ACCEPTED
ULTY OF GRADUATE STUDIES
[redacted]
DEAN
Sep 2/93

Predicting Achievement in a Computer Assisted Learning Environment

by

Joseph Michael Donnelly
B.A., Royal Military College of Canada, 1975

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF ARTS

In the Department of Psychological Foundations in Education

We accept this thesis as conforming to the required standard

[redacted]

Dr. W. Muir, Supervisor (Psychological Foundations in Education)

[redacted]

Dr. D.G. Bachor, Departmental Member (Psychological Foundations in Education)

[redacted]

Dr. L.G. Francis, Outside Member (Social and Natural Sciences)

[redacted]

Dr. T.J. Riecken, External Examiner (Social and Natural Sciences)

University of Victoria

Supervisor: Dr. Walter Muir

ABSTRACT

Computer assisted learning (CAL) is often linked to gains in student achievement and instructional efficiency. However, there is increasing evidence that individual student differences are associated with wide variability in student achievement in CAL settings. If CAL works to the advantage of some students, but hinders others, there is a need for more discriminating use of the CAL medium. Such discrimination would depend upon reliable prediction of student potential for learning via CAL.

This study was designed to develop a regression model for predicting achievement in a CAL environment. Based upon previous research, four student characteristics were identified to have predictive potential: (a) general learning ability, (b) specific learning aptitude, (c) learning style, and (d) previous experience with computers.

The study sample consisted of 50 Navy technicians who used a CAL-based algebra tutorial. Quantitative data were collected from recruiting test records, pre- and post-tests of achievement, the Kolb Learning Style Inventory, and a student questionnaire. Qualitative data were obtained from student interviews.

Only the specific aptitude variable (algebra pre-test) was found to significantly predict the achievement criterion variable (algebra post-test). Interviews indicated that students tended to discount previous computer experience and learning style, but rated previous algebra knowledge and general learning ability as important influences on achievement.

The results of this study suggest that other variables need to be identified to strengthen the prediction of achievement in CAL. Alternatively, examination of influences on CAL efficiency may yield more powerful predictive models.

Examiners: [redacted]

Dr. W. Muir, Supervisor (Psychological Foundations in Education)

[redacted]

Dr. D.G. Bachor, Departmental Member (Psychological Foundations in Education)

[redacted]

Dr. L.G. Francis, Outside Member (Social and Natural Sciences)

[redacted]

Dr. T.J. Riecken, External Examiner (Social and Natural Sciences)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

Background to the Problem

Computers in Education

From its introduction in the 1960s, computer assisted learning (CAL) was considered to offer an ideal medium for individualized instruction (Hickey, 1968). The escalating educational use of computers was accompanied by widespread optimism about the utility of CAL, expressed in statements such as the following: "the computer allows us for the first time to match the subject matter and learning style to the personality type" (Papert, 1984).

The increasing use of computers in education has been matched by increasing attention to the role of CAL, and to the best scope for its implementation. Some initial reviews of the research tended to credit CAL applications with widely generalized effects on both instructional efficiency and student achievement (e.g., Burns & Bozeman, 1981; Kulik, 1983; Niemiec, Blackwell, & Walberg, 1986).

Comparative Research Difficulties

As research comparing CAL with traditional instruction accumulated, there was less agreement on the benefits of CAL as an instructional medium, and on its suitability for all types of students. Clark and Leonard (1985) noted that many studies failed to control for the powerful effect of the instructional methods conveyed by the CAL media. Schlecter (1986) found that issues concerning the utility of CAL were clouded by a lack of consistent empirical evidence. He concluded that research had been confounded by problematic courseware, differences in instructional content, inappropriate comparisons, and program novelty effects.

Student Differences and CAL

While much emphasis was being given to comparative methods, research was less attentive to the human variables in CAL. Some emerging evidence suggested that individual differences in students are associated with wide variability in CAL achievement. By 1980, some exploration of relevant student characteristics had begun, and it was suggested that these included demonstrated ability, initial achievement levels, and prior familiarity with subject matter (Dence, 1980).

Again, conflicting results are found. Burns and Bozeman (1981) report that CAL was significantly more effective in promoting achievement among high and low achieving subgroups, but not among remaining students. (High achievement is typically defined as performance falling more than one standard deviation above the group mean; low achievement falling similarly below the group mean.) Jamison and Lovatt (1983) found that CAL benefited high (but not low) achievers. Murphy and Derry (1984) maintained that CAL was particularly appropriate for low ability students. Other authors (e.g., Hativa, 1988; Hativa & Shorer, 1989) suggest that CAL may actually widen the gap between high and low achieving student groups.

There is also some evidence that the CAL environment may differentially affect the learning of students with dissimilar cognitive styles (MacGregor, Shapiro, & Niemiec, 1988) and learning styles (Sein & Robey, 1991).

Statement of the Problem

If CAL works to the advantage of some students, but hinders others, there can be little justification for the indiscriminate use of CAL across student populations. There is a need to develop methods by which student potential for learning via CAL media can be identified.

Purpose of the Study

The purpose of the present study is to identify some variables which might serve to predict student achievement using CAL media.

Identification of reliable predictors could form the basis for more effective and efficient use of CAL. Students who are apt to learn effectively through the CAL medium could continue to benefit from the independent and self paced nature of CAL applications. At the same time students less likely to experience success with CAL could be directed to more appropriate learning situations. Instructors could focus their attentions more precisely where needed, either in conjunction with the CAL program, or in providing alternative instruction.

Chapter 2: Review of the Literature

Background

CAL Definitions

Early literature dealing with CAL topics was often rendered confusing by the inconsistent use of a number of terms. More recently, these terms have become more standardized and precise. The following taxonomy is consistent with contemporary sources.

Computer assisted learning (CAL). This is a generic term which embraces many types of computer applications in learning; the computer serves as either a tutorial device (to deliver instruction or guide practice) or as a tool (e.g., word processing, programming). In this study, CAL is considered to be an instructional medium (means of presenting instructional material) rather than an instructional method (design and organization of instructional material). The instructional method employed in CAL is by no means standard: it depends upon the pedagogical design incorporated in the computer program. Some poorly designed studies, and considerable confusion in the literature, stem from failure to recognize this important distinction (Clark & Leonard, 1985; Kozma, 1991).

CAL can be divided into three components: computer assisted instruction, computer managed instruction, and computer enriched instruction (Niemiec & Walberg, 1987).

Computer-assisted instruction (CAI). This refers to instruction in which the computer serves as a medium for drill and practice, tutorial, or dialogue applications. In drill and practice, the computer provides exercise in skills and concepts introduced in the classroom. A CAI tutorial expands upon drill and practice by also introducing new skills and concepts. Dialogues carry the process a step further by allowing students to address questions to the program, in natural language. Some sources refer to CAI as computer-based instruction, or CBI.

Computer-managed instruction (CMI). CMI differs from CAI in using the computer as an electronic file manager, rather than as a medium of instruction. The computer is used to track and guide students in mastery of a pre-defined curriculum, which may or may not be delivered by CAI.

Computer-enriched instruction (CEI). This is a relatively new term which refers to use of the computer as a tool to enhance conventional instruction.

Computer simulations and models are typical examples of CEI.

The Effectiveness of CAL

If predicting CAL achievement is to be a useful goal, it must be established whether, and under what conditions, CAL is effective. The field of literature dealing with CAL effectiveness contains reports of hundreds of studies, and cannot be examined in detail within the scope of this thesis. However, useful inferences can be drawn from analyses completed by other researchers, and these are discussed in the following paragraphs.

Reviews of the Research.

Most CAL researchers have conducted studies to compare CAL with other (usually conventional) instructional settings. The results of this research have been synthesized in a number of reviews and meta-analyses (e.g., Bangert-Drowns, Kulik, & Kulik, 1985; Forman, 1982; Kulik & Kulik, 1991; Niemiec & Walberg, 1987; Thomas, 1979;). The Kuliks and their colleagues have dominated the field of CAL reviews, applying meta-analytical techniques to literature dealing with a wide range of CAL applications.

Meta-analysis techniques. The Kulik and Kulik analysis of 1991 illustrated the degree to which their methods were refined as a result of experience gained over a decade of research. The search for pertinent literature was extended to reach beyond published journal articles, and to include the ERIC database and dissertation abstracts. For inclusion in the analysis, studies had to meet criteria for methodological soundness, and had to provide comparative quantitative results for an outcome variable measured both in CAL and conventional settings. This resulted in a final selection of 248 studies. To provide a common scale for comparison purposes, outcomes were coded according to effect size, defined as the difference between the mean scores of two groups divided by the standard deviation of the control group (Kulik & Kulik, 1991).

Review synthesis techniques. Another method of review is typified by the work of Niemiec and Walberg (1987). Rather than analyzing individual studies, their approach was to synthesize the results of previous reviews of CAL studies. They were looking for reviews which assessed the relationship between CAL and achievement or affective measures, and which included at least four classroom studies. The 16 studies which met the criteria were compared on dimensions of instructional level, CAL application, and number of studies reviewed. Results were then analyzed and synthesized.

Findings of the analyses. Although results of CAL comparative research show wide variability, certain trends have been identified as a result of meta-analyses of studies and syntheses of reviews:

1. CAL is associated with moderate achievement differences favouring the CAL classes. Individual study results vary widely, but Niemiec and Walberg (1987) report an average effect size of.42, while Kulik and Kulik (1991) report an average effect size of.30. Reported effect sizes are significantly higher when published in professional journals, when related to studies of four weeks or less, or when studies did not control for instructor effects (Kulik & Kulik, 1991). Niemiec and Walberg (1987) also suggest that higher achievement differences appearing in earlier studies may reflect novelty effects associated with the introduction of classroom microcomputers.

2. CAL is associated with significant reductions in instructional time. This has been a consistent observation spanning more than 20 years of CAL research. Of the 18 studies reviewed by Thomas (1979), 16 showed significant time reductions for CAL groups

(the others showed no significant difference). Kulik and Kulik (1991) report a time difference favouring CAL in 29 of 32 studies which included results for time used. On average, the time saved was about one third that required for conventional instruction.

3. There is no consistent evidence that CAL influences course completion rates, student learning retention, or attitudes toward subject material (Kulik & Kulik, 1991).

4. There is no consistent evidence to support a relationship between CAL effectiveness and (a) student age, or (b) instructional level (Kulik & Kulik, 1991).

5. There is no consistent evidence to support a relationship between CAL effectiveness and instructional subject area. Fisher (1983) suggests that CAL has been most effective in mathematics and science instruction, and less so with instruction in reading and language arts. However, he examined only five review articles, some of which were interrelated. There are two other reasons for caution in accepting his conclusion: (a) at the time of Fisher's review CAL studies tended to focus on mathematics and science more than on other subjects; for example, of 42 studies analyzed by Bangert-Drowns, Kulik, and Kulik (1985), 33 (79%) came from mathematics or physical science

classes, and (b) as CAL programming techniques and computer technologies progress, wider scope for CAL applications may result. A more recent analysis (Kulik & Kulik, 1991) reflects an increasing balance of CAL subject material: of 248 studies examined, mathematics and physical sciences accounted for only 133 (54%). In that analysis, effect sizes shown for studies related to mathematics and science programs are no higher than those shown for other subjects.

Student Characteristics and CAL

It has been demonstrated that CAL programs generally offer substantial achievement and efficiency gains, when such variables are compared between CAL and non-CAL student groups. The next step is to examine CAL as it relates to individual students - to identify student characteristics which may be associated with variability in CAL achievement.

A pattern of relevant student variables was identified from a review of previous studies. These pertinent variables can be grouped in relation to: (a) general learning ability, (b) specific learning aptitude, (c) learning style preferences, and (d) experience with computers.

General Learning Ability

General learning ability, as indicated by achievement under various other instructional methods and media, has been linked to CAL achievement. The relationship between general achievement level and that in a CAL setting has not been clearly established, nor has it been extensively researched (Hativa, 1988). Those researchers who have studied general learning ability and CAL achievement have reported differing effects, as outlined in the following paragraphs.

High and low achievement. Burns and Bozeman (1981) conducted a meta-analysis of studies focusing on the effectiveness of computer assisted instruction (CAI) in mathematics instruction in elementary and secondary schools. After examining 40 pertinent studies, they found that CAI was effective in promoting attainment among high and low achieving students, but not effective for others. They further noted that tutorial CAI, when used as a supplement to conventional instruction, was particularly effective in promoting achievement among disadvantaged students. (Classification criteria for the high and low achieving sub groups were not provided by Burns and Bozeman, possibly because criteria were not consistently used in the studies under analysis. Typically, high and low achievement is defined by achievement scores which fall more than one standard deviation above or below the group mean, respectively.)

Fisher (1983) reported similar findings, and added that benefits to low achievers tended to occur independently of the type of cognitive or social "disadvantage" used in various definitions of low achievement. Unfortunately, his synthesis encompassed only five reviews, some of which were interdependent; his conclusions may have been premature.

Low achievement. The link between general achievement and CAI effectiveness may be more limited. In their meta-analysis of 42 controlled evaluations conducted in secondary school settings, Bangert-Drowns, Kulik, and Kulik (1985) found that the clearest positive achievement effects were with low ability students. The authors assert that their study provides the strongest evidence, and the first statistical proof, of this relationship. It should be noted that this finding may have been the result of a bias in the literature under study: while 15 of the studies focused on disadvantaged learners, only 4 examined high aptitude students.

Divergent achievement. Hativa (1988) and Hativa and Shorer (1989) drew another conclusion from their studies of CAI and achievement. In the 1988 study, Hativa used a naturalistic approach of in-depth observations, with multiple sites, subjects and observers, over a 2- to 4-month period. Four high achieving and three low achieving students were observed and interviewed while using a mathematics CAI program included in the elementary school curriculum. In the 1989 study the focus was on high and low achievers, in a similar setting, but quantitative methods were applied across six groups totalling 211 students. Findings were consistent for both studies, and Hativa and Shorer suggest that CAI widens the gap between high and low achievers. Even though low achievers received easier exercises than did high achievers, they continued to show lower performance levels, and less gain in overall performance, than did the high achievers. Hativa (1988) suggested that low achievers used CAI time counter-productively, because they were less flexible in adjusting to the CAI environment, and were more likely to make errors related to hardware and software operation. Conversely, those who benefitted the most were the high achieving students, who received practice at higher levels and advanced more quickly within levels (Hativa & Shorer, 1989).

Learning ability as a predictor. Similar results were reported by Adams, Waldrop, Justen, and McCrosky (1987), who conducted a multiple regression study using CAI achievement as the dependent variable. Within the same instructional program, 35 college level physiology students completed three units of instruction using CAI, and three other units in a conventional lecture/discussion format. Two learning ability measures were selected as independent variables: American College Test scores and Grade Point Averages. The authors found that the learning ability measures predicted achievement under CAI conditions (R^2=.75) better than achievement under conventional instruction (R^2=.48). They suggest that an aptitude treatment interaction occurs with CAI. The authors fail to discuss controls for possible instructor effects or differing unit difficulties, and draw some unsupported inferences. Nonetheless, the potential usefulness of learning ability as a predictor variable is indicated.

Specific Learning Aptitude

General. In addition to general learning ability, prediction of learning achievement often relies upon measures of aptitude more specifically matched to the subject material. Some student characteristics have been identified, such as initial achievement levels and prior familiarity with subject matter, which respond well to the use of CAI (Dence, 1980).

Math aptitude and CAI. Enochs, Handley, and Wollenberg (1986) conducted a study comparing achievement gained under CAI conditions, against traditional self-paced instruction (paper based with some instructor/student interaction). Subjects were United States Navy personnel training to perform various administrative and clerical tasks, who were randomly assigned to two stratified groups (CAI and non-CAI) of 50 members each. Potential predictor variables included the seven sub scales of the U.S. Armed Services Vocational Aptitude Battery; other measures are discussed separately below. The authors found significant positive correlations between achievement (under either training condition), and six of the aptitude measures:

1. Word knowledge.
2. Arithmetic reasoning.
3. Mechanical comprehension.
4. Mathematical knowledge.
5. General science.
6. Electronic information.

Moreover, they found arithmetic reasoning to be more strongly associated with CAI achievement ($r=.53$, $p<.01$) than with traditional achievement ($r=.36$, $p<.01$). This finding is particularly notable because the training program focused on clerical rather than arithmetic tasks. It may be that arithmetic reasoning interacts with CAI, independently of the instructional subject being presented through the CAI medium.

Math aptitude and computers. Oman (1986) also reported a potential link between math aptitude and scholastic success involving computers. While this study involved instruction about computers (computer science) rather than instruction from computers (CAI), it serves to illustrate the predictive potential of specific aptitude measures. Oman used multiple regression analysis to develop a model for placing incoming college freshmen into introductory computer science courses. Subjects were 60 students enrolled in one of two introductory courses in computer programming. Grades awarded upon course completion formed the basis for the dependent variable; independent variables were limited to student information readily available to faculty members (questionnaire results and SAT scores). The author found that the Scholastic Aptitude Test (SAT) math score alone accounted for 65% of the subsequent grade variation. The addition of scores for SAT verbal proficiency and previous computing experience raised this value to 82%. The implication is that specific aptitude scores, even without reference to general learning ability scores, can be significant predictors of achievement in computer-related courses.

Learning Style

General. CAL achievement may also be sensitive to student learning styles. The learning style construct is that individuals have preferred and differing approaches to the acquisition and processing of knowledge. Because these differences are manifested in different cognitive, physiological, and affective behaviors, learning style can be operationally defined.

Potential as a predictor. The measurement of learning style has shown some potential as a predictor of achievement. Stott (1985) reviewed a number of studies which validated the concept of learning style as a predictor of achievement: in some cases, particularly in younger children, style was found to predict achievement as well as did IQ. Dillon (1986) argues that learning style measures can provide a useful supplement to traditional predictive measures such as aptitude test results. Some researchers (e.g. Burger, 1985) have suggested that specific learning styles can be matched to specific instructional approaches, and that such matches might foster higher student achievement.

Several learning style models, and many related measures, have been used in research linking learning style and CAI achievement. One model which has often been used by educational researchers is the theory of experiential learning (Kolb, 1984). The Kolb model integrates a number of previous theories, and is complemented by a measure known as the Learning Style Inventory.

An overview of Kolb's model. Kolb (1984) defines learning as "the process whereby knowledge is created through the transformation of experience" (p. 38). Knowledge therefore derives from two critical processes: (a) grasping experience through thoughts and feelings, and (b) transforming that experience into learned behavior by watching and doing. Each of these processes involves two dialectically related learning modes(thinking/feeling and watching/doing), and the four modes interact to form a cycle of learning:

1. *Concrete experience* (feeling) accentuates reliance on intuition, open-mindedness, and personal involvement with people.

2. *Reflective observation* (watching) emphasizes careful observation, leading to objective understanding of different points of view.

3. *Abstract conceptualization* (thinking) uses logic, ideas, and concepts to build general theories. It is opposed to concrete experience, which is more concerned with present reality than hypothetical relationships.

4. *Active experimentation* (doing) stresses pragmatic approaches to influencing people and manipulating the environment. It is opposed to reflective observation, which emphasizes understanding over practical application.

Because learning is a continuous process, individuals are constantly going through the four steps of this learning cycle. Kolb (1984) incorporates learning styles into the experiential learning model by suggesting that individuals develop preferences for certain modes. Thus, learning styles can be measured and compared on the basis of the relative emphasis of each stage of the cycle.

Relative preferences among the four learning modes have been used (Kolb, 1984) to categorize individuals according to one of four learning style types:

1. *Convergers* favor abstract conceptualization (AC) and active experimentation (AE), and show strength in problem-solving and decision-making. They prefer technical tasks to interpersonal issues.

2. *Divergers* emphasize concrete experience (CE) and reflective observation (RO), and are somewhat the opposite of convergers. They are interested in people and are good in situations which call for imaginative alternatives.

3. *Assimilators* combine preferences for AC and RO. They are usually adept at inductive reasoning and construction of general theories, and are less focused on people than ideas.

4. *Accommodators* tend toward CE and AE, and are opposite to assimilators. They show strength in adapting to new situations, prefer "hands-on" learning, and rely more upon feelings than logic.

Although experiential learning theory has generally been well received, Gregg (1989) argues that the classification of individuals into learning style types lacks supporting evidence, and has questionable meaningfulness. Nonetheless, researchers linking the

Kolb model with student achievement have tended to select learning style types as variables.

Learning style and computers. Sein and Robey (1991) applied the Kolb model to a study which examined achievement among 80 undergraduate students enrolled in an introductory computer course. Because computer systems are initially viewed as related "black boxes", and computer operation is learned in a "hands-on" manner, the authors hypothesized that individuals who preferred to learn by a combination of AC and AE (convergers) would exhibit higher achievement than other subjects. The results of the analysis of variance supported the hypothesis, showing a significant main effect for learning style ($F=2.85$, $p=.04$). However, in this study both the cell sizes and the variance within cells varied widely, so that one of the assumptions underlying analysis of variance may have been violated (Howell, 1989).

Learning style and objective tests. Markert (1986) investigated the contention that learners preferring the combination of AC and AE (convergers) achieve higher scores on objective examinations. In his study, 95 medical students who had completed the Learning Styles Inventory wrote a 125 item, predominantly multiple choice, test on biometrics. The

38 students who were classified as convergers achieved 29 "A" grades (76%), while non-convergers achieved only 27 "A" grades (47%)(chi-square=7.90, p=.005). Since CAI also tends to be objective both in format and in testing procedures, this suggests that converger group might also do well in the CAI environment.

Learning style and CAI achievement. Cordell (1991) attempted to link experiential learning theory more directly with CAI achievement. After completing the Learning Style Inventory, 200 medical centre employees were categorized by learning style type (converger, diverger, assimilator, accommodator). Members of each of the four categories were then randomly assigned to one of two CAI treatments: a linear program or a branching program. Each program presented a tutorial in weight management techniques. The author does not indicate cell sizes, but states the average to be 25 members. It was expected that the different learning style groups would exhibit differences in achievement in each of the two CAI designs. An analysis of variance, using post-test scores as the dependent variable, was conducted, but Cordell found no significant relationship between learning style and achievement. The author suggests that the experimental design may have been hindered by limitations in the instructional design of the CAI programs.

An additional viewpoint is provided by Harford (1991), who reviewed the literature with the aim of establishing a theoretical link between learning style preferences and CAL in general. She postulates that different individual learning styles would favour higher achievement under different types of CAL conditions. For example, those who dislike structured learning materials would prefer the simulations and games normally grouped with CEI. She argues that the inherent structure and pragmatism of CAI would tend to attract individuals who favour abstract concepts and organized learning materials, and to repel those who are people-oriented or dislike structure.

While Harford did not test her hypotheses, Hoffman and Waters (1982) found effects which seem to be consistent with her postulation about student preferences and CAI. In a study involving 155 military communications technicians, correlations were found between certain personality variables (measured by the Myers-Briggs Type Indicator) and CAI achievement rates. Two particularly clear relationships were noted: (a) those who preferred to perceive by the senses tended to finish the CAI program more quickly than those who preferred to perceive by intuition, and (b) extraverted, people-oriented students tended to drop out of the CAI program. To paraphrase these findings in experiential learning terms: those who preferred the AC mode tended to rapid achievement, while those who preferred the opposed CE mode tended to drop out. This calls attention to the importance of the opposed learning style modes, and suggests that a different approach to learning style measurement may be in order.

Categorical versus continuous variables. As has been seen, most investigations of learning style and CAI related achievement have used categorical learning style variables, generally with inconclusive results. It may be more useful to examine the relationship between the relative strength of learning style tendencies and CAI achievement. The experiential learning model and the Learning Style Inventory (Kolb, 1985) permit the measurement of such continuous variables. Measurement of tendencies along the two opposing axes (AC/CE and AE/RO) may be particularly useful.

Other learning style indicators. In addition to the learning style preferences which form the basis of the experiential learning model, three other learning style variables potentially related to CAL were identified in the literature. These were: (a) preference for independent study versus group instruction, (b) preference for self-paced versus externally paced instruction, and (c) preferred cognitive style.

Independent study. The requirement for independent work normally associated with CAL may not be appropriate for some students. For such individuals, the need for contact with instructors or peers may outweigh the advantages of a CAL program. Stephenson (1990, 1992) examined the relationship between instructors, students, and CAI. He found that instructor-student interactions fostered achievement during a CAI program, even though the program was designed to support independent student work. Moreover, he found that student-student interactions were equally effective in promoting achievement. This suggests that the social dimension in itself can be a very important influence on achievement, at least for some students.

This inference is supported by the findings of Johnson, Johnson, and Stanne (1985), who examined CAI achievement in cooperative groups of four students. They found that individual achievement in these groups surpassed achievement in individual or competitive settings. Similarly, Schlecter (1987) found that for lower ability students, computer-based instruction (CBI) in small groups was more effective than individual CBI, and resulted in lower demand for instructor assistance. In his study, however, low ability students were paired with high ability students, introducing an uncontrolled treatment variable: in some cases, peer tutoring may have supplanted CBI as the instructional treatment.

Pacing. Student preferences regarding pacing of instruction may also reflect a learning style variable which influences achievement. In an analysis of effective instructional behaviors, Brophy (1986) argued that brisk external pacing was important to student achievement. Canelos, Dwyer, Taylor, Belland, and Baker (1989) compared achievement for nine CAI groups for which treatment varied in amount of external pacing. They found that moderate levels of external pacing effectively promoted CAL achievement. Notwithstanding the case for external pacing, some students still prefer self-paced work. Student questionnaires administered by Milne, Cook, and Shiu (1990), during a study comparing tutorial CAI and traditional instruction, indicated that the self-paced nature of CAI was well liked. In sum, individual learners may prefer different amounts of external pacing, and these preferences may be reflected in achievement in a CAL setting.

Cognitive style. One aspect of learning style which has received some attention is cognitive style, which is usually defined as problem-solving methodology. The cognitive style approach most often linked with CAL research, and for which a large research base has been developed, is the concept of field dependency developed by Witkin and others (Sharma, 1987). While field dependent persons view items globally, field independent persons are able to analytically perceive items, distinguishing them from their embedding context (Canelos, Taylor, Dwyer, & Belland, 1988).

Researchers seeking links between cognitive style and CAI performance have had mixed but generally inconclusive findings.

Some success was reported by MacGregor et al. (1988), who investigated whether the CAI environment differentially affected achievement for students with dissimilar cognitive styles. They found that field dependent learners, who passively accepted the given organization of a field of knowledge, performed better in a CAI environment than did field independent learners.

In a similar study, Abouserie, Moss, and Barasi (1992) found no significant achievement difference between field dependent and independent groups, but did find that the field dependent group was more prepared to rely entirely upon CAL.

Because of the lack of consistent results in this research, it was decided not to include a cognitive style predictor variable in the present study. It was felt, however, that findings of cognitive style research reinforce the importance of examining learning style from the perspective of opposing tendencies rather than group membership.

Computer Experience

General. Previous experience with computers can also contribute to the prediction of achievement. In his previously described study examining performance in college level introductory computer science courses, Oman (1986) found that previous experience with computers was correlated with achievement ($r=.60$, $p<.01$). These findings were supported in a study by Kersteen, Linn, Clancy, and Hardyck (1988), which also examined achievement in undergraduate computer science courses. They reported that a 13 point experience scale (measured by student questionnaire) accounted for up to 25% of the variance in final course grades. In a study of computer literacy achievement among student teachers, Woodrow (1991) examined seven potential predictor variables; of the three which showed statistical significance, two were measures of previous experience - programming experience and computer literacy. (The other was a learning style measure - locus of control.)

Experience and attitudes. Because motivation influences learning, student acceptance of CAL as an effective and non-threatening medium can be an important side effect of previous experience. Brouard (1986) identified adult student concerns about keyboarding skills, equipment faults, inadequate control over program sequence, and lack of supplementary materials (including human assistance). Streibel (1985) expressed concern that many CAL programs are perceived as impersonal, artificial, and biased against experiential learning. Milne et al. (1990) noted that student background and experience with computers can play a role in shaping both attitudes and learning styles.

Experience and anxiety. Many studies related to CAI have focused on affective variables such as attitudes toward computers or anxieties about using computers. While some authors (e.g. Buchner, 1991) have reported significant rates of anxiety, the concept of computer anxiety has not received much empirical analysis (Heinssen, Glass, & Knight, 1987), and the relationship between computer anxiety and achievement is not clear. There is evidence, however, that experience interacts with both attitudes and anxiety: that greater experience is linked with greater acceptance of computers and more confidence in using them (Chen, 1986; Farrell, Cuseo-Ott, & Fenerty, 1988). For these reasons, it was decided that for the present study the experience variable had good potential for prediction, while attitude or anxiety did not.

Summary of the Review

In general, the review of the literature confirmed that while CAL is widely recognized as a beneficial instructional medium, the benefits are not generalizable across student populations. No single study has produced a strong prediction equation for achievement under CAL conditions, nor has any researcher attempted to identify and integrate the more promising variables into a single study. Based upon the results of previous research the following variables were identified as having the best predictive potential:

1. General learning ability.
2. Specific learning aptitude.
3. Learning style indicators.
4. Experience with computers.

Chapter 3: Rationale, Definitions, and Hypotheses

Rationale

In this study the author's intention was to investigate the feasibility of a predictive model for CAL achievement. It seemed appropriate to build upon the research of Burger (1985), Enochs et al. (1986), Adams et al. (1987), and Cordell (1991), all of whom had examined CAI achievement in relation to specific potential predictor variables. These variables had not yet been integrated in a single study, nor was there evidence that qualitative research had been used to guide or validate the selection of predictor variables.

Because the variables of interest were those which might predict CAL achievement, relationships between variables provided the focus for this research. The correlational method was chosen as the most appropriate framework to examine these relationships (Borg & Gall, 1989; Howell, 1989). Cooley and Lohnes (1976) argue that the correlational method is particularly well suited to evaluative research in education. This quantitative approach could be supplemented by qualitative methods.

Achievement, as demonstrated by student end performance on a post-test, was selected as criterion variable.

Definitions

Three terms used to define variables important to the present study are described below.

CAL achievement. This is the achievement demonstrated by the student during an instructional program which is primarily CAL based. Operationally, it can be measured by the score achieved on an achievement post-test.

High and low achievement. These are operationally defined as achievement represented by test scores which fall more than one standard deviation above or below the mean score respectively.

Hypotheses

Hypotheses were as follows:

1. General learning ability, specific learning aptitude, learning style, and previous computer experience will predict CAL achievement. (A significant multiple correlation will exist between CAL achievement and learning ability, specific learning aptitude, learning style, and computer experience.)

2. CAL achievement will be positively correlated with general learning ability.

3. CAL achievement will be positively correlated with specific learning aptitude.

4. CAL achievement will be correlated with learning style. Learning styles which favour the abstract over the concrete, and the passive over the active, will be positively correlated with CAL achievement.

5. CAL achievement will be positively correlated with amount of previous experience in computer operation.

Chapter 4: Method

Sample

Participants were Navy personnel enrolled in an intermediate level CAI mathematics (algebra) program at Canadian Forces Fleet School (CFFS) Esquimalt. All persons who underwent the program between mid October 1992, and the end of January 1993, were included in the initial sample. Final group size was 50.

Participants ranged in age from 18 to 34 years (mean=22.7, SD=3.29). All but four were high school graduates. Eleven had one or more years of post-secondary education; one had a baccalaureate degree. All Canadian provinces were represented in the participants' educational background (see Figure 1).

Participants were assigned to electrical or mechanical engineering occupations within the Navy. About two thirds were recent graduates of the Canadian Forces Recruit School, awaiting commencement of training specific to their trades. Others had completed basic occupation training, but were awaiting more advanced training within their occupations. In either case, participants were using the CAI program as preparation for conventionally presented courses of instruction focusing on engineering skills for technicians.

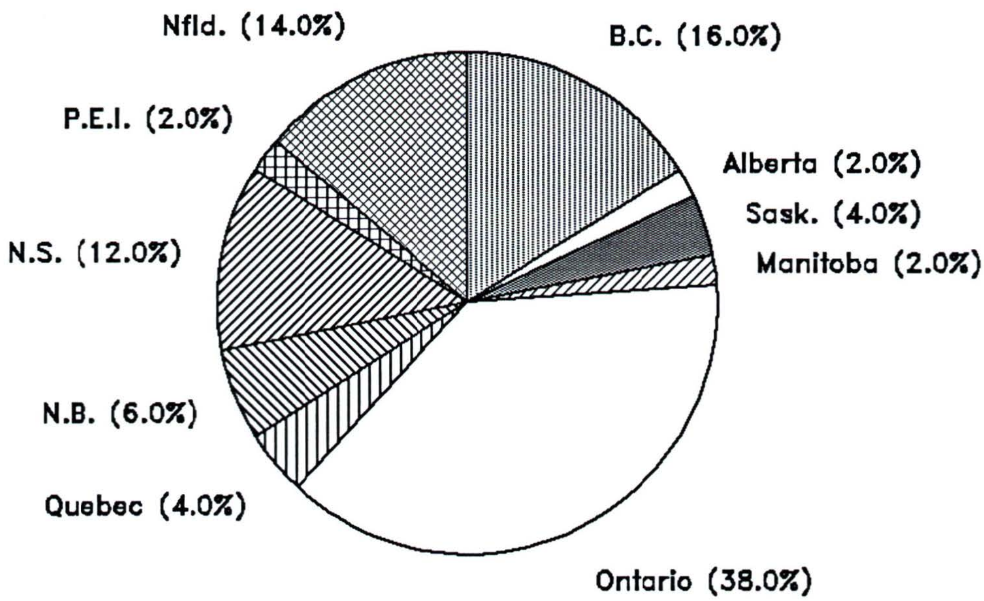

Figure 1. Participants' educational background, by Province where last formal education occurred.

Setting

Research took place in the CAL laboratory of CFFS Esquimalt. The laboratory consists of 17 student work stations linked to a Honeywell DPS6 mainframe computer. The laboratory is overseen by an academic instructor, and supervised on a full-time basis by a noncommissioned officer, both of whom are located in an adjoining office. Students have unlimited access to the CAL laboratory, on a drop-in basis, during normal duty hours. Access by modem is possible for students who possess compatible personal computer systems.

Instrumentation

Computer Software

CAL software selection. In selecting a CAL application for this study, it was important to identify a program which both had potential for providing effective learning, and which might be considered typical of CAL media. Based on the findings of previous research, it was decided that this should be a CAI application rather than CMI or CEI (Bangert-Drowns, Kulik, & Kulik, 1985), and that the CAI should include tutorial sequences (Burns & Bozeman, 1981).

The CAN/CAI project. The Fleet School CAL laboratory uses a set of such programs developed by the Ontario Institute for Studies in Education as part of the CAN (Completely Arbitrary Name) CAI project (Gershman & Sakamoto, 1981). From the nine available CAI programs, the intermediate algebra program, QMath, was selected as the best vehicle for the study. QMath was chosen because (a) it is the most widely used CAI program at the school, and (b) most students take QMath as their first CAI program.

The QMath Program. QMath is designed to provide tutorial instruction and practice in algebra at the grades 7-10 (Ontario) level (Gershman & Sakamoto, 1981). At CFFS Esquimalt, it is used to ensure that students achieve a requisite academic standard before commencing technical training. In addition to providing CAI, the program includes some CMI features. It records terminal time spent by each user on each of ten instructional modules. It also administers end-of-module tests, each of which must be passed to gain access to the next module. The program records the number of student attempts for each test, and the score achieved for each attempt. For a detailed description and pedagogical evaluation of QMath, see Appendix A.

Measures

Criterion variable measures. To measure the criterion variable (CAL achievement), pencil-and-paper pre- and post-tests were developed. This approach was selected for two reasons:

1. Although QMath includes embedded testing routines, all QMath tests are randomly generated for each student, and no record of actual test items is kept. The program also uses a testing model which

varies test length depending upon the number of initially correct responses. Test reliability analysis would therefore be impracticable.

2. An individual's test performance may be affected by unfamiliarity with, or aversion to, the computer medium (Meier, 1988). Paper-and-pencil tests were considered to offer a more valid measure of student knowledge of algebra.

Test development. Pre- and post-tests were developed by using the random item generation feature of the computer. An item was generated for each of the subtopics in the QMath program, numbered accordingly, and then transcribed to paper. This produced a single pre-test of 25 items to be used for all participants. The post-test was developed in the same way, so that the pre- and post-tests were parallel in form but not identical in actual test items. Internal consistency was estimated, using the Kuder-Richardson Formula 20, to be .82 for the pre-test and .55 for the post-test. The lower value in the latter case can be attributed to a ceiling effect in student scores.

General learning ability. This was measured by reference to scores achieved on the Canadian Forces General Classification Test (GCT), which is administered to applicants at Recruiting Centres. The

GCT is a standardized test of learning ability, comprising 80 items arranged in order of increasing difficulty, and administered with a 30 minute time limit. GCT scores also correlate highly (+.75) with the Wechsler Adult Intelligence Scale - Revised; it can be argued that the GCT is a measure of intelligence (Legras & Staples, 1983).

Although periodically analyzed for reliability and predictive validity, the GCT has remained essentially unchanged since 1942. The split-half reliability estimate for the complete test, corrected using the Spearman-Brown formula, is .89 (Angus & Halliwell, 1987). Correlation between GCT scores and training performance has been estimated to be r=.47. When combined with results from the more specialized aptitude tests subsequently administered to recruits, the GCT contributes to highly valid predictions of training performance (Cronshaw & Gowans, 1986).

Individual GCT scores were obtained from the Canadian Forces Personnel Applied Research Unit, through the office of the Base Personnel Selection Officer at CFB Esquimalt.

Specific learning aptitude. Specific aptitude was measured in two ways. The first was an Arithmetic Knowledge (AK) score obtained at Recruiting Centers during applicant testing. The AK subtest is a 30 item, 30 minute test of ability to solve mathematical problems, including basic algebra and interpretation of graphs. Internal reliability (Cronbach's coefficient alpha) is estimated to be .79 (Halliwell & Amyot, 1986). Correlation with subsequent training performance has been found to be r=.49 (Cronshaw & Gowans, 1986). Individual AK scores were obtained and interpreted in the same manner as the GCT scores.

The second academic measure was the achievement pre-test, the development of which was described above.

Learning Style. Learning style was measured by administration of the Learning Style Inventory (LSI) developed by Kolb (1985). This instrument is considered to be the most promising of several learning style measures (Harford, 1991), and takes less than ten minutes to complete. The LSI provides raw scores ranging from 12 to 48 which measure the extent of the individual's orientation toward each of four learning styles: (a) concrete experience, (b) reflective observation, (c) abstract conceptualization, and (d) active experimentation.

The LSI also makes use of two summed combined scores to indicate the extent to which the individual style favors (a) abstract versus concrete (calculated by subtracting the concrete experience score from the abstract conceptualization score), and (b) active versus reflective learning (calculated by subtracting the reflective observation score from the active experimentation score). These combined scores were considered to offer the best measure for this study, because of previous findings concerning the possible links between CAL achievement and preference for (a) abstract rather than concrete concepts (Enochs et al., 1986), or (b) passive rather than active learning (MacGregor et al., 1988).

The summed scores can be used to assign the individual to one of four learning style types; for reasons previously discussed, these categorical variables were not included in the present study.

Smith and Kolb (1986) report good internal consistency reliability for all six numerical scales (Cronbach's alpha ranging from .73 to .88; given as .88 for the AC/CE combined scale, and .81 for the AE/RO combined scale). The validity of the LSI is less well supported by statistical evidence, though elsewhere Kolb (1984) makes a convincing case for his theory of experiential learning.

To complement the LSI, a frequency count was kept of questions asked of the lab supervisor. This measure was used to indicate student need for interaction with a human instructor, and/or difficulty with the operation of the hardware or software. The observational form is shown as Appendix B. Because use of the observational form was difficult to monitor, this measure was cross-checked by student report during the follow-up interview.

Computer experience. Previous computer experience was measured by a questionnaire, which was given to students together with the LSI. This questionnaire used a 30 point scale; questionnaire items are shown as Appendix C.

Interview. All students were asked to participate in an interview with the researcher. Purposes of the interview were (a) to verify questionnaire responses, (b) to investigate student perceptions of the relative importance of the predictor variables, and (c) to search for other contributing variables. The interview guide is included as Appendix D.

Procedure

Staff Training. Before the study commenced, the CAL laboratory staff were briefed, and given a written instruction, concerning procedures for administration of instruments related to the study. They were also asked to otherwise maintain normal operating procedures.

Data collection sequence. Data collection occurred in three stages. To minimize potential novelty and experimenter effects during completion of the QMath program, activities which students would immediately associate with research (questionnaires and interviews) were limited to the third stage.

First stage. When students reported for the QMath program, they were first given the achievement pre-test. Although this was a new activity for the lab, it was considered to reflect good instructional practice, and was presented to students as part of the normal CAL lab routine.

Second stage. While students worked through the program, computer terminal use and program progress data were collected by the record keeping function of the computer system, the lab supervisors completed the observational forms, and student GCT and AK scores were obtained from military personnel files.

Third stage. Upon completion of the post-test, or upon withdrawal from the program, students were asked to complete the LSI and the questionnaire, and to consent to be interviewed (see Appendix E for the letter of consent form).

Data Analysis

A multiple regression analysis was conducted using CAL achievement as the criterion variable. Predictor variables were the GCT and AK scores, achievement pre-test scores, raw scores for each of the two combined LSI scales, and scores representing previous computer experience (derived from the questionnaire).

Data from interview questions were categorized and analyzed in a frequency table. Responses to open-ended questions were examined for consistency with other data, and for both expected and unforeseen opinions and ideas.

Chapter 5: Results and Discussion

Quantitative Data

A summary of the data collected by tests and questionnaires is shown in Table 1. N=50, except for GCT (n=48) and AK (n=49).

Table 1

Descriptive Statistics for Non-Interview Data

Variables	HPS	Mean	Range	SD
GCT Score	80	48.31	29 to 67	9.77
AK Score	30	19.33	10 to 27	4.53
Experience	30	10.90	0 to 25	7.46
AC-CE	48	9.22	-23 to 28	11.10
AE-RO	48	3.30	-23 to 23	10.88
Pre-test	25	18.50	6 to 25	4.13
Post-test	25	21.40	14 to 25	2.37

Note. HPS = highest possible score.

A comparison of the pre- and post-test means resulted in a correlated t-test value of 6.45 ($p<.001$). This indicated a statistically significant increase in mean test scores after the QMath program.

In comparison to pre-test scores, the range and SD of the post-test scores are reduced in value. This reduced variation conforms both with theory and with findings about mastery learning programs (Kulik, Kulik,

& Bangert-Drowns, 1990). However, in this case it more likely indicates the operation of a ceiling effect. This effect stemmed from the high entry level ability, in relation to the content of the QMath program, exhibited by many students. On the pre-test, 22 students (44%) achieved scores of 80% or more. Since the post-test items were of the same difficulty as the pre-test items, there was insufficient scope for the demonstration of differences in student achievement.

Intercorrelations

Intercorrelations of variables and associated levels of significance are shown in Table 2. The sample size was N=50, except for GCT (n=48) and AK (n=49).

Table 2

Correlation Coefficients between Variables

	1	2	3	4	5	6	7
1. GCT							
2. AK	.52**						
3. Experience	.27	.26					
4. AC-CE	.01	.09	.00				
5. AE-RO	.21	.23	.29*	.01-			
6. Pre-test	.38**	.38**	.39**	.03-	.09		
7. Post-test	.14	.21	.12	.01-	.09-	.64**	

* p<.05 Negative signs, where applicable, follow
** p<.01 the correlations.

Pre-test and Achievement. The highest correlation was between Pre-test and Post-test, and this was the only significant correlation with the criterion variable (CAL achievement). This finding is consistent with the frequently observed relationship between mathematics pre- and post-tests (Hativa & Shorer, 1989), but may also reflect a carry-over effect from pre-test to post-test.

General learning ability and achievement. The low correlation between learning ability (GCT) and achievement (post-test) was unexpected. However, a similar result was reported by Adams et al. (1987). In that study, GPA was found to predict CAI achievement better ($r=.83$) than did scores on the American College Test ($r=.74$). It was suggested that tests of potential may not predict as well as tests of performance. This is consistent with the present study, which found significance for the pre-test (a performance measure), but not for the GCT (a test of potential). An alternative explanation is offered by Kulik et al. (1990), who state that because mastery learning courses are designed to raise all but a few students to nearly the same high level of performance, the correlation between initial aptitude scores and final performance scores should be near zero.

<u>Learning styles</u>. Neither of the learning style combined scores showed a significant correlation with the achievement criterion variable. While this may indicate the absence of a relationship between CAI achievement and learning style, there are two possible alternative explanations:

1. The quantitative measurement of learning style may lack reliability. While Kolb (1984) argues that learning styles show long-term stability, measures such as the LSI may reflect short-term changes in individual preferences. This could stem from the structure of the LSI, which calls for self-descriptive sentence completion. Selections made by an individual on any given day might be subject to variations in individual self-concept.

2. A skew in the sample may have limited the range of learning style scores. Subjects in this study tended toward the abstract conceptualization end of the AC/CE axis. This is consistent with the contention that emphasis on the AC mode is related to success in engineering fields (Kolb, 1984), but other factors may also have been at work. Military selection procedures may have resulted in a group of individuals with similar preferences, or military training may have caused individual preferences to converge to some

extent. At any rate, the restricted range of the scores may have affected the value and significance of the correlation.

Multiple Regression Analysis

General. A stepwise multiple regression analysis showed only limited predictability for the criterion variable. Stepwise selection adds to the regression equation, at each step, the variable which most increases the R^2 value. Only those variables which are significant ($p<.05$) are included in each step of the regression analysis. For the post-test (achievement) variable, pre-test score was the only statistically significant predictor ($n=48$, $R^2= .41$, $p<.01$).

The regression model accounts for 41% of the variability in achievement. A standard or forced entry regression analysis, adding the remaining independent variables, increased this value to 44% (see Table 3). In standard entry, all variables are entered into the regression equation at once.

Table 3

Standard Entry Regression Analysis

Achievement as Criterion Variable

Predictor	Beta Weight	p(2-tail)
Pre-test	.71	.00
AC-CE	.01	.96
AE-RO	-.12	.35
GCT	-.10	.51
Experience	-.10	.46
AK	.04	.79

R^2=.44 F=5.47 df=6 p=.0003 n=48

The regression analysis did not provide evidence to support the selection of the GCT, arithmetic knowledge and learning style variables as predictors of achievement.

Interview Data

Interview results can be described in three categories: (a) student perceptions about their preparedness for CAL (in relation to the independent variables), (b) student impressions about CAL subsequent to working through the QMath program, and (c) student willingness to undertake future CAL programs. All 50 participants consented to the interview; individual responses to interview questions are summarized as Appendix F.

Preparedness

Previous computer experience. Six participants (12%) indicated having no prior experience with computers, and twenty one (42%) reported limited familiarity (some use of a single application, or rudimentary experience of several applications). Twenty three participants (46%) reported having substantial prior experience with at least two computer applications. This experience usually derived from a combination of high school courses (18 cases, 36%), and use in the home (16 cases, 32%). In all but two cases the active home users also reported having made substantial use of computers in high school. Twelve individuals (24%) had used computers in the workplace; in nine of these cases this use was very narrow in scope (e.g., inventory database for control of supply stocks).

CAL expectations. Fifteen participants (30%) expressed initial uncertainty or anxiety about the difficulty of the program- these individuals were all new to the CAL setting, and eight of them found the program easier than expected. Of those who expressed initial confidence (25 cases, 50%), twelve reported some sort of previous CAL experience. Overall, only two individuals said that they found the CAI program to be more difficult than expected.

General learning ability. Forty respondents (80%) judged their own general learning ability to be in the average range. Six (12%) clearly considered themselves to be above average, and four (8%) below average. For the latter two groups, these self evaluations were not generally consistent with either the individual GCT scores or the achievement scores.

Entry knowledge. Thirty-three participants (66%) expressed confidence in their threshold knowledge of algebra; these individuals generally considered the program to be a valuable and effective review of previous learning. Self reported estimates were more consistent for this variable: five of the six high achievers reported good algebra pre-knowledge, and five of the six low achievers reported poor algebra pre-knowledge. Forty-three students (86%) considered their pre-test score to be valid (four thought that it was too high, three that it was too low).

CAL Impressions

Learning style. Most participants (45 cases, 90%) felt that their individual learning styles were suited to CAL settings. Eleven members of this group expressed conditional acceptance, pointing out specific limitations to the instructional use of CAL (see Appendix F for specific comments).

Learning style inventory. At the end of the interview, participants were shown the results of their own Learning Style Inventory. Most (35 persons, 70%) felt that the inventory provided a good description of their preferred style. The others expressed ambivalence about certain descriptive phrases in the interpreting guide, but no one felt that the LSI was completely incorrect.

Experience effects. Only two individuals felt that their performance suffered from a lack of experience with computers. The vast majority (48 cases, 96%) felt that the program required no particular experience with hardware or software (several mentioned that the embedded introduction provided adequate orientation for using the program).

Weighting variables. In ranking the order of importance of predictor variables, participants generally regarded previous computer experience as unimportant, and considered learning style to be of minor importance. General learning ability and previous algebra knowledge were considered to be the major contributors to success. The two were weighted about equally, though learning ability was included in every participant's list, while four individuals did not consider previous algebra knowledge to be important enough to include.

Self pacing. Positive attitudes about the self paced nature of the program were reported by 45 students (90%). Nonetheless, 31 persons (62%) indicated a preference for some form of external pacing. Most commonly, 1 to 3 work deadlines (e.g. a daily quota of program objectives to be completed) were considered appropriate for the QMath course. This seems to be consistent with the findings of Grabinger and Jonassen (1988), who reported that independent study was preferred by a minority of students who were highly motivated and self assured. However, motivation and confidence were not measured in this study.

Seeking assistance. Thirty students (60%) reported one or more occasions in which they sought help outside that offered by the CAL program. The sources of such help were both instructional staff (12 persons, >40 occasions) and other students (16 persons, >50 occasions). Among the high achievers, only one individual sought outside help (one occasion). Among the low achievers, all but one individual sought assistance, and three reported doing so "often".

Summative evaluation. When asked to evaluate the effectiveness of the QMath program in retrospect, 48 participants (96%) reported the program to be a worthwhile learning experience, and 42 participants (84%) could propose no better method to learn/review algebra. Methods suggested to be more effective or efficient were; (a) human instruction (five cases), (b) more challenging material (two cases), and (c) more explanations and sample problems (one case).

CAL Readiness

The final question asked for a hypothetical choice for future training: conventional classroom instruction, CAL, or a combination of the two. Those who indicated a preference for a combination were asked to elaborate. Results were as follows:

1. Five participants (10%) preferred conventional classroom instruction without CAI.

2. Three participants (6%) preferred CAI in lieu of conventional instruction.

3. Forty one participants (82%) opted for a combination. The suggested balance between CAI and conventional instruction varied, but averaged about 50/50. In general, there was a clear preference for human instruction in the presentation of important new material, and for clarification of material causing repeated difficulty for an individual. CAL was seen to be better suited to tutorial work for less challenging material, drill, and practice.

4. One participant (2%) expressed no preference concerning future instructional settings.

Chapter 6: Conclusions

Summary of the Quantitative Findings

For each of the hypotheses, findings were as follows:

1. *General learning ability, specific learning achievement, learning style, and previous computer experience will predict CAL achievement.*
(A significant multiple correlation will exist between CAL achievement and learning ability, specific learning aptitude, learning style, and computer experience.)

This hypothesis was partially supported. The results of the study indicate that the criterion variable, achievement, can to some extent be predicted using previous achievement as measured by the pre-test score. The general learning ability, arithmetic knowledge and learning style variables did not significantly contribute to the prediction.

2. *CAL achievement will be positively correlated with general learning ability.*

This hypothesis was not supported by the findings. The correlation between learning ability and achievement was not significant.

3. *CAL achievement will be positively correlated with specific learning aptitude.*

This was partially supported by the findings. The pre-test measure was a strong predictor for achievement. Arithmetic knowledge did not have a significant correlation with achievement.

4. *CAL achievement will be correlated with learning style. Learning styles which favour the abstract over the concrete, and the passive over the active, will be positively correlated with CAL achievement.*

There was no support for this hypothesis. Neither of the learning style measures showed statistical significance.

5. *CAL achievement will be positively correlated with amount of previous experience in computer operation.*

This hypothesis was not supported. While experience did show a positive correlation with CAL achievement, the value of the correlation was not significant.

Synthesis of Qualitative and Quantitative Findings

General learning ability. Most students stated that general learning ability was important to their achievement in the QMath program. Though this was not consistent with the findings of the regression analysis, the latter may have been confounded by the ceiling effect.

Specific learning aptitude. Participants considered previous knowledge of algebra to be almost as important as general learning ability. This was borne out by the regression analysis, which identified the algebra pre-test score as a significant predictor. The more generalized measure of previous knowledge, the Arithmetic Knowledge score, did not significantly improve the prediction equation. Again, the ceiling effect may have diminished the usefulness of this variable.

Learning style. Learning style measures did not add significantly to the calculated predictions. In interviews, students expressed interest in the concept of learning styles, and were receptive to the LSI results. However, in comparison to learning ability and previous algebra knowledge, students considered learning style to be a tertiary influence upon performance in QMath.

Interview findings did not generally support the completely independent and self-paced use of CAI; most students expressed the need for human assistance at least occasionally, and most preferred to have some external pacing. Similarly, there was little support for completely computer-based programs: students preferred a combination of conventional instruction and CAL.

Previous computer experience. Although participants as a group ranged widely in previous computer experience, this variable did not contribute to the prediction of achievement. Interview results supported this finding: students did not consider previous computer experience to be an important influence on subsequent performance in the QMath program.

Implications For Theory and Practice

The results of this study have at least two implications concerning the prediction of CAL achievement.

Identifying variables. The first implication is that more useful predictor variables have yet to be identified. Previous research with CAL has utilized various combinations of aptitude, threshold performance, experience, attitude, and learning/ cognitive style variables. Although the most promising of these were selected for this study, the results fell short of practical utility. If better predictor variables cannot be found, and a more powerful regression equation developed, the reliable prediction of CAL achievement may be impossible. If that is the case, the prescriptive use of CAL for only selected students may prove to be an elusive goal.

Timeliness of variables. The second implication is that the best predictors of CAL success may not be available when most useful for purposes of student placement; that is, before commencing a program of instruction. For example, student engagement time is a recognized predictor of achievement (Brophy, 1986), but because it is apt to vary under different methods and media, is not reliably measurable in advance of a program.

In a more general sense, the results of this study suggest that if CAL achievement cannot (at least for the present) be reliably predicted, then educators should recognize limitations to the use of CAL across student populations. As long as a more discriminating assignment of students to CAL remains out of reach, certain compensatory measures should be implemented.

These include: (a) supplementing CAL with ample opportunities for students to interact with instructors and other students, (b) providing some external guidance for the pacing of student work, and (c) using CAL in combination with conventional instruction, favoring the latter for the presentation of new, difficult, or important material.

Limitations of the Study

The internal validity of this study may have been threatened by difficulty in controlling several extraneous variables related to the instrumentation employed.

Test sensitization. First, the similarity between the pre- and post-tests, which were usually completed within a few days of each other, may have contributed to higher individual achievement not related to use of the QMath program. Experience with the pre-test may have helped prepare students for the post-test. This carry-over effect may have been particularly strong for those individuals with substantial previous knowledge of algebra: the pre-test itself might serve as an impetus for the recall of previous learning.

Ceiling effect. Second, the measure of achievement may have been hampered by the reduced variance of the post-test scores. To some extent, this effect is expected in mastery learning programs, but it may have been aggravated by the simple nature of the material (relative to the student sample), by the relatively short test length of 25 items, and by the lack of internal consistency within the post-test.

Statistical regression. The relatively simple nature of the subject material may have contributed to a third confounding effect: statistical regression. Because many of the participants achieved high scores on the pre-test, statistical regression would tend to move the corresponding post-test scores toward the mean. In fact, 20% of individual post-test scores were lower than corresponding pre-test scores, and in all these cases the pre-test scores exceeded the mean. This suggests that statistical regression may have occurred.

In assessing the external validity of this study, several factors need to be considered.

Population validity. The population used in this study varied in age and was drawn from across the country, but was narrowly defined in other respects. Participants had been (a) screened for admission to the military, then (b) based upon previous experience, aptitude testing, and personal preferences, assigned to naval engineering trades. Most had just completed a rigorous course of basic training which emphasized the value of human interaction, teamwork and group cohesiveness. All of these factors would suggest caution in generalizing results to dissimilar populations.

Ecological validity. Any study involving CAL is inherently limited by the nature of the instructional content, media and method employed. This study used algebra material, a CAI medium, and a mastery learning method; research evidence (not limited to this study) suggests that this combination can produce effective learning. However, different combinations of material, medium, and method may well produce different results. Generalization beyond a specific combination of circumstances is therefore ill advised.

Implications for Future Research

Prediction of achievement under CAL conditions is an attractive goal. Additional research might focus on the identification of significant and readily available predictors of achievement. A useful starting point might be the refinement of measures of general learning ability and specific learning aptitude. Among the variables examined in this and other studies, these two seem to have the the best predictive potential. The challenge will be to produce measures which are both: (a) predictive (alone or in combination with other measures), and (b) readily available to those who will decide which students will benefit from the media.

The learning style construct may have a certain appeal to educators and students, and this is reinforced by the simplicity of measures such as the LSI. Nonetheless, the measures of learning style used here do not seem to have much potential as predictors of CAL achievement. Those studies which report links between learning style measures and achievement tend to use categorical data of questionable validity. Critics of learning style measures in general, and the LSI in particular, argue that the scores lack stability over even short periods of time (Rule & Grippin, 1988; Sewall, 1986).

The lack of a strong predictive model in this study may provide evidence for the contention that instructional methods influence achievement, while media such as CAL influence efficiency (Clark & Leonard, 1985). If this fundamental distinction is accepted, future predictive research investigating CAI should use efficiency measures (e.g., program completion time) as criterion variables. Reliable prediction of student efficiency using CAL media would offer certain benefits, particularly in cost-oriented instructional settings such as military training.

If, on the other hand, it is believed that media do influence achievement for some learners (e.g., Kozma, 1991), research must concentrate on specifying the characteristics of these individuals. The results of this study suggest that strong predictors of CAL achievement may not be those related to student background or learning preferences. Better determinants may be found in variables of instructional design and presentation.

References

Abouserie, R., Moss, D., & Barasi, S. (1992). Cognitive style, gender, attitude toward computer-assisted learning and academic achievement. Educational Studies, 18, 151-160.

Adams, T. M., Waldrop, P. B., Justen, J. E., & McCrosky, C. H. (1987, December). Aptitude-treatment interaction in computer-assisted instruction. Educational Technology, pp. 21-23.

Angus, R. J., & Halliwell, S. T. (1987). Psychometric analyses of the general classification test - form 3 (GC3) (Technical Note 13/87). Willowdale, ON: Canadian Forces Personnel Applied Research Unit.

Bangert-Drowns, R. L., Kulik, J. A., & Kulik, C. C. (1985). Effectiveness of computer-based education in secondary schools. Journal of Computer-Based Instruction, 12(3), 59-68.

Borg, W. R., & Gall, M. D. (1989). Educational Research: An Introduction (5th Ed.). New York: Longman.

Brophy, J. (1986). Teacher influences on student achievement. American Psychologist, 41, 1069-1077.

Brouard, J. (1986). An evaluation of computer assisted learning in the workplace (NRCC No. 25255). Ottawa, ON: National Research Council.

Buchner, M. S. (1991). Computer fear and anxiety in the United States Army. Unpublished master's thesis, Naval Postgraduate School, Monterey, CA.

Burger, K. (1985). Computer assisted instruction: Learning style and academic achievement. Journal of Computer-Based Instruction, 12(1), 21-22.

Burns, P. K., & Bozeman, W. C. (1981). Computer-assisted instruction and mathematics achievement: Is there a relationship? Educational Technology, 21, 32-39.

Canelos, J., Dwyer, F., Taylor, W., Belland, J. (1988,). Cognitive style factors and learning from micro-computer based and programmed instructional materials: A preliminary analysis. Proceedings of Selected Research Papers presented at the Annual Meeting of the Association for Educational Communications and Technology. New Orleans, LA. (ERIC Document Reproduction Service No. ED 295 630)

Canelos, J., Dwyer, F., Taylor, W., Belland, J., & Baker, P. (1989). The effect of embedded learning strategies in microcomputer instruction. Journal of Experimental Education, 57, 301-317.

Canfield, A. A. (1980). Learning styles inventory. Ann Arbor, MI: Humanics Media.

Chen, M. (1986). Gender and computers: The beneficial effects of experience on attitudes. Journal of Educational Computing Research, 2, 265-282.

Clark, R. E., & Leonard, S. (1985, March). Computer research confounding. Paper presented at a meeting of the American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 263 876)

Cooley, W. C., & Lohnes, P. R. (1976). Evaluating Research in Education. New York: Irvington.

Cordell, B. J. (1991). A study of learning styles and computer-assisted instruction. Computers and Education, 16, 175-183.

Council of Ministers of Education, Canada. (1985). Software Evaluation: Criteria for Educational Software Evaluation. Toronto: Author

Cronshaw, S. F., & Gowans, S. R. (1986). Validity generalization of Canadian Forces selection tests (Research Report 86-5). Willowdale, ON: Canadian Forces Personnel Applied Research Unit.

Dence, M. (1980). Toward defining the role of CAI: A review. Educational Technology, 20, 50-54.

Dillon, R. F. (1986). Information processing and testing. Educational Psychologist, 21(3), 163-174.

Enochs, J. R., Handley, H. M., & Wollenberg, J. P. (1986). Relating learning style, reading vocabulary, reading comprehension, and aptitude for learning to achievement in the self-paced and computer-assisted instructional modes. Journal of Experimental Education, 54, 135-139.

Farrell, A. D., Cuseo-Ott, L., & Fenerty, M. (1988). Development and evaluation of a scale for measuring practitioners' attitudes toward computer applications. Computers in Human Behavior, 4, 207-220.

Fisher, G. (1983). Where CAI is effective: A summary of the research. Electronic Learning, 3, 82-84.

Forman, D. (1982, January). Search of the literature. The Computing Teacher, pp. 37-51.

Gershman, J., & Sakamoto, E. (1981). Computer-assisted remediation and evaluation: A CAI project for Ontario secondary schools. Educational Technology, 21, 40-43.

Grabinger, R. S., & Jonassen, D. H. (1988, January). Independent study: personality, cognitive, and descriptive predictors. Paper presented at the meeting of the Association for Educational Communications and Technology, New Orleans, LA.

Gregg, N. (1989). Review of the learning-style inventory. In J. C. Conoley & J. J. Kramer (Eds.), _The Tenth Mental Measurements Yearbook_ (pp. 441-442). Lincoln: The University of Nebraska Press.

Halliwell, S. T., & Amyot, K. A. (1986). _Psychometric evaluation of the arithmetic knowledge subtest of the Canadian Forces classification battery_ (Technical Note 22/86). Willowdale, ON: Canadian Forces Personnel Applied Research Unit.

Harford, L. A. (1991). _The application of learning styles to computer assisted instruction in nursing education_ (Report No. AFIT/CI/CIA-91-069). Wright-Patterson AFB, OH: Air Force Institute of Technology.

Hativa, N. (1988). Computer-based drill and practice in arithmetic: Widening the gap between high- and low-achieving students. _American Educational Research Journal_, _25_, 366-397.

Hativa, N., & Shorer, D. (1989). Socioeconomic status, aptitude, and gender differences in CAI gains of arithmetic. _Journal of Educational Research_, _83_, 11-21.

Heinssen, R. K., Glass, C. R., & Knight, L. A. (1987). Assessing computer anxiety: Development and validation of the computer anxiety rating scale. Computers in Human Behavior, 3, 49-59.

Hickey, A. E. (Ed). (1968). Computer assisted instruction: Survey of the literature (3rd ed.). Washington, DC: Office of Naval Research.

Hoffman, J. L., & Waters, K. (1982, March). Some effects of student personality on success with computer-assisted instruction. Educational Technology, pp. 20-21.

Howell, D. C. (1989). Fundamental Statistics for the Behavioral Sciences (2nd Ed.). Boston: PWS-Kent.

Jamison, R. N., & Lovatt, K. F. (1983). Classroom delinquency, achievement, and computer assisted instruction. Journal of Computer-Based Instruction, 9, 145-147.

Johnson, R. T., Johnson, D. W., & Stanne, M. B. (1985). A comparison of computer-assisted cooperative, competitive and individualistic learning (Tech. Report No. CLC006). Arlington, VA: Defence Technical Information Center.

Kersteen, Z. A., Linn, M. C., Clancy, M., & Hardyck, C. (1988). Previous experience and the learning of computer programming: The computer helps those who help themselves. Journal of Educational Computing Research, 4, 321-333.

Kolb, D. C. (1984). Experiential Learning: Experience as The Source of Learning and Development. Englewood Cliffs: Prentice-Hall.

Kolb, D. C. (1985). Learning Style Inventory (2nd ed.). Boston: McBer.

Kozma, R. B. (1991). Learning with media. Review of Educational Research, 61, 179-211.

Kulik, J. A. (1983). Synthesis of research on computer-based instruction. Educational Leadership, 41, 19-21.

Kulik, J. A. (1985, April). Consistencies in findings on computer-based education. Symposium conducted at a meeting of the American Educational Research Association, Chicago, IL.

Kulik, C. C., Kulik, J. A., & Bangert-Drowns, R. (1990). Effectiveness of mastery learning programs: A meta-analysis. Review of Educational Research, 60, 265-299.

Kulik, C. C., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. Computers in Human Behavior, 7, 75-94.

Legras, L. P., & Staples, R. E. (1983). A correlational analysis of the relationship of the Wechsler adult intelligence scale - revised with the general classification battery - English and the Canadian Forces classification battery (Personnel Selection Services Report 1983-1). Borden, ON: Base Personnel Selection Office.

MacGregor, S. K., Shapiro, J. Z., & Niemiec, R. (1988). Effects of a computer-augmented learning environment on math achievement for students with differing cognitive style. Journal of Educational Computing Research, 4, 453-465.

McCombs, B. L. (1985). Instructor and group process roles in computer-based training. Educational Communication and Technology Journal, 33, 159-167.

Meier, S. T. (1988). Predicting individual differences in performance on computer-administered tests and tasks: Development of the computer aversion scale. Computers in Human Behavior, 4, 175-187.

Milne, S., Cook, J., & Shiu, E. (1990, March). An investigation of students' learning activities: A comparison of tutorial CAL and traditional methods. Paper presented at the International Conference on Technology and Education, Brussels, Belgium.

Murphy, D. A., & Derry, S. J. (1984, April). Description of an introductory learning strategies course for the job skills education program. Paper presented at a meeting of the American Educational Research Association, New Orleans, LA. (ERIC Document Reproduction Service No. 244 108)

Niemiec, R., Blackwell, M. C., & Walberg, H. J. (1986). CAI can be doubly effective. Phi Delta Kappan, 67, 750-751.

Niemiec, R., & Walberg, H. J. (1987). Comparative effects of computer-assisted instruction: A synthesis of reviews. Journal of Educational Computing Research, 3(1), 19-37.

Oman, P. W. (1986). Identifying student characteristics influencing success in introductory computer science courses. AEDS Journal, 19(2-3), 226-233.

Papert, S. (1984). New theories for new learnings. School Psychology Review, 13, 422-428.

Rule, D. L., & Grippin, P. C. (1988, February). A critical comparison of learning style instruments frequently used with adult learners. Paper presented at a meeting of the Eastern Educational Research Association, Miami, FL.

Sakamoto, E. J. (1980). The CAN/CAI User's Manual. Toronto: The Ontario Institute for Studies in Education.

Schlecter, T. M. (1986). An examination of the research evidence for computer-based instruction in military training (Technical report 722). Fort Knox, KY: Army Research Institute Field Unit.

Schlecter, T. M. (1987). The effects of small group and individual computer-based instruction on retention and on training lower ability soldiers (Report No. 1497). Alexandria, VA: Army Research Institute.

Sein, M.K., & Robey, D. (1991). Learning style and the efficacy of computer training methods. Perceptual and Motor Skills, 72, 243-248.

Sewall, T. J. (1986). The measurement of learning style: A critique of four assessment tools. Green Bay: Wisconsin University, Assessment Center. (ERIC Document Reproduction Service No. ED 267 247)

Sharma, S. (1987). Learners' cognitive styles and psychological types as interviewing variable influencing performance. Journal of Educational Technology Systems, 15(4), 391-399.

Smith, D. M., & Kolb, D. A. (1986). User's Guide for the Learning Style Inventory. Boston: McBer.

Stevenson, S. D. (1990). A first look at the effect of instructor behavior in a computer-based training environment. Proceedings of the 32nd Annual Conference of the Military Testing Association (pp. 144-149). Pensacola, FL: Naval Education and Training Program Management Support Activity.

Stephenson, S. D. (1992). The effects of student-instructor interaction and paired/individual study on achievement in computer-based training (Report No. AL-TP-1992-0003). Brooks AFB, TX: Human Resources Directorate.

Stott, D. H. (1985). Learning style or `intelligence'? School Psychology International, 6, 161-174.

Streibel, M. J. (1985, April). A critical analysis of computer-based approaches to education: Drill-and-practice, tutorials, and programming/simulations. Paper presented at a meeting of the American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 263 881)

Thomas, D. B. (1979). The effectiveness of computer assisted instruction: Secondary schools. AEDS Journal, 12, 103-116.

Woodrow, J. E. (1991). Determinants of student teacher computer literacy achievement. Computers & Education, 16, 247-256.

Appendix A

Evaluation of the QMath Software

This evaluation was prepared in accordance with guidelines published by the Council of Ministers of Education, Canada (1985). It begins with a brief description of the QMath program. This is followed by appraisals of the program's pedagogical content, instructional format, technical design, and implementational support.

Description

Scope

The intermediate algebra course (QMath) was produced in 1980 as a part of a CAI project undertaken by the Ontario Institute for Studies in Education, in cooperation with the Ontario Ministry of Education and six Ontario Boards of Education. The target audience for the CAI project comprised secondary school mathematics and physics students, at an intermediate grade level. Like other CAI programs in the series, QMath was developed by a project team composed of educators and instructional programmers.

QMath is a tutorial application of CAI, based upon a 95% mastery model of learning. To pass through the program, students must demonstrate mastery of the following objectives:

1. Translating words to mathematics.
2. Substituting.
3. Substituting in formulas.
4. Simplifying.
5. Solving linear equations in one variable.
6. Solving equations (simplification).
7. Solving equations (rational expressions).
8. Inequalities.
9. Manipulating formulas.

A sequential probability testing procedure is used to determine mastery. This means that a student will pass an objective test with: (a) the first 5 test items correct, (b) 7 out of the first 8 correct, or (c) 10 out of 12 correct. A student will fail (i.e., be referred for remedial instruction) with the first 2 items wrong, or with any 3 errors. (Sakamoto, 1980).

<u>Sequence</u>

The student must work through the topics in the order shown above. However, the amount of time and detail spent on each topic can vary widely. At the beginning of each topic, an example is shown of an item from the terminal objective test. An opportunity is offered to take the objective test immediately; if the test is taken and passed, the student moves directly to the next topic. Otherwise, the student is shown a list of lower level objectives, then selects a starting point for tutorial instruction.

<u>Depth</u>

Within each objective, the student makes several decisions concerning the number of illustrative examples and sample problems to be viewed while proceeding through the lower level objectives. All examples, problems, and test items are randomly generated by the computer. Eventually, the terminal test is offered again. If the test is failed twice, the student is prompted to seek assistance from an instructor, then logged out of the system. While the student can log on again whenever desired, the log off and referral is noted by the CMI routine, and appears on the student record printout.

Evaluation - Pedagogical Content

The QMath program reflects the benefits of sound instructional analysis and course design. The objectives of QMath are clearly defined in achievable terms, and narrow enough in scope that progress can be easily monitored. The objectives and subobjectives are presented in logical order of increasing complexity.

Students have reasonable control over the depth of the learning experience, because they can select or repeat instruction, example, and problem routines. Instructional segments are clearly written, well illustrated by examples, and somewhat varied in format. Unfortunately, the program does not provide much scope for the inquisitive or adventurous student: there are no discretionary topic areas or optional problems of a more challenging nature.

Evaluation - Instructional Format

Student interaction with QMath is frequent. There are frequent opportunities for the student to enter choices about program sequence, and to select a desired number of examples or problems. The program pauses after every few lines of screen output to solicit a student input. These inputs are limited to single keystrokes (y/n) for selecting options for program sequence, and to numerical responses to practice problems and test items. This makes the program easy to use regardless of student typing ability, though occasional requirements for short text answers would add variety, and could help confirm student understanding.

The questioning technique is effective. Numerals and variables are randomly generated, though the supply-type item format does not vary. Questions during instructional subroutines follow and take the same format as examples provided, as shown in the following extract from a student session:

```
** Instruction on Objective 2.1: Whole number
substitution

Let's look at an example of substitution.
        If n = 13, what is n-5?

Well, if n = 13, then n-5
                    = 13-5   replace n by 13
                    = 8
So, if n=13, then n-5 is 8.

Try this one, Joe.

If n = 8, what is 7 + n ?14
No.  Check your work and try again.  ?15
Good work.

If n = 2, then 9n = ?18
Great.

If n is 6, what is 24/n ?3
No.  Check your arithmetic and try again.  ?4
Right.

Would you like two more problems for practice ?y

If n = 12, what is 19 - n ?7
That's right.

If n = 3, then 6n = ?12
No.  Just replace n with 3 and multiply.  Try
again.  ?15
Sorry.  If n = 3, then 6n
                     = 6*n
                     = 6*3
                     = ?18
Good.
```

Feedback to student responses is well handled. Correct answers are confirmed with short, positive, and varied statements. As illustrated in the last problem above, the program will identify an initially incorrect answer, then allow the student a second chance to supply the correct one. If the second reply is also incorrect, a demonstration of the correct calculation is provided. This helps to compensate for one limitation of the program - that it cannot directly check student calculations. However, the program will recognize and point out common errors such as incorrect valence symbols or the use of the wrong arithmetic function. Error indications correctly avoid visual or audible cues which might discomfit the user.

QMath is a particularly strong program in the area of evaluation. The mastery testing model is well implemented in the use of the computer as a test administrator. Student threshold knowledge is used to identify a start point for instruction and practice, and successful test performance is required for advancement through the sequence of objectives. The program provides some diagnostic functions, and will refer students to instructional subroutines, or to a human instructor, at appropriate points. Finally, the program aids the human instructor or supervisor by keeping detailed records of: (a) student time spent on each sub objective, (b) test attempts and outcomes, and (c) instances of referral for remedial help.

Evaluation - Technical Design

Compared to the capabilities of more recent hardware and software applications, the presentation of QMath outputs is primitive. The program makes no use of color, specialized graphics, or sound. The screen output is limited to the display of standard keyboard text and symbols, although these are occasionally employed in simple diagrams. Characters are presented in only one font and font size.

Despite these technical limitations, QMath is effectively designed for the purpose of providing an algebra tutorial. Displays are functional, readable, and free of spelling or grammatical errors. The program is free of processing delays and rarely locks up or crashes.

QMath is generally easy to use. The first time students log on, they are presented with a tutorial on how to use the keyboard to enter commands and responses. At any time, students can summon a list of available commands by entering HELP, and can escape from the program with a double key press (reentering will return the student to the beginning of the current subobjective). Typographical error correction is awkward; because the backspace key is disabled, the input line must be deleted and retyped.

Evaluation - Implementational Support

The QMath program is one of a series of similar tutorials, all of which are supported by a comprehensive User's Manual (Sakamoto, 1980). This manual includes a general discussion of the rationale for the mastery model, test procedures and criteria, and student record formats. It also devotes a separate chapter to each tutorial, describing the pedagogical objectives and other peculiarities of the individual program.

The system provides useful restricted access for managerial purposes. For example, the system manager can grant an instructor access to records for his or her students only. The instructor would receive detailed records for each individual, and a summary showing descriptive statistics for the class.

The CAN/CAI system also provides an authoring function. This is not used at Fleet School and was not evaluated as part of the present study.

Summary

The QMath program is an example of an excellent tutorial application, when viewed in comparison to contemporary efforts. The combined efforts of educators and programmers have embedded a sound pedagogical design into a functional software design. The program offers good student control, effective feedback, and useful evaluation procedures. With modern computer technology, it could be vastly improved by enhancing the video display, and by providing more varied requirements and opportunities for student inputs.

Appendix B

Observational Form

Student ID: ____________________

1. Check each question asked by the student into one of the following categories:

	Frequency	Total
a. Hardware operation:		
b. Software operation:		
c. Program interpretation (reading difficulty):		
d. Math concepts:		
e. Other (see para 2):		

2. For questions marked "Other" above, briefly describe the nature of the question in the space below. If the question did not pertain to the CAL program, write only "N/A". Count all questions, including those of an administrative or personal nature.

Appendix C

Student Questionnaire

Instructions

Before you leave the QMath program, please complete this short questionnaire. The information will assist us in ensuring that the CAL Lab best meets the needs of our students.

The questionnaire has two parts. Part 1 asks for information about your experience in using computers. Part 2 asks about the way in which you learn or deal with new experiences. Please complete each part carefully.

To help protect your identity, do not put your name on any part of this questionnaire. These questionnaires will be destroyed after the information has been analyzed. No information related to the questionnaires will be placed in your service records, and your name will not appear in the records kept by the CAL Lab.

Please turn the page.

Part 1 - Computer Experience

The following questions ask you to describe the amount of experience you have had using computers in different situations. For each question circle the number which, in your opinion, best describes your own experience prior to the QMath program. Use the following guide when selecting your responses:

0 - Never
1 - Rarely
2 - Sometimes
3 - Often

In this questionnaire, the term "computer" means a micro or mainframe computer with a keyboard. It does NOT include devices designed solely for games (e.g., Nintendo).

1.	In my junior high school classrooms, I used a computer:	0	1	2	3
2.	In my high school classrooms, I used a computer:	0	1	2	3
3.	In my home I have used a computer:	0	1	2	3
4.	I have used a computer for:				
	a. word processing	0	1	2	3
	b. spreadsheet	0	1	2	3
	c. database	0	1	2	3
	d. games or simulations	0	1	2	3
	e. programming	0	1	2	3
5.	I have used a computer assisted learning program (other than QMath)	0	1	2	3
6.	I have taken a course entirely by computer:	0	1	2	3

Part 2 - Learning Style Inventory

Please turn to the next page and read the instructions given there. [Not included in appendix]

Appendix D

Interview Guide

Part One - Computer Experience

1. Before attending this training program, how much had you operated a microcomputer:

    a. at home? For what purposes?

    b. at school? At what grade levels? For what purposes?

    c. in a job? For what purposes?

2. Before you commenced this training, did you anticipate that computer assisted learning would be easy or difficult? Why? Were your expectations correct?

Part Two - Perceptions of Predictor Variables

3. How would you describe your own general learning ability?

4. Before commencing QMath, how well did you think you understood algebra? Did the pre-test confirm this? Was your pre-test score accurate?

5. Do you feel that your learning style is suitable for CAL situations? Why or why not?

6. Do you feel you had enough computer experience to commence the QMath program? Why or why not?

7. To what extent do you feel that the following factors affected your performance in QMath (rank order):

a. your general learning ability?

b. your previous knowledge of algebra?

c. your learning style?

d. your previous experience with computers?

e. other (explain)?

Part Three - Other Factors

8. How do you feel about the self-paced nature of the program? Would you prefer some external pacing? Completely external pacing?

9. Was the time you spent in QMath well invested? Might the time have been spent on more efficient or effective learning? How?

10. How often did you find that you needed more explanation than the computer offered? Where did you go to get the information you required (lab supervisor, academic instructor, another student, books, other)?

11. Given the (hypothetical) choice, which of the following would you prefer for your next course:

a. traditional classroom instruction?

b. computer assisted learning?

c. combination of the two? (What proportion?)

d. another option? (Explain)

Appendix E

Consent for Participation

Canadian Forces Fleet School (Esquimalt) wants to ensure that the CAL Lab assists student learning as fully as possible. The School is supporting research to examine some aspects of computer assisted learning.

You are asked to cooperate in this research by completing a simple questionnaire (a 20 minute task). You may also be asked to participate in a short interview, to discuss some aspects of your experience in the CAL Lab.

All information given by you will be treated in confidence. Your identity will not appear in any records or publications resulting from this research.

This research is concerned with student ideas, experiences, and opinions. No experimentation is involved. There is no personal risk to participants, and there is no penalty should you choose not to participate. You may also choose to withdraw from the study at any time, without penalty.

Questions regarding this research, and your rights with respect to it, may be directed to Capt J.M. Donnelly, at local 4497.

(signed by)
L.P. Mosley
LCdr
for Commandant

Consent Form

I have read and understand the notice of Consent for Participation. I do/do not consent to participate in the computer assisted learning research.

________________ Date

________________ Signature and printed name

Appendix F

Summary of Interview Responses

During interviews, student responses were recorded in note form, using direct quotes of key words and phrases, where this helped convey meaning. These key words and phrases were then entered into the response database. Interview questions are presented in full at Appendix D.

The following abbreviations are used in the response summaries:

ID - participant identification number

WP - word processing applications

DB - database applications

SS - spreadsheet applications

D&P - drill and practice

Gr - school grade level

Prog - programming

Intro - introduction

CALLAB - Computer Assisted Learning Laboratory

Exper- previous experience

nr - no record

na - not applicable

ID	Home use of computer
1	Nil
2	Occasional games
3	Nil
4	10 years- WP, CAI, DB
5	Nil
6	Nil
7	Nil
8	Rarely- WP
9	VIC20- programming
10	Nil
11	6 years- SS,WP,games
12	WP,DB, drill & practice for children
13	Rarely- WP
14	Nil
15	Rarely(1985)- WP
16	Nil
17	SS- baseball statistics
18	2 years- WP, games
19	7 years- WP, games
20	Nil
21	Nil
22	Nil
23	8 years- games
24	5 years- WP
25	10 years- WP, SS, DB, games
26	Commodore64- basic prog
27	Nil
28	Occasional- SS
29	Nil
30	10 years- prog, DB, games
31	Commodore64- WP, games
32	WP, prog, SS, DB
33	Nil
34	Nil
35	Prog, WP, SS, DB, games
36	WP, Art
37	Nil
38	Nil
39	WP- essays
40	Nil
41	Amiga- games
42	Nil
43	Nil
44	Nil
45	Nil
46	Nil
47	Familiarized through a friend
48	Nil
49	Nil
50	Nil

ID	School use of computer
1	High school computer science
2	Nil
3	Nil
4	Gr12- prog/University- computer aided design
5	Gr11- basic
6	Gr11- intro
7	Gr10- intro
8	Gr10- elementary programming
9	Junior high & high school- basic/club member
10	Nil
11	Nil
12	na (15 years out of school)
13	Gr9-12, English & Math
14	Games only
15	Gr12- WP, Night school- SS, DB, Programming
16	Nil (7 years out of school)
17	Gr9- intro, Gr12- Math
18	Gr9- prog, Gr13- graphs
19	Gr8- intro
20	Gr10- intro, Community college- ADP course
21	Nil
22	Nil
23	Gr7-10, prog/drawing
24	Gr10-13, computer science ,WP
25	Gr6, 10-12, most applications
26	Gr10- WP, prog/Community college CAI
27	Nil
28	Gr11- prog, SS, WP, DB
29	Gr10-11, prog, WP, SS, DB
30	Gr12-13, basic programming languages
31	Gr7-9, WP and intro
32	University- prog, intro course
33	SAIT- 3 CAI courses
34	Community college- basic prog & intro
35	Gr9-13, programming
36	Gr11- intro
37	Gr10- 12, WP, DB, graphics
38	Gr12- SS(accounting)
39	Intro using Commodore64
40	Nil
41	Nil
42	Gr10- intro
43	Nil
44	Nil
45	Nil
46	Gr10-11, WP, P, SS, DB
47	Gr11- limited math
48	Nil
49	Gr10- basic programming, WP
50	Nil

ID	Job use of computer
1	Nil
2	Nil
3	Nil
4	Nil
5	Nil
6	Video store- SS
7	Nil
8	Nil
9	Nil
10	Nil
11	Aboard Ship- parts DB
12	DB, WP
13	Nil
14	Reserve supply- WP,SS
15	Nil
16	Nil
17	Nil
18	McDonald's restaurant inventory
19	Nil
20	Video store- DB
21	Nil
22	Dow Chemical- pump control
23	Nil
24	Nil
25	Nil
26	Nil
27	Military Finance- DB, SS
28	Nil
29	Nil
30	UnisysCanada- programmer
31	Nil
32	WP
33	Nil
34	Nil
35	Nil
36	Nil
37	Nil
38	Nil
39	Nil
40	Nil
41	Nil
42	Nil
43	Machinery control panel
44	Nil
45	Nil
46	Nil
47	Nil
48	Canadian Tire- DB
49	Bartender- till
50	Nil

ID	CAI Expectations	Confirmed?
1	No expectations	na
2	A little leery	nr
3	Easy	Yes
4	Easy- CALLAB experience	Yes
5	Easy- CALLAB exper	Yes
6	Moderate- CALLAB exper	Yes
7	Progressively difficult	Yes
8	Easy	Slow pace
9	Easy- CALLAB exper	Yes
10	Not bad- CALLAB exper	Yes
11	Easy- CALLAB exper	Yes
12	Fairly easy- CALLAB exper	Yes
13	Easy (WordPerf tutorial)	Yes
14	Unknown but intrigued	Better
15	Easy	Yes
16	Easy	Eventually
17	Easy/Interesting	Yes
18	Unknown but excited	Yes
19	Not too hard	Yes
20	Perhaps difficult	No- easy
21	Perhaps difficult	No- easy
22	Uncertain	Easy use
23	Wary of typing	Fairly easy
24	Math hard/computer easy	Yes
25	Unknown but challenging	Yes
26	Easy- CAI exper (Math D&P)	Yes
27	Difficult	No- easier
28	Easy	Yes
29	Math hard/computer easy	Yes
30	Easy	Yes
31	Hard	No- easier
32	Easy	Yes
33	Easy- exper	Yes
34	Easy	Yes
35	Moderate difficulty	Yes
36	Moderate difficulty	Yes
37	Easy	No- bit harder
38	Moderate difficulty	Yes
39	Easy	Yes
40	Uneasy	Y&N: need patience
41	Easy- CALLAB exper	Yes
42	Easy	Bit harder
43	Easy- CALLAB exper	Yes
44	Easy- CALLAB exper	Yes
45	Unknown	Easy
46	Easy	Yes
47	Difficult- math anxiety	Easier
48	Easy- CALLAB exper	Yes
49	Increasing difficulty	Yes
50	Not difficult	Yes

ID	Perceived Learning Ability
1	Practical- quick/Theory- need repetition
2	Fairly good if material explained
3	Average
4	Fast if analytical material
5	Average
6	Very good
7	Average
8	Average if doing
9	Average if hands on
10	Average
11	Rapid if shown
12	Good if I can practice
13	Average, slow if theory
14	Above average
15	Average, fast if hands on
16	Good, if I can see it done (demonstration)
17	Very good especially math
18	Fairly quick with numbers
19	Excellent- enjoy it
20	Rapid if mechanically oriented, slow if arts
21	Have to work at it
22	Fairly quick if hands on
23	Average, prefer math/science
24	Quick if computer or math oriented
25	Pretty quick if structured
26	Average
27	Quick but slow if math
28	Fairly quick especially soc studies, chem/phys
29	Average- prefer mechanical applications
30	Fairly quick- can grasp & apply
31	Easy
32	Good
33	Good if interested
34	Quick if math, otherwise average
35	Good
36	Fairly good
37	Good
38	Bit slow- require persistence
39	Quick
40	Slow- poor retention
41	Takes a few practices
42	Fairly quick
43	Quick if shown
44	Not real quick
45	Average
46	Fairly well
47	Quick if hands on, average or less if otherwise
48	Really quick
49	Bit above average
50	Average

ID	Algebra preknowledge	Pretest accurate?/score
1	Very well	Yes- 22
2	Very little	Bit high- 18
3	Very little	Yes- 10
4	Quite well	Yes- 22
5	Not bad	Yes- 19
6	Minimal despite 3 crses	Yes- 19
7	Above average	Yes- 21
8	Well	Yes- 21
9	Well	Yes- 20
10	Pretty good	Yes- 18
11	Very well	Yes- 19
12	Well	Yes- 20
13	Average	Yes- 17
14	Poorly- little exper	Bit low- 17
15	Average	Yes- 19
16	Well but rusty	Yes- 18
17	Well	Bit low- 22
18	Well	Yes- 20
19	Very well	Yes- 25
20	Poorly	Yes- 14
21	Strong but rusty	Yes- 19
22	Fairly well	Yes- 22
23	Well	Yes- 21
24	Ok	Yes- 23
25	Ok	Yes- 21
26	Very little	Yes- 19
27	Fair	Yes- 16
28	Much forgotten	Yes- 16
29	Fair	Yes- 16
30	Good but much forgotten	Yes- 19
31	Good	Yes- 22
32	Good	Yes- 25
33	Not well	Yes- 17
34	Good	Yes- 20
35	Average	Yes- 19
36	Poor- 3 yrs outdated	Yes- 16
37	Very good	Low- 17
38	Not well	Yes- 17
39	Well	Yes- 23
40	Not at all	Bit high- 13
41	Very well	Yes- 25
42	Ok- but 4 yrs outdated	Yes- 17
43	Not well	Yes- 7
44	Poor	Yes- 10
45	Much forgotten	Yes- 15
46	Fairly well	Bit high- 22
47	Poor	Bit high- 20
48	Well	Yes- 24
49	Poor	Yes- 6
50	Really well	Yes- 20

ID	Learning style suitable for CAL?
1	Yes- repetition available if necessary
2	With help from instructor
3	Yes
4	Yes- prefer logic
5	Yes- learn on own
6	No- prefer classroom
7	Yes- material is black/white, right/wrong
8	Yes- only necessary instruction is given
9	Yes- self pace, visible results, range of help
10	Yes- like self pace
11	Yes- if can ask questions when desired
12	Yes- self pace
13	Partly- need hands on
14	Yes but prefer traditional methods
15	Y- hands on, N- can't see practical progress
16	Yes- see examples, learn by steps
17	Yes- keeps interest
18	Yes for maths/physics
19	Yes
20	Yes for learning theory, but prefer hands on
21	Yes- interactive, feedback
22	No- prefer human contact
23	Yes- own pace, follow instructions
24	Yes- interaction
25	Yes- can relate to computers
26	Yes- can work out material on own
27	No- prefer paper & note taking
28	Yes- explanations and optional D&P
29	Yes
30	Hard to say
31	Yes- accessible, easy, explanations available
32	Yes- logic, feedback
33	Not solely CAL- need human help
34	Yes- I seek shortcuts, CAI allows some
35	Yes- logic & clarity
36	Yes- if instruction is good
37	Kind of- computer operation was difficult
38	No- slow to adapt previous learning
39	Yes but prefer hands on
40	Not in isolation- want instructor present
41	Yes- adequate practice
42	Ok- new experience
43	Yes- with keyboarding practice
44	Yes- no pressure, work it out
45	Yes- comfortable
46	Yes- confident with computer
47	Yes- self pace, review
48	Yes- see logic of material
49	Y&N- successful, but prefer mix of instruction
50	Yes- but would like text as adjunct

ID	Enough computer experience?
1	Yes
2	Yes
3	Yes- easy
4	Yes
5	Yes
6	Yes
7	Yes
8	Yes- my mother could do it
9	Yes
10	Yes
11	Yes
12	Yes
13	Yes
14	Yes
15	Yes
16	Yes
17	Yes
18	Yes
19	Yes
20	Yes
21	Yes
22	Yes
23	Yes
24	Yes
25	Yes
26	Yes
27	Yes
28	Yes
29	Yes
30	Yes
31	Yes
32	Yes
33	Yes
34	Yes
35	Yes
36	No- hardware operation gave difficulty
37	Yes
38	Yes
39	Yes
40	Yes
41	Yes
42	Yes
43	No- keyboarding gave difficulty
44	Yes
45	Yes, after symbols for ops (*,/) learned
46	Yes
47	Yes
48	Yes
49	Yes
50	Yes

ID	Rank-Learning Ability	Rank-Prior Algebra
1	2	1
2	1	3
3	1	3
4	2	4
5	2	1
6	2	1
7	2	1
8	3	1
9	1	4
10	1	2
11	2	1
12	2	1
13	4	2
14	1	3
15	2	1
16	3	na
17	2	1
18	3	1
19	2	1
20	3	4
21	3	1
22	2	1
23	2	1
24	2	3
25	1	2
26	2	1
27	2	1
28	1	4
29	2	3
30	1	2
31	1	na
32	1	4
33	1	na
34	3	1
35	1	3
36	1	2
37	2	1
38	2	1
39	2	1
40	1	1
41	4	1
42	2	1
43	1	3
44	1	3
45	2	1
46	2	1
47	1	3
48	2	1
49	2	na
50	3	1

ID	Rank-Learning Style	Rank-Computer Experience
1	3	4
2	2	na
3	2	4
4	1	3
5	3	na
6	3	na
7	3	na
8	2	4
9	2	3
10	3	4
11	3	4
12	3	na
13	3	1
14	2	3
15	4	3
16	2	1
17	3	4
18	4	2
19	3	4
20	2	1
21	4	2
22	4	3
23	na	3
24	1	3
25	3	na
26	3	na
27	3	na
28	2	3
29	1	4
30	3	na
31	2	3
32	2	3
33	2	na
34	2	4
35	2	na
36	3	4
37	3	na
38	3	4
39	2	3
40	2	na
41	3	2
42	3	4
43	2	na
44	2	na
45	3	na
46	3	4
47	2	na
48	3	na
49	1	na
50	2	na

ID	Self-pacing opinion	External pacing?
1	Like it	No
2	Good, esp for review	No
3	nr	No
4	Like- productive time	Some
5	Like it	Some- final deadline
6	Good, but needs discipline	Some-3 or 4 deadlines
7	Right up my alley	No
8	Like it	No
9	Like it	Some- to motivate
10	Like- not sociable	Some- ensure progress
11	Real good- challenge	Some
12	Good	No
13	Like it	Some
14	Good- break when needed	Some- increase output
15	Excellent	No- don't push
16	Great- own speed	Some- procrastinator
17	Enjoyed- own breaks	Some- final deadline
18	Best part about it	Some-3 or 4 deadlines
19	Great	No
20	Like it	No
21	Yes	Some- final deadline
22	Like a lot	Some- half days
23	Like it- quicker	Some- final deadline
24	Like it	Some- 3 deadlines
25	Like- excel or ponder	Some- final deadline
26	Not entirely suitable	Some- one per day
27	Enjoyed	Some- final deadline
28	Like it	Some- daily deadlines
29	OK	Some- final deadline
30	Really like it	Some- final deadline
31	Pretty good	Many- every 20 min
32	Good	No
33	Ok	No
34	Good	Some- 3
35	Good	Some- progress norms
36	Like it	Some- final deadline
37	Like it	No
38	Excellent	Some- deadline/obj
39	Fine	Some- daily
40	Like- no boredom or shame	Some- deadline/obj
41	Appealing- no pressure	No
42	Ok	No
43	Pretty good	Some- final deadline
44	Good	Some-
45	Good	No
46	Great- no rush	Some-2 or 3 deadlines
47	Comfortable	No
48	Best part of it	No
49	Good	No
50	Good	No

ID	Worthwhile?	Better method?
1	Yes	No
2	Yes	Human tutor/classroom
3	Yes	No
4	Yes	No
5	Yes as review	No, self study on par
6	Yes as refresher	One on one w/supervisor
7	Yes	No
8	No- math too basic	Start at threshold
9	Yes	Higher threshold
10	Yes	No
11	Yes	No
12	Yes	No- with self discipline
13	Yes	No
14	Yes	No
15	Yes	No
16	Yes	No
17	Yes- excellent review	No
18	Yes	No
19	Yes- good review	No
20	Yes	No
21	Yes- kept attention	No
22	Yes	More explanations/samples
23	Yes- good refresher	No
24	Yes	No
25	Yes	No
26	Yes	No
27	Yes	No- not as review
28	Yes	No
29	Yes	No
30	Yes	No
31	Yes	No
32	Yes	No
33	Yes	No
34	Yes	No
35	Yes	No
36	Yes	No
37	Yes	No
38	Yes	Instructor to show errors
39	Yes	No
40	No- math not needed	Instructor to show errors
41	Definitely	No
42	Yes	No
43	Yes	Uncertain
44	Yes	1 on 1 with instructor
45	Yes	No
46	Yes	Unsure
47	Yes	No
48	Yes	No
49	Yes	Unsure
50	Yes	No

ID	Help frequency	Help source
1	0	na
2	3	Instructor- avoided CAI tutorial
3	Often (12+)	Instructor
4	0	na
5	0	na
6	2	Student or CAI tutorial
7	0	na
8	0	na
9	0	na
10	2	Self- worked out
11	1	Instructor
12	0	na
13	1	Instructor
14	2	Student
15	2	Self- review by CAI
16	6	Self- review by CAI
17	0	na
18	2	Student
19	0	na
20	1	Student
21	0	na
22	0	na
23	0	na
24	3	Student
25	0	na
26	3	Student
27	2	Student
28	1	Student
29	0	na
30	2	Instructor
31	1	Book
32	0	na
33	24+	Instructor 3, student 21
34	2	Instructor
35	0	na
36	2	Instructor
37	4	Instructor
38	3	Student
39	1	Student- easier than CAI tutorial
40	8	Instructor
41	0	na
42	2	Student
43	Often	Instructor
44	5	Instructor 3, student 2
45	0	na
46	2	Student
47	10	Student
48	0	na
49	Quite often	Student mostly, also instructor
50	0	na

ID	Preferred method
1	Combination- CAI for practice & test
2	Traditional class
3	Combination- 70% traditional/30% CAI
4	Combination- 30/70
5	Combination- 25/75
6	Traditional class
7	Combination- 40/60
8	Combination- 20/80
9	Combination- 50/50; CAI valuable for review
10	Combination- 60/40
11	Combination- 60/40; need some human instruction
12	Combination- 70/30; instructors for new material
13	Combination- 50/50; CAL gives good examples
14	Combination- 70/30; instructors have more tricks
15	Combination- 25/75; based on previous CAI exper
16	Combination- 40/60
17	CAI
18	Combination- 50/50; often want specific answers
19	Combination- 70/30; need instructor personality
20	Combination- 40/60; good instr> CAI> bad instr
21	Combination- 40/60; new information from instr
22	Combination- 50/50; new information from instr
23	Combination- 20/80
24	Combination- 40/60; human demonstration of skill
25	Combination- 40/60
26	Combination- 30/70; human explaining can boggle
27	Combination- 40/60; up to 100% CAI for review
28	Combination- 50/50; class work for skills
29	Combination- 65/35; class work for new material
30	Combination- 60/40
31	Combination- 20/80
32	Unsure
33	Combination- 40/60; class work for new material
34	Combination- 50/50
35	CAI
36	Combination- 60/40
37	Combination- 40/60
38	Combination- 70/30
39	Combination- 60/40
40	Combination- 40/60
41	Combination- 80/20; CAI for D&P
42	Combination- 70/30
43	CAI- save time
44	Traditional class; prefer human contact
45	Traditional class; like interaction with instr
46	Combination- 25/75
47	Combination- 40/60
48	Combination- 5/95; class work for clarification
49	Combination- day traditional, evening CAI
50	Traditional class; nothing beats good instructor

VITA

Surname: Donnelly	Given Names: Joseph Michael
Place of Birth: Regina	Date of Birth: Jan 29, 1954

Educational Institutions Attended:

Royal Roads Military College	1971 to 1973
Royal Military College of Canada	1973 to 1975
University of Victoria	1991 to 1993

Degrees Awarded:

B.A.	Royal Military College	1975

PARTIAL COPYRIGHT LICENSE

Title of Thesis: Predicting Achievement in a Computer Assisted Learning Environment.

Author [redacted]
(Signature)

JOSEPH MICHAEL DONNELLY
(Name in Block Letters)

18 JUNE 1993
(Date)