400
    0: CALL 149 * 256:WR% = 230:
    P1% =  - 16300:P2% =  - 1629
    9:GS% =  - 16304:FP% =  - 16
    302:HR% =  - 16297
130  GOTO 520
140  CALL 149 * 256 + 3:S =  PEEK
    (8): IF S = 0 THEN 155
145 IC = IC + 1: CALL 149 * 256: IF
    IC > 4 THEN  TEXT : HOME : PRINT
    "PLEASE CHECK ALL CONNECTION
    S ON THE     POWERPAD AND RE
    -RUN THIS PROGRAM." CHR$ (7)
    : END
150  GOTO 140
155 IC = 0: CALL 149 * 256 + 6:XQ
     =  PEEK (7):YQ =  PEEK (6):
     IF F% > 4 THEN F% = 4
210  IF XQ = 0 AND YQ = 0 THEN F%
     = F% + 1: GOTO 235
215 YQ = YQ - 25: IF YQ < 0 THEN
    YQ = 0
220  IF F% = 4 THEN XP = XQ:YP =
    YQ
230 F% = 0: POKE WR%,64: HCOLOR=
    3: HPLOT 260 - XP * 2,YP * 2
     TO 260 - XQ * 2,YQ * 2: HPLOT
    260 - XP * 2 + 1,YP * 2 TO 2
    60 - XQ * 2 + 1,YQ * 2:XP =
    XQ:YP = YQ
235 C =  PEEK ( - 16384) - 128: IF
    C <  > 32 THEN 140
240  RETURN
520  TEXT : HOME : HCOLOR= 0: POKE
    WR%,32: HPLOT 0,0: CALL  - 3
    082: GOSUB 900: HCOLOR= 0: POKE
    WR%,64: HPLOT 0,0: CALL  - 3
    082
540  VTAB 10: HTAB 4: PRINT "PLEA
    SE PRESS THE KEY OF THE LETT
    ER": VTAB 12: HTAB 8: PRINT
    "YOU WANT TO PRACTICE...";: POKE
     - 16368,0
550  GET A$: IF  ASC (A$) < 65 OR
     ASC (A$) >  = 91 THEN 550
560 A = ( ASC (A$) - 64)
570  POKE GS%,0: POKE P1%,0: POKE
```

```
     WR%,32: POKE FP%,0: POKE HR%
     ,0: HCOLOR= 2
580  ON A GOTO 590,600,610,620,63
     0,640,650,660,670,680,690,71
     0,720,740,750,760,770,780,79
     0,800,810,820,830,860,870,88
     0
590  GOSUB 950:W = 133:X = 134:Y =
     64:Z = 65: GOSUB 1020:V = 1:
     XO = 114:YO = 90:FLAG = 1: GOSUB
     1130:W = 133:X = 134:Y = 85:
     Z = 86: GOSUB 1020: GOSUB 10
     60: GOTO 520
600  GOSUB 930:W = 133:X = 134:Y =
     16:Z = 17: GOSUB 1020:V = 2:
     FLAG = 0:XO = 153:YO = 90: GOSUB
     1130:W = 133:X = 134:Y = 85:
     Z = 86: GOSUB 1020: GOSUB 10
     60: GOTO 520
610 V = .8:FLAG = 1:AB = 143:XO =
     114:YO = 90: GOSUB 1130:W =
     130:X = 131:Y = 77:Z = 78: GOSUB
     1020: GOSUB 1060: GOTO 520
620  GOSUB 930:W = 133:X = 134:Y =
     16:Z = 17: GOSUB 1020:V = 1:
     XO = 114:YO = 90:FLAG = 1: GOSUB
     1130:W = 133:X = 134:Y = 85:
     Z = 86: GOSUB 1020: GOSUB 10
     60: GOTO 520
630  FOR G = 91 TO 139: HPLOT G,8
     5 TO G,93: NEXT :W = 95:X =
     96:Y = 88:Z = 89: GOSUB 1020

635 V = .95:FLAG = 1:AB = 158:XO =
     114:YO = 90: GOSUB 1130:W =
     133:X = 134:Y = 88:Z = 89: GOSUB
     1020: GOSUB 1060: GOTO 520
640 V = .75:XO = 153:YO = 40:FLAG
      = 1:AB = 75: GOSUB 1130: FOR
     X = 44 TO 116: HPLOT 129,X TO
     139,X: NEXT :W = 165:X = 166
     :Y = 25:Z = 26: GOSUB 1020
645  FOR X = 131 TO 160: HPLOT X,
     60 TO X,70: NEXT :W = 134:X =
     135:Y = 64:Z = 65: GOSUB 102
     0: GOSUB 1060: GOTO 520
650 V = .8:FLAG = 1:AB = 140:XO =
     116:YO = 90: GOSUB 1130:W =
     133:X = 134:Y = 75:Z = 76: GOSUB
     1020: GOSUB 970:V = 1:FLAG =
     0:AB = 68:XO = 114:YO = 141:
      GOSUB 1130:W = 133:X = 134:
     Y = 64:Z = 65: GOSUB 1020: GOSUB
     1060: GOTO 520
660  GOSUB 930:W = 133:X = 134:Y =
     16:Z = 17: GOSUB 1020:V = 2:
```

```
     XO = 153:YO = 90:FLAG = 0:AB
      = 90: GOSUB 1130
665  FOR X = 91 TO 116: HPLOT 168
     ,X TO 178,X: NEXT :W = 133:X
      = 134:Y = 85:Z = 86: GOSUB
     1020: GOSUB 1060: GOTO 520
670  GOSUB 950:W = 133:X = 134:Y =
     64:Z = 65: GOSUB 1020: FOR X
      = 49 TO 58: HPLOT 128,X TO
     139,X: NEXT :W = 133:X = 134
     :Y = 49:Z = 50: GOSUB 1020: GOSUB
     1060: GOTO 520
680  GOSUB 970:V = 1:FLAG = 0:AB =
     68:XO = 114:YO = 141: GOSUB
     1130:W = 133:X = 134:Y = 64:
     Z = 65: GOSUB 1020
685  FOR X = 49 TO 58: HPLOT 128,
     X TO 139,X: NEXT :W = 133:X =
     134:Y = 49:Z = 50: GOSUB 102
     0: GOSUB 1060: GOTO 520
690  GOSUB 930:W = 133:X = 134:Y =
     16:Z = 17: GOSUB 1020:X3 = 1
     56:Y3 = 66:Z3 = 170:A5 = 0:A
     [illegible] 29: GOSUB 1110:W = 165:X
      = 166:Y = 64:Z = 65: GOSUB
     1020:X3 = 128:Y3 = 80:Z3 = 1
     43:A5 = 0:A6 = 35: GOSUB 109
     0:W = 133:X = 134:Y = 85:Z =
     86
695  GOSUB 1020: GOSUB 1060: GOTO
     520
710  GOSUB 930:W = 133:X = 134:Y =
     16:Z = 17: GOSUB 1020: GOSUB
     1060: GOTO 520
720  GOSUB 950:W = 133:X = 134:Y =
     64:Z = 65: GOSUB 1020:V = 2:
     XO = 153:YO = 90:FLAG = 0:AB
      = 90: GOSUB 1130: FOR X = 9
     1 TO 116: HPLOT 168,X TO 178
     ,X: NEXT :W = 133:X = 134:Y =
     85:Z = 86: GOSUB 1020
725  V = 2:XO = 192:YO = 90:FLAG =
     0:AB = 90: GOSUB 1130: FOR X
      = 91 TO 116: HPLOT 207,X TO
     217,X: NEXT :W = 173:X = 174
     :Y = 85:Z = 86: GOSUB 1020: GOSUB
     1060: GOTO 520
740  GOSUB 950:W = 133:X = 134:Y =
     64:Z = 65: GOSUB 1020:V = 2:
     XO = 153:YO = 90:FLAG = 0:AB
      = 90: GOSUB 1130
745  FOR X = 91 TO 116: HPLOT 168
     ,X TO 178,X: NEXT :W = 133:X
      = 134:Y = 85:Z = 86: GOSUB
     1020: GOSUB 1060: GOTO 520
750 XO = 142:YO = 90:X1 = 142:Y1 =
```

```
    90:V = .5:FLAG = 1:AB = 180:
     GOSUB 1130:W = 141:X = 142:
    Y = 69:Z = 70: GOSUB 1020: GOSUB
    1060: GOTO 520
760 GOSUB 970:W = 133:X = 134:Y =
    64:Z = 65: GOSUB 1020:V = 2:
    FLAG = 0:XO = 153:YO = 90: GOSUB
    1130:W = 133:X = 134:Y = 85:
    Z = 86: GOSUB 1020: GOSUB 10
    60: GOTO 520
770 GOSUB 970:W = 133:X = 134:Y =
    64:Z = 65: GOSUB 1020:V = 1:
    FLAG = 1:XO = 114:YO = 90: GOSUB
    1130:W = 133:X = 134:Y = 85:
    Z = 86: GOSUB 1020: GOSUB 10
    60: GOTO 520
780 GOSUB 950:W = 133:X = 134:Y =
    64:Z = 65: GOSUB 1020:V = 2:
    XO = 153:YO = 90:FLAG = 0:AB
     = 70: GOSUB 1130:W = 133:X =
    134:Y = 85:Z = 86: GOSUB 102
    0: GOSUB 1060: GOTO 520
790 TEXT : HOME : VTAB 12: HTAB
    10: PRINT "LETTER NOT AVAILA
    BLE YET.": FOR XX = 1 TO 500
    0: NEXT : GOTO 520
800 GOSUB 930:W = 133:X = 134:Y =
    16:Z = 17: GOSUB 1020: GOSUB
    1000:W = 106:X = 107:Y = 35:
    Z = 36: GOSUB 1020: GOSUB 10
    60: GOTO 520
810 FOR X = 66 TO 90: HPLOT 90,X
     TO 100,X: NEXT :V = 2:XO =
    114:YO = 90:FLAG = 1:AB = 90
    : GOSUB 1130:W = 95:X = 96:Y
     = 64:Z = 65: GOSUB 1020
815 GOSUB 950:W = 133:X = 134:Y =
    64:Z = 65: GOSUB 1020: GOSUB
    1060: GOTO 520
820 X3 = 96:Y3 = 66:Z3 = 112:A5 =
    0:A6 = 49: GOSUB 1090:W = 10
    4:X = 105:Y = 64:Z = 65: GOSUB
    1020:X3 = 191:Y3 = 66:Z3 = 2
    07:A5 = 0:A6 = 49: GOSUB 111
    0:W = 199:X = 200:Y = 64:Z =
    65: GOSUB 1020: GOSUB 1060: GOTO
    520
830 FOR X = 66 TO 116: HPLOT 120
    ,X TO 131,X: NEXT :W = 126:X
     = 127:Y = 64:Z = 65: GOSUB
    1020
832 X3 = 152:Y3 = 86:Z3 = 164:A5 =
    0:A6 = 29: GOSUB 1110:W = 15
    8:X = 159:Y = 86:Z = 87: GOSUB
    1020:X3 = 152:Y3 = 86:Z3 = 1
    64:A5 = 0:A6 = 29: GOSUB 109
```

```
     0:W = 158:X = 159:Y = 86:Z =
     87: GOSUB 1020
835  FOR X = 66 TO 116: HPLOT 185
     ,X TO 196,X: NEXT :W = 191:X
     = 192:Y = 64:Z = 65: GOSUB
     1020: GOSUB 1060: GOTO 520
860  X3 = 98:Y3 = 66:Z3 = 110:A5 =
     0:A6 = 49: GOSUB 1090:W = 10
     4:X = 105:Y = 64:Z = 65: GOSUB
     1020:X3 = 146:Y3 = 66:Z3 = 1
     58:A5 = 0:A6 = 49: GOSUB 111
     0:W = 152:X = 153:Y = 64:Z =
     65: GOSUB 1020: GOSUB 1060: GOTO
     520
870  X3 = 98:Y3 = 66:Z3 = 110:A5 =
     0:A6 = 49: GOSUB 1090:W = 10
     4:X = 105:Y = 64:Z = 65: GOSUB
     1020:X3 = 193:Y3 = 66:Z3 = 2
     05:A5 = 0:A6 = 100: GOSUB 11
     10:W = 199:X = 200:Y = 64:Z =
     65: GOSUB 1020: GOSUB 1060: GOTO
     520
880  FOR X = 102 TO 146: HPLOT X,
     67 TO X,76: NEXT :W = 102:X =
     103:Y = 70:Z = 71: GOSUB 102
     0:X3 = 146:Y3 = 67:Z3 = 158:
     A5 = 0:A6 = 47: GOSUB 1110:W
     = 150:X = 151:Y = 70:Z = 71
     : GOSUB 1020
885  FOR X = 110 TO 155: HPLOT X,
     104 TO X,113: NEXT :W = 106:
     X = 107:Y = 110:Z = 111: GOSUB
     1020: GOSUB 1060: GOTO 520
900  HCOLOR= 6
910  HPLOT 1,16 TO 279,16: HPLOT
     1,17 TO 279,17: HPLOT 1,65 TO
     279,64: HPLOT 1,65 TO 279,65
     : HPLOT 1,115 TO 279,115: HPLOT
     1,116 TO 279,116: HPLOT 1,16
     7 TO 279,167: HPLOT 1,168 TO
     279,168
920  HCOLOR= 2: RETURN
930  REM  VERT. LINE FOR B,D,H,K,
     L,T.
940  FOR X = 17 TO 116: HPLOT 128
     ,X TO 139,X: NEXT : RETURN
950  REM LINE FOR A,I,N,R
960  FOR X = 66 TO 116: HPLOT 128
     ,X TO 139,X: NEXT : RETURN
970  REM VERT. LINE FOR P,Q
980  IF A = 7 OR A = 10 THEN  FOR
     X = 66 TO 145: HPLOT 128,X TO
     139,X: NEXT : RETURN
990  FOR X = 66 TO 166: HPLOT 128
     ,X TO 139,X: NEXT : RETURN
1000  REM THE T
```

```
1010  FOR X = 103 TO 162: HPLOT X
      ,30 TO X,41: NEXT : RETURN
1020  REM FLASH POINT & WAIT FOR
      SPACE BAR
1025  POKE  - 16368,0: POKE WR%,3
      2: POKE P1%,0
1030  HCOLOR= 1: HPLOT W,Y TO X,Y
      TO X,Z TO W,Z TO W,Y: FOR B
      B = 1 TO 501: NEXT
1040  HCOLOR= 2
1050  HPLOT W,Y TO X,Y TO X,Z TO
      W,Z TO W,Y: FOR BB = 1 TO 50
      0: NEXT
1055 C =  PEEK ( - 16384) - 128: IF
      C <  > 32 THEN 1030
1057 F% = 4: POKE  - 16368,0: GOSUB
      140: HCOLOR= 2: POKE WR%,32:
      RETURN
1060  POKE  - 16368,0: CALL 38234

1070 C =  PEEK ( - 16384) - 128: IF
      C <  > 32 THEN 1070
1080  RETURN
1090  HPLOT X3,Y3 TO Z3,Y3:X3 = X
      3 + 1:Y3 = Y3 + 1:Z3 = Z3 +
      1:A5 = A5 + 1: IF A5 = A6 THEN
      RETURN
1100  GOTO 1090
1110  HPLOT X3,Y3 TO Z3,Y3:X3 = X
      3 - 1:Y3 = Y3 + 1:Z3 = Z3 -
      1:A5 = A5 + 1: IF A5 = A6 THEN
      RETURN
1120  GOTO 1110
1130  HCOLOR= 2
1140  IF AB = 0 THEN AB = 178
1150 :R1 = 15:DHPI = 2
1160 R = 25
1170 DPHI = 2
1180 X = X0 + R
1190 X2 = X0 + R1:Y2 = Y0
1200 Y = Y0
1210  HCOLOR= 2
1220 DPHI = DPHI * 3.14159 / 180
[illegible]0 DHPI = DHPI * 3.14159 / 180
[illegible]0  IF FLAG = 1 THEN  FOR PHI =
      DPHI TO 6.2824 STEP DPHI: GOTO
      1260
1250  FOR PHI = 6.2824 TO DPHI STEP
      - DPHI
1260 X = 1 - R *  COS (V * 3.142 -
      PHI)
1270 X2 = 1 - R1 *  COS (V * 3.14
      2 - PHI):Y2 = 1 - R1 *  SIN
      (V * 3.142 - PHI)
1280 Y = 1 - R *  SIN (V * 3.142 -
      PHI)
```

```
1290 X = XO + X
1300 X2 = XO + X2:Y2 = YO + Y2
1310 Y = YO + Y
1320 AX = AX + 1:AY = AY + 1
1330  HPLOT X,Y TO X2,Y2
1340 AZ = AZ + 1: IF AZ = AB THEN
     AB = O:AZ = O: RETURN
1350  NEXT PHI
1360 AB = O:AZ = O: RETURN
14000  FOR X = 149 * 256 TO 149 *
     256 + 127: READ Y: POKE X,Y:
      NEXT : RETURN : DATA 76,9,1
     49,76,22,149,76,44,149,173,9
     0,192,173,88,192,173,89,192,
     173,88,192,96,169,0,133,8,16
     2,255,160,255,173,99,192,16,
     8,136,208
14010  DATA 248,202,208,245,230,8
     ,96,173,91,192,173,90,192,32
     ,67,149,133,6,32,67,149,133,
     7,173,89,192,173,88,192,96,1
     62,7,173,91,192,173,90,192,1
     73,97,192,10,102,8,202,208,2
     41,165,8,73,255,74,96
14020  DATA 169,0,133,2,133,0,169
     ,32,133,3,169,64,133,1,160,0
     ,177,0,17,2,145,2,192,255,20
     0,208,245,230,1,230,3,165,3,
     201,64,208,235,96
```

TECHNICAL POINTS

Resolution:
* 120 x 120
* 10th of an inch in both directions
* 100 switches to a square inch (for most computers
* there are 14,400 points on the surface

* Electronics of PowerPad scans the entire work suface about 30 times a second in search of contact points.

* PowerPad "talks" to a computer through the game port on most home computers: involves a software interface.

* Is not a generic interface. (a joy stick is a generic interface).

* Can run programs written by user in BASIC

* CONNECTS to a computer through a serial interface (4 wire interface - 2 in , 2 out); usually the game port-with PowerPad connector cable.

* CONNECTS TO: Commodore-64 - through Port 1
  Vic-20 - 1st control port receptacle
  Atari - 1st controller jack (joystick)
  Apple - requires our special starter cable to connect to the I/O game receptacle INSIDE the computer.
  Franklin Ace/1000 - will connect w/Apple Starter Kit if it has a 16 pen dip connector.
  IBM - also requires our special cable. Will connect to the Bus inside the machine. Our Starter Kit will include a small printed circuit board which will plug into the IBM Bus: a cable will run from the back for connecting to the PowerPad.

* Most products written in assembler BASIC machine language or LOGO.

INTERFACING:

PowerPad can be interfaced with other computers but requires someone with interfacing experience; can use our PowerPad Programming Kit for reference.

RS232C: (is not a computer - but a standard) Our PowerPad has a serial interface, but is not 232.