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ABSTRACT

The current state of the art on the educational use of microcomputers was explored through a review of the literature, observations, and interviews with teachers and practitioners. A working taxonomy to characterize typical computer-augmented learning environments (CALEs) was developed which consisted of environmental elements, activity segments, teacher-learner environment situations, and learner attributes. Results of the interviews with teachers and practitioners showed that in their CALEs, teachers concentrated less on the presentation of curriculum context and more on computer literacy, thinking, and problem skills, and computer applications. Their expressed needs were for more computers, quality software, and computer-related teacher training. Positive and negative factors affecting CALEs included: (1) the "hardware reliability" problem, (2) the "access" problem, (3) the "friendly environment" problem, (4) the "social pressure" problem, and (5) the "overbearing person" problem. A hierarchy of achievement that most students pass through was specified, which included fear, curiosity, understanding, and tool use. The profile of a successful computer student showed that such learners tended to be bright, often boys, math and science oriented, logical or analytical thinkers, and persevering. Details on the survey itself and on the taxonomy are appended, and extensive references are provided. (Author/BK)

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EXPLORING THE MICROCOMPUTER LEARNING ENVIRONMENT

LIZA LOOP

PAUL CHRISTENSEN

Report # 5

Independent Research and Development Project Reports

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Without your cooperation and support this research could not have been done. Without your creative participation the computers in education movement would move much more slowly indeed.

FOREWORD

This report describes the results of one in a series of Independent Research and Development Projects funded by the Far West Laboratory for Educational Research and Development, using its own resources generated by fees earned on various contracts. These Independent Research and Development Projects, conducted by individual professional staff members of the Laboratory, represent pilot efforts that address new problem areas of significance to regional or national educational needs or that create new resource or methodological areas heretofore unexplored by Laboratory staff.

Awards are made on a competitive basis annually or semiannually, depending on available funds. In addition to requirements that projects be completed within nine months and require less than one quarter person year effort of any Laboratory employee, the proposals are scored on four criteria: (a) they must promise to open a new area of research or development or extend significantly the productivity of an existing area, (b) they must be of high quality, (c) they must be difficult to fund through known private, governmental, or foundation funding, and (d) they must be closely related to the Laboratory's mission.

Following review by the Independent Research and Development Committee, recommendations for funding are forwarded through the Laboratory Director to the Program Committee of the Board of Directors of the Laboratory for their review and approval.

The following is a listing of the Independent Research and Development Project award recipients and a brief description of their projects.

Joaquin Armendariz. Development of Resources Relating to Systemic Design Models and Methodologies. This project tests the feasibility of developing instructional resources in design models and design methodologies for educational practitioners. Two monographs describing significant design approaches and key reference works will be prepared.

Ann Bouie. Identification of the Problematic Situation. The extent to which students assume responsibility for the acts that result in disciplinary measures as compared to the extent to which they see the causes as lying outside their control is the primary focus of this study. Though much of literature explains student misbehavior, the vast majority of these explanations cite factors beyond direct student control, thus overlooking the potential influence of free choices, perceptions of acts, and contexts in which these occur.

Matilda Butler. Dynamics of School Health Education in the Far West Laboratory Region: A Pilot Study. School health education represents a challenge for the 1980s. This project is designed to provide information on the needs, goals, programs, participants, materials, etc., of school health education in Northern California, Utah, and Nevada.

Information was gathered through interviews with key state personnel and questionnaires sent to school district personnel.

Paul R. [illegible]stensen. Educational Use of Microcomputers. This project summarizes the current state-of-the art on educational use of low-cost, high-capacity, self-contained microcomputers; develops a taxonomy by which to characterize typical computer-augmented learning environments; and describes teacher perceptions of the "computer readiness" of students and the positive and negative factors in the learning environments.

Natividad DeAnda. Competencies of Leaders and Managers in Educational R&D. The study's goal is to produce an outline of competencies essential to successful management and leadership of educational projects, by analyzing job descriptions of managers and non-managers at the Laboratory for skill and knowledge areas utilized in their work. The study provides data for determining which competencies are considered essential to program management at the Far West Laboratory.

Jill S. [illegible]son. A Survey of Work-Related Attitudes of Professionals in Special Education. This study examines the attitudes toward work of teachers and administrators engaged in special education--persons who are in a position to exert strong influence on the developing work values of handicapped young persons. The study is seen as an exploratory step into needed research in work-related attitudes of handicapped young people and the effect on them of attitudes of their teachers.

J. Ronald [illegible]lly. Expanding Experiences and Employment for the Elderly Through Non-Center Based Family Child Care. This project is a needs assessment and feasibility study designed to investigate the possible creation of a system for delivering quality child care services and meaningful employment for the elderly in child care.

Chesca Piuma. Feasibility Study: Developing a Vocational Education Training Program for Severely Handicapped Adolescents and Young Adults. This study investigates the feasibility of developing five vocational education curricula for severely handicapped (trainable mentally retarded) adolescents and young adults (ages 13-21) in the employment areas of gardening, housekeeping, laundry, minor auto maintenance, and food services.

The Far West Laboratory Independent Research and Development Committee:

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ABSTRACT

EXPLORING THE MICROCOMPUTER LEARNING ENVIRONMENT

Liza Loop and Paul Christensen

It was expected that someday computers would play a major role in education. With the technical advancements that have resulted in low cost, high capability, self-contained microcomputers, the realization of that prediction is technically plausible. Computer (including toy) manufacturers are beginning to have an impact through the ballooning sale of these microcomputers, often called personal computers or home computers, which are finding their way into the classrooms as well as the homes, offices, and other places in the community.

Much of the microcomputer development, the hardware, software, reaearch, and support activity is concentrated in the (greater) Bay Area. FWL is in a unique position to contribute to the educational applications of this enterprise.

The intent of this study was to explore the microcomputer learning environment through examination of the literature, observations, and interviews with teachers and other practitioners in the San Francisco Bay Area. The objective was to summarize the current state-of-the-art on the educational use of microcomputers; develope a taxonomy by which to characterize typical Computer-Augmented Learning Environments (CALEs); and describe teacher perceptions of the "computer readiness" of students and the positive and negative factors in the learning environments.

From a review of the current status of the use of microcomputers in learning, two major conclusions can be drawn: (a) the "horizontal" spread of microcomputers in education throughout the population has been much more rapid than expected; and (b) vertical growth, interms of new knowldege of how to use computers for learning, has made very little progress when viewed from a twenty year perspective.

A convenient way to partition and describe Computer-Augmented Learning Environments (CALEs) is according to their (a) Environmental Elements, (b) Activity Segments, (c) Teacher-Learner Environment Situations, (d) Learner Attributes, and (e) Educational Functions and Levels. A working taxonomy was formulated using those major categories.

In their CALEs, Bay Area teachers concentrated less on the presentation of curriculum content; more on computer literacy, thinking and problem solving skills, and computer applications. Their expressed needs were for more computers, quality software, and computer-related teacher training.

Recommendations are made in the report for exploring and systematically describing existing Computer-Augmented Learning Environments (CALEs), studying the emerging role of computer learning facilitators, and preparing materials for teacher training in educational computing.

I. THE STUDY IN BRIEF

A. INTRODUCTION

It is now twenty years after the first predictions of an imminent revolution in education based on computer technology. During these years, dramatic changes in three factors, the size, cost, and computational power of computers have been accomplished. These factors were thought to be the major roadblocks to the educational use of computers. They have been overcome. But today, the impact of computers on the practice of learning and teaching is still very slight and computers in the classroom remain an object of controversy. What are the arguments in this debate?

Those who oppose the expenditure of funds to bring computers into education claim that:

- computer education doesn't work,
- it is too expensive,
- it is a threat to teachers' jobs,
- it is an inhumane environment for learners

Those who support computers in education claim, on the other hand, that:

- the computer works better than many other educational device - sometimes better than teachers,
- it is cost effective,
- it does not threaten the "good" teacher, only one who refuses to enter the 20th century,
- the computer provides a more individualized and less judgemental environment and is, therefore, more "humane" than many teachers. (Heuston, 1980)

In addition, many proponents feel that the computer is a unique and effective laboratory for teaching an elusive skill commonly called "thinking."

How can these assertions be evaluated and a rational decision reached by parents, teachers and others responsible for creating educational environments? To understand what the debators really claim, the issues must be stated more precisely. To determine whether or not computers "work" in education we must understand what is supposed to be taught and have a way of measuring whether it has been learned. To evaluate the cost-benefit of computers, we must compare the cost of teaching like curricula by different methods. To decide whether jobs are threatened, we need to understand the role of the teacher in a learning environment which has computers in it. To judge whether all learning environments which contain computers are "inhumane" or not, we must first observe several such environments and decide whether they are sufficiently alike to be considered as a single class.

The report that follows documents several months of observation and analysis directed towards a clear restatement of the computer in education debate. No attempt is made to reach a definitive resolution of this controversy since many pivotal issues, such as cost-benefit, are not addressed at all. However, two important contributions are offered:

a. a perspective which brackets the spectrum of environments in which learners use computers, and

b. a vocabulary which permits analysis of the static elements and dynamic processes taking place within such environments.

Armed with these tools, parents and educators can come to their own rational conclusions regarding the use of computers in their particular situations.

B. SPECIFIC GOALS OF THIS STUDY

The study presented in this report was a pilot effort funded by Far West Laboratory. Our goals were:

a. To explore the state of the art of computers in education

b. To characterize some Computer-Augmented Learning Environments (CALEs) and begin to define:

(1) positive and negative factors in the environment,

(2) successful experiences for the learner,

(3) prior conditions or experience that may promote "computer readiness" for the learner.

c. To provide a basis for clarifying issues by developing a tentative exposition of the relevant dimensions (a taxonomy) in the microcomputer learning environment and then to test this taxonomy against existing educational computing projects in the greater San Francisco Bay area.

d. To suggest areas for further research which would aid educational practitioners (including parents) in making decisions on the use of computers for learning.

C. APPROACH

Analysis and interpretation were interwoven with data collection throughout the period of this study. Sources of data included the literature, observations of computer-learning settings around the Bay Area, pilot survey questionnaire, and telephone interviews.

This study proceeded in two stages. The first stage included several activities that will be described in the "BACKGROUND" section. They consisted of:

a. Examination of written materials on the educational use of microcomputers.

b. Field study of local (San Francisco Bay Area) Computer-Augmented Learning Environment (CALEs)

c. Design and tryouts of survey and questionnaire items.

d. Participation in relevant conferences.

e. Development of a working taxonomy for use in describing Computer-Augmented Learning Environments (CALEs).

Stage One provided a picture of the current literature, current field practices, character of interview and questionnaire responses, and concerns expressed by educators. From this base, the activities of Stage Two were begun. They consisted of:

a. additional data collection by further observation and interviews with teachers and other experts on computers and learning,

b. analysis of data,

c. interpretation of findings,

Results of Stage Two will be discussed in sections III through VIII.

The interviews with teachers employed a sample, questions, and parts of the taxonomy developed in Stage One. The objective was to begin to study the concepts of "computer readiness" and to study teachers' perceptions of factors associated with successful computer applications in education.

Data collected aided in defining the static parameters operative in Computer-Augumented Learning Environments and in identifying the activities and processes which commonly take place in them.

D. SUMMARY OF FINDINGS

1. About Current Status

This report concludes six months of formal observation and interviews about the current use of computers for learning. Two major conclusions are drawn from review of current status:

a. The "horizontal" spread of microcomputers in education throughout the U.S. population has been much more rapid than expected.

- Microcomputers are already a significant tool for learning in schools which should be studied and supported.
- The microcomputer has broken a price barrier making it accessible to learners at any school and in many homes, wherever there is a perceived need.
- Educators, egged on by the media and the prevalence of computer-controlled devices in daily life, are placing a higher priority on learning about computers and how to use them.
- Teachers are filling almost every course they can find which might possibly train them to use computers in their work.
- There is an expressed need for support including texts, computer programs, audio-visual materials, and evaluation for learning and teaching with microcomputers.

Even with such rapid growth in this movement, the majority of students and teachers in this country have not yet touched a computer. The individuals we encountered who attend conferences and contribute to the literature in this field report that "computer users" are a tiny minority in their schools and neighborhoods. In the rare cases where a large percentage of students at a school have any direct access to computing, this activity usually represents a small percentage of their total educational program.

b. Vertical growth, in terms of new knowledge of how to use computers for learning, has made very little progress when viewed from a twenty year perspective.

- The software design principles now being used to develop programs for microcomputers are the same as those used on large machines in the '60's and early '70's. This is because "micro" and "maxi" computers are often similar from the user's point of view. They provide pictorial as well as text displays and non-keyboard input devices such as joysticks may be used. Small and middle-sized computers have historically been limited to keyboard input and typed output, and thus require more limited program design.

- The curricula which present computers in education, although now more common, are not radically different from those available to a few gifted students of a decade ago. Getting comfortable with computers, learning to "think," learning other subjects through CAI, and exploring decision making through simulations- these have always been the common objectives in computer-augmented learning environments.

The dream of CAI -- of using the computer as a complete, cost-effective, individualized, instructional delivery system -- has not yet been met. The advent of microcomputer hardware has removed what was thought to be the biggest obstacle to CAI, the lack of powerful, low-cost hardware. But a bigger problem has emerged, the creation of software that is of acceptable quality. Straightforward drill-and-practice programs and simulation games with educational value are now quite common. But these materials only serve as supplements to more traditional presentation of material. To produce software that adequately presents new curricular material has proven to be difficult and expensive. To produce computerized diagnostic instruments that can identify and correct mistakes in a student's knowledge is even harder. Many computer teachers are solving their software deficit by writing their own. Unfortunately, the materials generated this way tend to be idiosyncratic in content, style, and reliability. They are rarely suitable for inclusion in any library without many hours of revision and "polishing."

2. About the Scope of Bay Area Environments

Educational environments with computers in them were available for study in the San Francisco Bay area. These environments vary in who uses them, when, how long, under what circumstances, for what purposes. We found students from five to eighty-five years old using computers. Many were playing their first computer game. A few worked with a computer daily. Some felt like isolated pioneers inventing their course of study as they learned it. Others encountered the computer on familiar territory, surrounded by supportive friends, confronting traditional scholastic material through this new medium. Most often, Bay Area classrooms offered computer literacy, computer games and simulations, drill and practice to supplement traditional curricula, or BASIC language computer programming.

The local computer environments appear to be similar to those found nationwide but comparisons based on this preliminary study are necessarily very rough. We found a growing body of common experience among computing teachers and an intense desire for more intercommunication.

We also found that professional meetings in this field are helpful and of two distinct types. Some, such as the California Mathematics Council's Annual Conference at Asilomar, are dominated by teachers beginning to use computers and trying to catch up to the state of the art. Less common, but equally important, are meetings exclusively for leaders in educational computing. These serve as a spawning ground for new concepts or insights in this rapidly changing area.

3. Classifying Computer-Augmented Learning Environments (CALEs)

Much variability was noted in the use of terms for describing what is happening in Computer-Augmented Learning Environments (CALEs). To help ourselves understand and communicate about this largely undelineated area, we formulated a provisional taxonomy. The taxonomy, presented in brief below (and in detail in Appendix B), set up classifications for the physical and social setting, types of activity, and terminology for variations among learners and teachers. The taxonomy provided a model with which to organize observations and interviews.

Much work remains to be done on this preliminary classification scheme. The teacher interviews, reported below, reveal modifications appropriate for the hardware, software, and learning environment sections. Additional evaluation must be done with activities and student profiles.

4. About Teachers

Typically, junior or senior high-school math teachers are the vanguard of computer teachers. However, teachers from other disciplines and lower grades are quick to see the possibilites of the computer. If they can overcome their initial anxiety about learning to use this new technology, computer use will spread throughout a school. Among those we encountered in the study, many were newcommers who had had access to a computer for less than two years. They were all enthusiastic when discussing how much their students enjoyed working with the machine and were looking forward to increasing computer use in their classes. These newcommers reported that they needed more orientation to the field of educational computing and hoped that this study would be useful to them.

The more experienced teachers from our interviews, those who had been using computers for more than two years, offered many more insightful comments about the nature of their students and how to set up successful environments. Experienced teachers felt they knew what made a successful CALE and mentioned positive and negative factors they had encountered. They were familiar with software and could suggest programs for use with particular student groups. Experienced teachers were all equally enthusiastic and delighted to help "spread the word."

5. <u>About Students</u>

Because we interviewed teachers without much direct observation or testing of students, we were forced to see students through their teachers' eyes. Most teachers expressed the belief that all students could use computers and they judged student success on an individual basis. At first many teachers were surprised and confused when asked to describe the characteristics of "successful" computer students. When the question was modified to ask which students learned most easily and were able to handle more complex tasks, teachers reported similar characteristics:

- males, or very bright females,
- bright or gifted, although not necessarily high academic achievers,
- able to follow and initiate logical or step-by-step procedures,
- perseverent, willing to spend extra time and thought on a project.

It is possible to use computers with non-readers, teachers said, but a reader or someone who already knows the game must be present to help. The play must be simple enough to let the player memorize how to do it. When a student was not "successful" with a certain computer program, the teacher would search for another one rather than allow "failure." Teachers who use computer games encourage kids with low academic motivation to read and practice math. Video games requiring advanced eye-hand coordination were very popular with preadolescent boys. Basically, we found that teachers set up different CALEs for different student groups although they were not able to describe this at first.

Although many Bay Area computer learning environments began as enrichment programs for gifted students, most teachers we interviewed recommended that computers be available to all students.

6. Tasks Emphasized by Teachers

Much of the literature on computers in education, especially the popular press, focuses on Computer Assisted Instruction (CAI) and Computer-Managed Instruction (CMI). In CAI, the computer either presents new material in the absence of a teacher or provides supplementary drill and practice on subjects already introduced by the teacher. In CMI, the computer is used by the teacher for record keeping with on-line testing, diagnosis, and prescription of remedial lessons available on the most suphisticated systems. But in this study of mirocomputers, we found a disproportionately small number of learning environments in which the computer's major purpose was to present the curriculum content contained in the program or to support classroom managment functions.

Local teachers are concentrating on:

a. Computer literacy. Although the exact content of each course is modified to suit the level of the student, a central message unites all computer literacy courses observed in this study be comfortable using the computer, learn to control it. Use it as your personal tool. Know that wherever you find a computer, a person is responsible for creating its program and thus its behavior. Be aware of how pervasive the computer is in modern [illegible]

b. Thinking and problem solving skills. I[illegible] activity, operating the computer itself is the fir[illegible] blem. This requires step-by-step procedures, memory, accura[illegible] rseverance, and often a good deal of creative guessing. As operation of the computer is mastered, the privilege of using the computer becomes part of the motivation to address further puzzles or problems. Writing computer programs of increasing complexity is one type of puzzle. Preprogrammed games and simulations may also be used.

The problem presented by the program must be appropriate for the physical, intellectual, and emotional level of the learner. As the learner's skill improves, the puzzle becomes more difficult. This increase in difficulty can be controlled 3 ways, by:

1) using a "smart" program, which branches to harder problems whenever a high percentage of right actions or answers are given;

2) providing the student free access to a large library of programs so that he can choose his own challenges;

3) sequencing a curriculum, beginning with simple games and simulations, and mov[illegible]ng on to simple and then complex programming.

c. Computer applications. In a few cases, we found that students use the computing and data processing capacities of the computer to aid them in the job of learning much the same way other professionals use it in their work. <u>Word processing</u> helped them with report writing, computation provided numerical results that would otherwise be too costly in time and effort, data base storage and retrieval aided in holding, organizing, and accessing cumbersome amounts of information, and simulations permited exploration of the effect of several variables in situations too costly or too dangerous to learn about directly.

7. Common Needs of Local Teachers

When asked about their needs, most teachers mentioned the same themes: more computers are needed so more students could have more time to work with them, more and better quality software, and more teacher training.

a. More computers. The computer industry is now becoming responsive to both the consumer and educational market and is therefore making more powerful computer equipment available in the $500 to $5,000 price ranges. There remains a need for teachers to specify more completely what equipment they want. These specifications must be communicated to manufacturers, school boards, and to fellow teachers.

Those who control the budgets of learning environments -- parents, school boards, and administrators -- are also becoming aware that computers can be effective educational tools. However, they are often unable to get a clear, succinct explanation of how or why the computer is an improvement over conventional teaching methods. This study is designed to contribute to that explanation.

b. Quality software. Most teachers said they needed better software. They seemed to be able to recognize good quality software when they saw it, but they rarely wrote it themselves. Even specifying the characteristics of good software seemed to be prohibitively difficult. This may be why there is so little good software available at the present time from any source. However, it may not be wise to conclude that an influx of well-written CAI software will be of greatest benefit to computing students (as compared to teachers).

One could speculate that the existence of the highly innovative and creative uses of the computer found in the Bay Area are a direct result of the lack of ready-made teaching programs. The use of ready-made CAI is much easier for the teacher but may be much less valuable to today's students than learning to use computer tools in a variety of software environments.

c. Teacher training. Teachers who had never seen computers used before were observed at several conferences and training sessions. The state of the art of computers in education has advanced far enough so that they could immediately grasp the power and motivational value of this new learning medium. These total beginners in computer use were often afraid of and bewildered by the technology. They wanted computer literacy courses to begin their training.

In addition, they asked for information on curricula they can incorporate into existing classes and knowledge about other educational computer applications. Many would like to learn programming so that they can teach it or develop educational software. Teachers are currently using almost every available source of training from enrolling in jr. college classes to sitting in on the classes given in their own schools. Many teachers have bought their own personal computers and are learning on their own time at home. They are asking for more in-service programs, state college courses, conferences, and professional meetings to help them.

E. RECOMMENDATIONS

The findings reported in this study were gleaned from somewhat meager amounts of data. However, we believe they cover several extremely important areas which deserve further and more rigorous attention. Therefore, we suggest that the following four projects be undertaken in the near future.

1. The Development and Publication of In-depth Descriptions of CALE Models

Farther on in this report, we discuss, in brief, seven Computer-Augmented Learning Environments. There are many others which we have not had time to study. Each environment should be explored in-depth and written up with a check list of factors which indicate which CALEs are most effective with different student populations.

This document could be used by educators as a basis for grant proposals, and presentations to school boards. It could also provide guidelines for teachers while in the actual process of setting up their computer-augmented classrooms.

2. <u>The Role of the Learning Facilitator in CALEs</u>

Teachers in our study were performing many tasks not generally required of their non-computing colleagues. They served as electronics repair people, programmers, community liasons, career counselors, and librarians - to name a few. The more traditional role of "information siphon," -- transfering knowledge from a book, through the teacher's brain, into the student's memory -- became less important in some cases while teaching problem solving was emphasized.

We recommend that a study be done which looks at role changes now being experienced by computing teachers and which projects several years into the future. Attention should be paid to training requirements for teachers, changing job descriptions within school settings, and the possible rise of new learning environments that might employ computer learning facilitators.

3. <u>Designing Successful CALES for Teaching Logical Thinking</u>

Teachers, when prodded, were able to identify those students who would "take to computers" easily. Usually such students were already interested in math or science, able to understand and generate logical sequences, and willing to stay focused on a problem. But teachers also reported that working with computers teaches these same skills.

Very little data was available on people who did not choose to work with computers. Are they different from those who succeeded in becoming "computer comfortable?" Do computers really teach "logical thinking" or do they merely strengthen by providing a laboratory where students may exercise logical skills which they already have? Can one design a computer-augmented learning environment for artistic, right-brained children; for kinesthetic learners; for adults who are afraid of technological equipment?

With computer-controlled machines becoming increasingly common in modern society, we recommend research in this area. Some work has been done in the fields of personnel screening and individual differences but it has not been applied to basic education. Companies that produce products for "the office of the future" need this information as do educators who forsee increasing automation in their own institutions.

4. Materials for Teacher Training in Educational Computing

There was a strong need expressed by most people involved in this study for teacher training at the upper class college level and for inservice training. Many such courses exist but there are not enough to meet the demand. Each new trainer must design his own course and gather materials from a potpourri of sources. Although efforts to evaluate and disseminate educational computer software are underway by project MicroSIFT of Northwest Regional Laboratory (Edwards, 1980) and CONDUIT (CONDUIT, 1980) at the University of Iowa, there is no coordinated push to organize material in print, slide, and video tape media.

We recommend that a project be mounted to produce sets of multimedia material and course outlines suitable for use as one unit of upper class credit in microcomputer applications in education. This package would draw largely on items now available with new materials developed to fill in the gaps. It should not be based on a single manufacture's hardware and should include many of the findings of this research.

II. BACKGROUND

A. CHARACTERIZATION OF THE FIELD

Significant changes are occuring with computers in education. But, up to the present, their pace has been evolutionary rather than revolutionary. However, if one looks at the field of computer technology in 1980 one sees that the pace is quickening. Many of the technological obstacles to the application of computers to learning have been overcome. The emergence of the microcomputer, especially, has opened the portals. The microprocessor-based computer is entering into the consumer market place along with a profusion of electronic toys. Individual families and classrooms can now purchase machines capable of delivering much of the computer-assisted instructional materials developed privately and under federal contracts during the past 20 years (PCC, 1975). Since these microcomputers can support high level programming languages, they can also be used to teach children computer programming. They can deliver the more interesting of the proliferating computer games and simulations. They also are opening up the most exciting educational application, that of student controlled, unstructured learning (as compared to pre-programmed computer-assisted instruction).

Trends in educational use of computers noted in our literature review are that the frequency of use is going up while the cost per unit contact hour is going down. This drop has been estimated to be from $4.00 to $1.00 for large machines. One can expect the costs for stand-alone microcomputers to be less by as much as 50% for limited-branching branching and self-assessment programs. On the other hand, the cost per contact hour for traditional schooling is going up while the quality of education appears to be no more than holding its own (Time, 1980).

Distinctions between terms for small computers are getting more and more fuzzy, as machines with much the same capabilities are called microcomputers, home computers, personal computers, office computers, or even, for some, computer toys. The typical low-cost microcomputer has a microprocessor, memory chips, a TV console for displaying data, a keyboard for entering information, and a cassette or diskette recorder/ player for saving programs and data for future use. There are many variations of this configuration. Microcomputers commonly found in educational settings include the Tandy Radio Shack (TRS-80), Commodore Pet, Apple II, Compucolor II, Atari 800, North Star Horizon, and others.

Microcomputers are getting cheaper and more powerful. They are supplementing and/or supplanting the timeshared configurations or augmenting them. They have been made possible through such developments as solid state and large scale integrated electronics, and "tiny" but powerful, high level, computer languages. There are currently more than 500,000 microcomputers in homes, schools, businesses and laboratories in operation (Tandy, 1980). And that number continues to increase at a surprising rate. Microcomputer equipment is rapidly appearing in schools, libraries, and learning centers. The impact of these systems is likely to be underestimated.

At the heart of the microcomputer system lies the computer circuitry miniaturized on silicon chips, a large percentage of which are manufactured in Silicon Valley in the southern sector of the San Francisco Bay Region. Much of the computer development, computer manufacturing, research, and application development resides in this same area. The computers in education movement has found fertile ground to grow among this highly sophisticated, technologically oriented population. It is believed there have been more computers in educational settings for longer periods of time in this region than in any other part of the world. It is a fascinating setting in which to conduct this study.

B. CHARACTERIZATION OF THE LITERATURE

A large literature on the use of computers in education extends back to the early sixties. Much of it is repetitious and confusing because so many kinds of computing are subsumed under this one heading. Educational computing includes all levels - from kindergarten skill development to advanced degrees in computer science. Basically, every computer is "educational" because several people must learn how to run it.

Early on, substantial grants from the National Science Foundation, Carnegie-Mellon, Ford Foundation, and others stimulated research and development in the use of large time-shared computers as educational delivery systems (see, for example Papart, 1975 on Logo; Control Data, 1976 on Plato). These funding sources also promoted the education of professional computer scientists. As microcomputers became more accessible they were introduced into general education classes.

A computer search was made through the Lockheed omnibus document search system and pertinent documents were examined. Six trends in the literature on computers in education were noted.

1) Educational Data Processing: the use of computers to automate all forms of record keeping necessary for the administration of educational institutions. Although this is an important application of computers in education it is not a direct part of either teaching or learning and is therefore outside the scope of this study.

2) Computer Science: programming and electronics. Until recently, these subjects were introduced only in technical schools or universities and were not in any way considered "general education." Now, references to computer programming and the operation of (and occasionally even construction of electronic equipment) is done in fourth and fifth grade classes.

3) Computer Literacy: the demystification of computing equipment and practices and the understanding of some of the social effects of computers.

4) Games and Simulations: the development and use of computer software which turns the computer into a game board, a game opponent, or a stage setting within which the player may try different tactics to accomplish a specified goal. Simple games are available to teach preschoolers the alphabet or color discrimination while complex ones challenge adults to land an imaginary plane or toy with national economic decisions.

5) CMI: Computer-Managed Instruction. Usually available on larger computers, this involves the use of computers to track student progress through curricula which may or may not be computer-based.

6) CAI: Computer Assisted Instruction. Although many names are used, CAI is the most common one for using the computer to deliver, drill, or test specific curricular material. (Frenzel, 1980).

For the purposes of this study, two important developments documented in the literature are notable: first, the advent of the microcomputer, second, the development of several kinds of computer software: a) many computer games, b) computer simulations of current or historical events, c) high-level computing languages which allow children and non-mathematical adults to use the computer as a tool, d) languages for use by teachers and curriculum developers for creating automated lessons.

Much of this software development was done on bigger computers, many of which are still being installed in schools. One major problem of large computers arises because their computing power makes them capable of handling most of the data processing problems encountered by schools and school districts. The school administration and the instructional program find themselves competing for limited computer time. Up until the present, schools have judged data processing to be a more important and more cost effective use of the computer than classroom use. Use by individuals or families has in the past been out of the question because of the $10,000 to $500,000 price tag associated with almost all stand-alone computers, big and small. Although the cost per student contact hour of large computers has dropped, it has not reached a sufficiently low level to have widespread acceptance.

Meanwhile, between 1972 and 1975, microcomputers were introduced (Roberts, 1975) and found to be capable of delivering many of the functions of the larger systems at a much lower price. Microcomputers had additional advantages. Because they were not usually connected to data bases containing sensitive information, they did not need to be programmed in such a complex manner and free access could be permitted to relatively "irresponsible" students. The portable microcomputer could be taken home by teachers so that they could bone up on its use before turning their students loose on it. In the past five years, a small but rapidly growing new generation of computing teachers has emerged ready to bring the wonders of educational computing to anyone willing to learn. In the most recent literature these new teachers are beginning to report their experiences and voice their complaints.

Many market studies prepared for industry contain projections of the populations of computers compared to populations of people (Personal Computing Industry, 1978). A number of universities have published surveys on who bought what microcomputer and what they say they are using it for (Fitting, 1979; Holmen, 1979).

There are two bodies of literature not reviewed during this study that are likely to yield additional relevant information:

1) cognition, creativity, and problem solving.
2) personnel selection and training within the computer and data processing industry.

These should be fruitful areas for future study.

C. SURVEY OF "BAY AREA" COMPUTER-AUGMENTED EDUCATION

Formal surveys which report percentage of schools using computers in specific geographical areas are not uncommon. However, such surveys rarely provide a view of the environment within which the student meets the computer. Even when a break-down by academic department is given or the number of students who access the computer per year is stated, we are still insufficiently informed. We have no idea of how much actual computer access time each student has (in some cases this turns out to be fifteen minutes per year!) or what the quality of the experience is.

During the early, exploratory phase of this study, we took an informal survey by visiting several sites where computers were being used for learning and by discussing computer projects in-depth with teachers at several conferences. Appendix A of this report contains notes on this survey.

To begin to form a comprehensive picture of a computer-augmented learning environment, previous experiences in local CALEs, site visits in the course of the study, and the teacher interviews all proved useful. Site visits alone often did not reveal the intentions of the teacher; and teachers in interviews often assume that what they intend is actually happening. One application of the taxonomy presented in the following section is to use it as a check list for collecting data about CALEs. Such a use in the future might reduce some of the controversy and misunderstanding that often pervades discussions about computers in education. Additional study to assist in definition of CALEs is needed.

III. A PROVISIONAL TAXONOMY OF COMPUTER-AUGMENTED LEARNING ENVIRONMENTS (CALEs)

In both the literature and in discussions with practitioners in the field, we found considerable variation in the terminology used to describe the use of computers in education.

For example, computer terms included: computer awareness, computer literacy; computer-based, -managed, -augmented, or -assisted instruction; computer-augmented learning; computer programming; and on and on. We chose the phrase "computer augmented learning environment (CALE) to describe any situation in which a person uses a computer in the learning process. This term avoids sticky distinctions between "instruction" vs. "learning" and "based" vs. "assisted." It is "content free," i.e., it implies nothing about what is being learned. It diverts attention away from the computer system itself and encourages one to look for all the factors that may affect the learner. It specifically excludes administrative uses of computers or uses by teachers that do not directly affect the learner (such as grade averaging).

Variations in terminology were observed in describing equipment (hardware and software), the learner, the teacher, and the settings in which equipment, learners, and teachers were found. These variations made accurate descriptions of learning environments difficult and comparisons nearly impossible. One teacher claimed that her five year old kindergarten students benefited enormously from working with the computer while another teacher said students must be ten or older before they can learn about computers. Upon further discussion the first teacher revealed that the kindergarten computer is set up by the teacher before class begins with a single program which presents a counting game. The other teacher expected her students to compose BASIC language computer programs using a self-teaching manual and minimal supervision.

To solve this problem, we devised a taxonomy or classification system. It is intended to completely describe the conditions under which the learner and computer come together. The taxonomy is made up of a descriptive vocabulary which names all elements in a computer-augmented environment and a structure which indicates relationships between these elements.

Figure 1 on the following page shows the major categories of the taxonomy developed in the course of the study. (On the last pages of the Appendix is presented the more complete form of the provisional taxonomy, labeled Figure 2.) The first-level headings shown in Figure 1 are: 1. Environmental Elements, 2. Activity Segments, 3. Teacher-Learner Situations, 4. Learner Attributes, and 5. Educational Functions and Levels.

FIGURE 1

PRELIMINARY TAXONOMY OF COMPUTER-AUGMENTED LEARNING ENVIRONMENTS (CALEs)

A. ENVIRONMENTAL ELEMENTS	1. TEACHER 2. INSTITUTIONAL SETTING 3. PHYSICAL SETTING 4. SOCIAL SETTING 5. SOFTWARE 6. HARDWARE
B. ACTIVITY SEGMENTS (LEARNING, USING, TEACHING)	1. LEARNING THE SYSTEM 2. PROGRAMMING 3. APPLICATIONS
C. TEACHER-LEARNER ENVIRONMENT SITUATIONS	1. INDEPENDENT WORK 2. TEACHER-STUDENT WORK 3. NON-INSTRUCTIONAL USE OF STUDENT TIME 4. LEARNER-LEARNER ACTIVITY
D. LEARNER ATTRIBUTES	1. DEMOGRAPHY 2. RELATED EXPERIENCE 3. ACHIEVEMENT PROFILE 4. COGNITIVE PROFILE 5. CONATIVE PROFILE
E. EDUCATIONAL FUNCTIONS AND LEVELS	1. EDUCATIONAL FUNCTIONS 2. EXPERIENCE LEVELS

A. ENVIRONMENTAL ELEMENTS

There were several environmental elements to consider in developing a description of a computer augmented learning environment: 1. teacher, 2. institutional setting, 3. physical arrangement, 4. social setting, 5. software, and 6. hardware. Altogether these elements form a context for carrying out successive tasks of this research study.

1. TEACHER

Within the context of a given environment (hardware, software, and physical setting) we cannot ignore the people - teachers and learners. For our purposes, teachers may be classroom instructors parents, youth workers, social directors or librarians (often found in community institutions), or peers (people distinguishable from learners only because they possess a little more knowledge, experience, or perhaps only confidence). A relevant description of the teacher might note:

a. RELATIONSHIP TO LEARNER
b. PERCEPTION OF TASK OR OBJECTIVES FOR THE LEARNER--

for example, TO LEARN:

(1) TRADITIONAL CURRICULUM
(2) COMPUTER AWARENESS CURRICULUM
(3) COMPUTER PROGRAMMING
(4) ELECTRONICS
(5) DATA PROCESSING (VOCATIONAL)

c. USE OF OBJECTIVE FOR LEARNER
d. PROVISION FOR MOTIVATION OR REWARD
e. RELATIONSHIP TO THE SOCIAL ENVIRONMENT
f. KNOWLEDGE OF COMPUTER ENVIRONMENT

2. INSTITUTIONAL SETTING

Hardware and software, taken together comprise the "system environment." Many computer enthusiasts assume that when they have described the "system environment" they have said all one needs to know about computers in education. Obviously the picture is larger since each computer is found within a physical setting - the room and its furniture within an institution.

Typical Institutional setting types are:

a. HOME
b. CLASSROOM
c. LIBRARY
d. OTHER PUBLIC CENTER
e. INDEPENDENT STUDY (IN SCHOOL)
f. CLUB
g. OTHER

3. PHYSICAL SETTING

Even within given institutional types there is room for considerable variation between physical settings. We chose not to develop this part of the taxonomy a priori since we could imagine many more settings than we actually expected to find. The teacher interviews reported below yielded much information useful in clarifying our notions about physical setting.

a. DESCRIPTION OF ROOM
b. FURNISHINGS
c. EQUIPMENT
d. ACCESS
e. ETC.

4. SOCIAL SETTING

Another element, the social milieu, is a derivative of all the others. Its categories include:

a. PEER INTERACTION
b. AVAILABILITY OF KNOWLEDGEABLE HELP
c. PERCEIVED OBJECTIVES OF LEARNER
d. LOCUS OF CONTROL OF ACTIVITIES
e. COMPETITION FOR A LEARNING STATION

The rules operating in the social milieu are initially dictated by the teacher, although often unconsciously. There is much work to be done in analyzing this element. It is obvious from our observations that experienced computer teachers have experimented in this area of the social setting. They know and can articulate positive and negative factors which must be dealt with. Further, they refuse to allow the limitations of computer systems and institutional inflexibility to dictate how to organize their environments.

5. SOFTWARE

We must then turn our attention to the computer software. Just as the sound that comes out of a phonograph is a function of what music is on the record played, not who made the turntable, the effect of a computer is largely determined by the design of the software run on it. Software found in educational settings has been categorized (Lathrop, 1980) as follows:

(a) DRILL AND PRACTICE
(b) EDUCATIONAL ACTIVITY
(c) TUTORIAL
(d) LOGICAL THINKING/PROBLEM SOLVING
(e) SIMULATION
(f) EDUCATIONAL GAME
(g) DEMONSTRATION
(h) AUTHORING PROGRAMS
(i) CLASSROOM MANAGEMENT
(j) UTILITY

Another categorization of software was developed during subsequent teacher interviews. This latter classification, found at the end of the appendix to this report, places emphasis on student level and teacher intention.

6. HARDWARE

A wide variety of computer hardware is used for education. Data in reports of studies often includes information on some of these features:

a. FEATURES

1. MANUFACTURER OF COMPUTER
2. AMOUNT OF MEMORY
3. PERIPHERALS (DISKS, PRINTERS, ETC.)
4. OPERATING SYSTEM
5. NETWORK AVAILABILITY
6. RELIABILITY

More important for this study than the manufacturers' name or amount of memory is the relative computing power and ease of operation of each computer. Therefore, we decided to divide all computers encountered into six classes of increasing capability.

b. CLASSES

1. CLASS 1- PERSONAL COMPUTERS (PET, APPLE, TRS-80...) WITH 16K OR LESS, INTEGER BASIC* ONLY, CASSETTE TAPE DATA STORAGE.

2. CLASS 2- PERSONAL COMPUTERS WITH LARGER MEMORY CAPACITY BUT CASSETTE TAPE STORAGE.

3. CLASS 3- PERSONAL COMPUTERS WITH 16K OR MORE MEMORY AND ONE FLOPPY DISK, FLOATING-POINT BASIC** AND SOME GRAPHICS.

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* Integer basic is a computer language which allows one to calcule with whole numbers but not decimals. Typically such languages also have other important limitations.

** Floating point basic permits decimal calculations and usually contains several additional complex functions.

4. CLASS 4- PERSONAL COMPUTERS WITH NETWORK, LARGE DISK, OR MULTIPLE LANGUAGES.

5. CLASS 5- PERSONAL COMPUTERS DEDICATED TO SPECIFIC SOFTWARE.

6. CLASS 6- TIMESHARING (WHERE SEVERAL COMPUTER TERMINALS ARE CONNECTED TO A SINGLE, MEDIUM, OR LARGE COMPUTER. WHEN SUCH A SYSTEM IS WORKING PROPERLY EACH USER OPERATES THE COMPUTER INDEPENDENTLY AND IS UNAWARE THAT OTHERS ARE SHARING THE COMPUTER AT THE SAME TIME.)

For an explanation of the other categories of the taxonomy appearing in Table 1, see Appendix B. The remaining major divisions covered in the Appendix are more dynamic, process-oriented than the environmental elements discussed above. Categories described in the Appendix B are: B. ACTIVITY SEGMENTS, C. TEACHER-LEARNER ENVIRONMENT SITUATIONS, D. LEARNER ATTRIBUTES, and E. EDUCATIONAL FUNCTIONS and EXPERIENCE LEVELS. At the end of the Appendix is presented the complete taxonomic schema, in Figure 2, under the heading "Provisional Taxonomy of Computer-Augmented Learning environments (CALEs)."

From our interviews we conclude that some elements of the taxonomy, such as Hardware and Software, are well understood, easily described, and have been explored by most computer teachers. In other areas, such as teacher objectives and learner attributes, a number of teachers did not deal with the questions or found them difficult and thought provoking. Many had no information to offer while others came up with observations that were relevant but not part of a coherent thesis.

In our judgement, all of these categories are important dimensions in education and therefore should be investigated further as they apply to the computeraugmented learning environment. Since even experienced teachers had not explored the complete taxonomy during the course of teaching, we feel it should be included as part of the curriculum for training computer teachers.

IV. THE COURSE OF THE TEACHER INTERVIEWS

A. PROCEDURE

What is the experience of teachers currently working with students in computer-augmented learning environments? To find out, we contacted twenty-eight teachers, by phone or in person, and conducted a structured interview. Individuals were chosen from respondents to the research announcement and pilot questionnaire, members of a Bay Area organization called CUE (Computer Using Educators), and personal contacts made by the authors. The sample included teachers and other practitioners involved with computers in education with a wide variety of experience in many different environments. The interviews proceeded as follows:

- Contact made by phone or in person and interviewer introduces self.
- Requests interview for research by Far West Laboratory on teacher attitudes and experiences with computers in education. Explains time required is 20 to 60 minutes. Offers to make appointment to call back at a convenient time.
- Asks whether interviewee would prefer not to be identified or quoted. Asks for permission to tape record conversation to facilitate note taking. Offers to explain research further and answer questions about the research at the conclusions of formal questions.
- Questions initially presented as written. If interviewee expressed confusion, further explanation or rewording is offered. (See interview questions below.)
- As "additional comments" trail off into unstructured conversation, interviewer declares the formal interview over and stops the tape recorder.
- Interviewer answers questions about the study and Far West Laboratory, thanks interviewee for participating, and offers to send a copy of the report.

B. THE INTERVIEW QUESTIONS

1. Environment - your experience - how long teaching with computers? How many students?
   a. Students - Age
   b. - Educational Level - Special Characteristics
   c. - How class was selected
   d. Computer System - Class 1-6
   e. Software - What kind of?
   f. Social Environment - What kind of experience do you offer?

2. What do you consider to be a successful computer experience or experiences? (How do you know when it happens? observable behavior).

3. What do you want your students to accomplish?

4. Can you generalize about the kind of student who is successful? Do so.

5. What is most likely to cause an unsuccessful experience?

6. Why do students drop out of not complete courses?

   % quit

7. Do you notice any factors in the surrounding environment which are

   a. Beneficial or favorable
   b. Unfavorable

   Is the surrounding environment important to success? Factors: social setting, institutional setting, access time.

8. What other things are your students learning during their computer experiences? Side benefits?

9. Are there any prerequisites for working with a computer?

10. Additional comments.

C. SUMMARY OF TEACHER RESOURCES AND SITUATIONS

All interviewees expressed enthusiasm about computers in education and had plans to do more in this field. No one felt computers should be used less or that they had any negative effects although lots of problems were identified. There was some variation in the confidence with which teachers approached the interview. Teachers who had not been teaching with computers very long didn't have as many comments on student characteristics. If they also expressed ignorance about the computer itself they made few comments about it too. Those who understood the computer usually had a lot to say about positive and negative factors.

Teacher Experience -(from question 1.)

The teachers in our sample had been working with computers for periods varying from less than one year to twenty years. One subject had not yet taught any students although she had been trained on the computer while another had had contact with more than 3000 students.

Student Groups

Groups of students at all grade levels, elementary through graduate school, plus in-service teachers, other professionals and undifferentiated groups of adults had been observed learning to work with computers. Some groups were gifted, learning disabled, below grade level, educable mentally retarded, or non-English speaking. More than half of the groups were elective or volunteer although the data included observations of students who were required to take the computer class.

Very few teachers felt they understood those kids who choose not to work with computers. Many teachers worked with several different groups of students and reported that environments did need to be changed depending on the type of student group. Typically software and classroom management was different. These changes could be correlated with the elements of the concept of "Readiness" quoted in Appendix A.

Computer Systems

Teachers were working with a variety of computer makes, models, and component packages, all of which fit into the six classes developed in the taxonomy - small and large memory microcomoputers with cassette tape recorders (Classes 1 and 2), micros with diskettes (Class 3) micros with time-sharing capability, large capcity disks, or networking features (Class 4), micros dedicated to running single purpose software (Class 5), and timeshare systems (Class 6).

During informal discussion following the interview many teachers agreed that computer brand was less important than the combination of components reflected by the 6 classes. Many teachers expressed dissatisfaction with cassettes and wanted to move to disks as soon as funding permitted.

Software

Software is to computers as print is to books: if you haven't got any, you have to write it yourself or have the students write it. Each new program (i.e., piece of software or set of computer instructions) can make the computer take on a whole new flavor or character. Today's microcomputers can display letters, numbers, charts, graphs, and simple pictures. Some have color, some sound effects, some can turn an audio cassette tape off and on. All have keyboards to receive student responses but many permit the use of video game controls, light pens (which record the place on the screen touched by the student), handwritten characters, even single spoken words. Most software available today imploys only letters or simple pictures displayed on the screen, the keyboard is used for input, and a few sound effects for reinforcement.

Students began to use computers at all ages - from five to eighty-five. So teachers had to find software which matched their students in two ways: their expertise in operating the computer itself and their age group.

Teachers named titles of familiar software they had collected and described new software they had written. The interviewer recorded this information and later derived the following types for software reported used by learners:

1. Non-reading games with easy eye-hand coordination.
2. Limited reading games.
3. Limited math games.
4. Specific drill & practice
5. Non-reading games with advanced eye-had coordination.
6. Simulations - for logic and strategy.
7. Simulations - for content
8. Integer basic
9. Floating point basic.
10. Other high-level languages: Fortran; Pascal; Pilot; Cobol; APL; WSEN.
11. Assembly language.

There was a definite split between teachers who used games as the primary vehicle either to establish a comfortable attitude toward the machine or to teach specific content and teachers who taught programming only, with games outlawed during instructional periods. The general concensus was that although computers might have something for everyone, not every piece of software was appropriate or useful for everyone.

Sources for Software.

Teachers mentioned where they had obtained the programs they were using as they described them. Sources were: MECC, Cursor, Penninsula School, magazines, public domain, users groups for different computers.

Institutions (including social setting).

A microcomoputer can be set up on almost any surface near an ordinary electrical outlet. This means that any classroom, living room, or corridor can become the physical setting for a computer augmented learning environment. But most teachers did more than plug in the computer. They determined how students would gain access to the computer itself, to further information about the computer, to fellow students, and to the teacher. The following categories were abstracted from teacher responses:

1. Formal lecture - with lab.
2. Computer lab* in school media center or library.
3. One time demo or school field trip.
4. In open classroom as learning station.
5. In class or teacher-scheduled Drill and Practice
6. After school club or drop-in centers for games and recreational activities.
7. After school clubs for programming.
8. In class, supplement or motivational.
9. Community club (Boyscouts..)
10. Private home.
11. Public library.

* In several classes, the computer was wheeled in on an AV cart and remained only temporarily in one classroom.

These institutional settings provide one way of classifying CALEs. Teachers typically described their computer system first, then the student group. Sometimes they had to be prompted to add the institutional data. However, if one starts with the institution and adds the student group, it might be quite easy to predict the hardware and software necessary for success.

Other parameters were important. A few representative ones were:

- availability of self-instructional materials and reference manuals, peer tutors and adult experts around to help.
- how the student gained access to the computer-free choice , with sign-up, teacher assigned.

Student-machine ratio — 1-1,2 or 3-1
Small Group 4 -8
Scarce, much competition for learning stations

Supervision - peer only
- experienced adult
- inexperienced adult

Responses to the balance of the questions did not separate neatly by question. The same comment, "computers teach children to cooperate socially" for example, was offered by one teacher in response to the success question (#2), by another in response to the accomplishment question (#3), and by a third teacher in response to question #8, as a side benefit to computer experience. Many teachers repeated the same point in answer to several questions. Teachers who intended that students learn "program content" saw "learning about computers" as a side benefit. Those who felt they were "teaching computers" found "learning program content" to be a side benefit. Responses did fall into three general categories: what the learning environment was like, good and bad elements in the environment, what the students learned, and what kind of people the students were. These findings are discussed under separate headings below.

D. IMPRESSIONS

The "don't know phenomenon" was common. Many respondents answered questions 2, 3, 5 & 7 with "none" or "don't know." After thinking and receiving encouragement from the interviewer many came up with several items.

In many cases respondents left out details because they believed the interviewer was familiar with the environments being described.

From our interviews we conclude that environmental elements and activity segments of the taxonomy are areas which teachers were forced to explore thoroughly during their first two years of teaching with computers. Unfortunately no one reported that they had been informed in these areas before their computer arrived. This material could easily be included in teacher training in the future.

The last three parts of the taxonomy, teacher-learner environment, learner attributes, and educational functions has not been studied enough to be presented as "educational dogma." Teachers should, however, be made aware of the issues as they begin their careers with computers.

V. CALEs -- LEARNING ENVIRONMENTS WITH COMPUTERS

For the purposes of this study, a computer-augmented learning environment (CALE) is any place in which a person uses a computer to help himself learn anything. Question 1 of the teacher interview was designed to provide us with the descriptions of the environments our interview subjects had set up. From the responses, we hoped to be able to test our preliminary (i.e., theoretical) taxonomy against real environments and correct any ommissions or inaccuracies. Having developed a comprehensive classification system for computer augmented learning environments, one could then proceed to see how student success varies in relation to student profiles within comparable environments.

The six classes of computers outlined in the taxonomy all appeared in CALES according to our teachers. Typical responses gave make and model only or make, model and peripherals (Apple II with dual disk drives) to describe computer hardware. The interviewer inquired about amount of memory in the computer, type of display, presence of printer and other details respondent might have left out. Many teachers worked with equipment from more than one manufacturer. Often each computer was set up with a different set of peripherals. The six categories served well for teachers responses to part of question #1. Two minor changes were adopted. Class 1, small memory microcomputers with cassette were split into Classes 1 and 2, small and large memory microcomputers respectively, both with cassette recorder. Classes 5 and 6, small and large time-shared computers were combined into a single Class 6. This arrangement more accurately reflected the distinctions made by teachers.

Other portions of our preliminary taxonomy did not map onto teacher responses so neatly. Although a considerable number of the items contained in the taxonomy were mentioned during the interviews, very few relationships between the items were pointed out by teachers for example, several teachers noted that students who sought help at appropriate times were more successful than those who did not. Many also mentioned that fear of making mistakes interferred with success. A few teachers felt that students were learning when to ask for help. Many also reported that the kind of help available made a great deal of difference. The taxonomy prepared for this study notes "seeks help from teacher" as one of the actions to expect in a CALE (in Classification C. Teacher-Learner Environment Situations). But clearly getting help and helping were important and complex activities for the point of view of our teachers. A rigorous classification of helping systems related to the characteristics of the people who can use each helping system could be of great benefit to teachers, software designers, instructional manual writers, and ultimately to the learners themselves. Our teacher interview yielded data on a much simpler level. On the basis of the interviews, CALEs could be classified by class of computer system, type of software (see IVC above) and institutional setting (also see IVC above). Our twenty-eight teacher interviews reported observations of students working with six classes of computers, running eleven kinds of software, in thirteen different institutional settings. We might have been looking at 858 different learning environments.

In one sense we were observing at least that many unique learning environments and that is exactly why teachers who have used computers are so often enthusiastic about the medium. Most of the microcomputers currently found in classrooms in the San Francisco Bay region can be programmed to do something interesting and educational for every student at every level. It is only within the last two years that enough software has been written and adapted for enough different computers to make this claim an actuality rather than a prediction.

ERIC

We can identify several models of CALEs from our interviews. These might serve as models which other schools could copy or vary to fit their needs. Each CALE summarized below represents a frequently encountered type.

1) Computer Literacy Class - A three week mini-course for 7th and 8th grade participants in mentally gifted minors programs. The objectives of this course are for students to become comfortable working with a computer and to understand that it is a people controlled tool. Class I computers are used with a small library of games, basic language, and a set of lessons designed by the teacher. Class is held in a normal classroom adjacent to the computer lab (housed in a former closet). Students work singly or in pairs at the computer, taking turns by sign up sheet. They must have planned out their game or program before they may go to the keyboard. There are both peer and adult aides available at all times.

A great deal of effort has been put into the development of computer literacy programs in recent years. Such classes represent one of the most common and well-defined CALES enountered. The Minnesota Educational Computing Consortium, with additional funding from NSF, is developing specific objectives for computer literacy and several of our interviewees were using their course materials.

2) Basic Language Programming Class - A one-semester high school elective open to all students with no prerequisites in Mountain View, California. This is a structured lecture class with assignments to be done on the Class 2 and 3 computers. The teacher expects his students to become comfortable operating the computers, to master the basic concepts of programming and to complete a series of assignments. Although it is possible to fail this course, assignments are flexible and the work is individually paced. Many students find working with the equipment and being responsible for their own projects to be a new atmosphere not commonly encountered in school. Peer interaction is important here and much personal instruction occurs. He has found only a few students who could not handle this environment although it should be noted that his class is elective.

Basic programming classes such as this one are probably the most common CALES. Similar classes were encountered in upper elementary school, Jr. High, and Community Colleges as well as public computer centers and museums. Students are often heading for a computer science career, need programming for their business, or about to purchase a microcomputer for a hobby.

ERIC

3) <u>Computer Assisted Instruction</u> - This single computer-based laboratory exercise provides community college students with practice identifying minerals for a geology class. The program, written by the instructor is accessed on timeshare terminals in the college library.

Students work on a screen and keyboard with sample minerals on the table beside them. A printout of the session is available to take home. The instructor gives the students a short instruction period on operating the computer and then expects them to complete the exercise on their own time. He finds they are more successful if they work in groups of two's or three's and help each other to operate the computer and master the program content. He has had one student who could not type the correct spelling of a mineral name even while it was displayed on the screen in front of him and therefore could not complete the assignment. For the most part students are able to muddle through. He would like all his students to have had previous experience on "computer systems so that they could concentrate on the course materials" he is presenting. He is currently converting this program to run on a microcomputer.

Many colleges have a smattering of CAI courseware available on their timeshare computers. As in this case, only a small number of exercises have been written for any one course. Considerable effort is being made to provide fully computerized courses which present new material, drill and practice problems, review sessions and testing. Stanford University uses such a system to keep esoteric courses in their catalog even though only a few students each semester may wish to take them*. Most microcomputers are not connected to large enough storage disks to permit easy use of this type of courseware. However, new disk technology, including the video disk, is rapidly changing this situation The primary roadblock is the lack of able authors for this medium.

4) <u>Primary School Computer Play</u> - This Class 3 computer serves as a learning station at an Elementary School in Hayward, California. As with other Montessori materials, any child may use the computer whenever no one else is using it. There is a small library of limited reading, math, and logic game which the Director loads into the computer each morning. The computer is not the central focus of the classroom and she wants her students to approach it as one tool among many. She finds the kids are improving in the skills necessary for the games-reading, math, and logic. Not all her students choose to work with the computer. It is most popular with the girls who are already able to read although everyone played Tic-Tac-Toe until they figured out how to win every time.

* Personal Communication Marion Bear, IMSSS, Stanford University.

This CALE is unusual in our study because the computer appears to be so well integrated into the larger environment. Hopefully it will become the rule rather than the exeption as more primary teachers discover how to use computers effectively. It is interesting to note that this teacher does not feel that she must have a huge number of programs in order to use her computer well.

5) Computer Simulation Pull-Out Program - In this 8th grade History class every student gets to be a pioneer on the Oregon Trail via a Class 3 computer. The teacher knows almost nothing about the computer herself so she uses the computer literate students from her class as monitors. At about twenty minute intervals, groups of three wander into the central area of their POD classroom wing. The monitor operates the keyboard and the other students make decisions and supply the input for the Oregon Trail simulation. During the one week per year that the computer is parked here, few problems are encountered and all students learn a little bit more history and gain some "understanding about computers and how they can be used more than just in industry." Says this teacher, "I wish schools would think computers are more important. They could have unlimited use in social studies and in language arts." When this unit of the history class is over at the Middle School, the computer resource teacher takes it into her own general math class or delivers it to someone else in the school.

This type of highly structured, limited access CALE is typical of those set up by teachers who have caught the computer bug but have not had a chance to become computer literate themselves. To some, it may seem like a trivial use of the computer. However, it does spread the word and permits a large number of people to have at least one hands-on computer experience.

6) Teacher/Administrator Training - Along with several types of elementary school classes, the instructor teaches a course for teachers and administrators at De Anza Community College. The point of this class is to acquaint school staff members with the different kinds of hardware and software which are now available as well as magazines and teacher conferences. Hopefuly she will also get them over their fear of the computer. Her comments are in line with those of others in similar circumstances. There is a lot of content to learn. Adults often have time conflicts so that they miss a class. Since there are no make-up classes they may get discouraged and quit. The drop-out rate is actually very low (6%) but other teachers are not always so lucky. Adult learners are generally reported to be much more fragile than kids, they are more afraid of machines, and more discouraged if their sequence of learning is disturbed.

Teachers are filling courses offered for them in colleges, private groups, and school districts. Often these courses are hastily put together with too much survey of the field and too little beginners orientation. However, there is so much to learn that few complaints are heard except for "we need more teacher training."

At the moment, the software pickings are so slim and budgets are so small that CALES are potpourris of teacher intention and student opportunity.

(7) <u>After School Computer Lab</u> - Most teachers find that so many kids catch the computer bug that an after school computer club is in demand. One teacher's program is an informal drop-in arrangement. She does little direct teaching at this time and counts on the kids to help each other when necessary. Kids usually play games or input their own programs while working at the machine, read magazines and manuals, or discuss their latest game program ideas with friends. Success in this environment happens, according to one teacher, when kids "discover ways in which they can work together on projects instead of "kill each other in games." Another teacher remarked "you can't peel them away from the computer."

VI. POSITIVE AND NEGATIVE FACTORS AFFECTING COMPUTER-AUGMENTED LEARNING ENVIRONMENTS

The two problems cited most often by teachers were "not enough hardware" and "poor quality software." Running a close third was the need for more teacher training. Several other problems were also mentioned quite often.

A. THE "HARDWARE RELIABILITY" PROBLEM

Since, by definition, all CALEs have computers in them, they are beset by the same set of problems encountered by data processing shops in business and industry - hardware which is not 100% reliable, variable power supplies, not enough or incompatible software, a shortage of well-trained staff. Many teachers mentioned these. Those teachers who had had no previous exposure to the data processing industry were comforted when they met their colleagues and discovered that they are not alone with these frustrations. Also, since progress toward solving these problems is visible industry wide, they felt these could be dealt with as irritations which will be ameliorated rather than major stumbling blocks which may sabotage one's whole curriculum.

B. THE "ACCESS" PROBLEM

Frequently teachers said that they do not have enough hardware and cannot provide their students with enough access to the computers they do have. The problem is not only how many computers, it is also when students may use them. Even 100 microcomputers, if they are in a locked building, are not available to the students. In many school computer projects much time was wasted moving the machines around to different classroom and schools and moving them to secure storage at night. Teachers reported that if students could have more time to work with the computers within the existing computer-augmented environments currently in use, they would learn a lot more.

C. THE "FRIENDLY ENVIRONMENT" PROBLEM

Computing is a challenging intellectual activity requiring some order and quiet. Teachers noted that regardless of whether the student focused on the computer itself or on program content, concentration was necessary. On the other hand, computing was most effective when there was an oppportunity for a lively exchange of ideas among learners and between learners and teachers. Thus, a delicate balance had to be maintained between too much structure and chaos. Most teachers felt that children needed adult supervision to control roughhousing, noise, and competition for keyboard time from more agressive learners. Experienced teachers said that they had to give up the idea of unsupervised or student-supervised computer rooms. However, it was equally important not to impose "sterility" or "intimidating" conditions.

D. THE "SOCIAL PRESSURE" PROBLEM

Students felt both positive and negative social pressures. "Discouragement for girls from parents and teachers" was noted on one side of the scale with "science fairs and other people around to have a good time with" on the other. Students who already had many social commitments were not likely to gravitate to the computer and adults frequently felt that they could not spare the time off from their jobs and families to study computing.

E. THE "OVERBEARING PERSON" PROBLEMS

Fellow students, peer teachers, and even the computer teacher were frequently viewed as negative factors. The "person who wants to do everything for you" gets in the way as does "the teacher who can't admit it when she doesn't know the answer." Inexperienced teachers were likely to be too achievement oriented and inhibit exploration, according to their more seasoned colleagues. Enthusiastic students, often adolescent boys, were obsersved to take over the computers if not supervised.

VII. FINDINGS ON ACTIVITIES AND ACHIEVEMENTS IN CALEs

Most teachers reported that all their students were successful and that the specific content of that success depended on the individual learner. Although teachers rarely gave an organized exposition of it, a hierarchy of achievement emerged from interview responses as a whole.

Most learners proceeded through these stages:

1. Overcoming fear of technology in general and computers specifically.
2. Developing enough curiosity and awareness about computers to begin "to question."
3. Understanding the cause and effect relationships between keyboard, screen, program, and program storage medium. Operating the computer "comfortably" - loading, running, and restarting programs.
4. Using the computer with existing programs as a personal tool- to "be demystified on the machine, so that they view the computer as a tool- one that doesn't exclude other tools."
5. Learning to construct programs in any one of several computer languages. Programming new solutions to make the computer a better tool.

This hierarchy is related to our definition of readiness, cited in Appendix A, which includes "freedom from...threat, sense of danger."

1. Fear. Overcoming any fear of computers is the first common success theme throughout the interviews. All students eventually made it although most teachers noted that fear was a rare phenomenon in children and common among adults.

Referring to our readiness definition we note "freedom from discouragement (expectation of failure)." One special education teacher reported that knowing computers were "not just for the brains" was an important achievement for her students. Several teachers mentioned "increased self-esteem" was an outgrowth of computer success.

2. Curiosity. Once students moved beyond fear, teachers wanted students to "have fun" and "be comfortable." As one teacher put it "total novices who are interested but have trepidation move on to joy and mastery." Fun and joy lead to a "wish to return" to use the computer again. Thus students voluntarily get more computer experience.

3. Understanding. The next step, as expressed by one of the most experienced teachers, is the "realization that you are in control of the computer, that it can only do what a human has told it to do. Even if you haven't written the program, a human has written it." One respondent described the change of attitude he was looking for as a progression from "a sense of awe and magic through a willingness to continue learning brought about by contact with an understandable program."

4. Tool Use. Once a student realizes he is in control he must move on to use "the computer as a personal tool." One teacher said, "young students think in terms of what it can do instead of what it is." Another expressed it this way, "the person says 'which way do I go?' instead 'of which button do I push?' The emphasis shifts to program content."

The expectations of those who taught programming courses were nicely summarized by one teacher. His students usually reached one of three levels:

a. Turn on the computer, type in a program they design, save program on disk or tape.

b. Know 60-70% of the core commands of the language being taught.

c. Know techniques and good programming practices.

Some teachers felt that computers could be introduced at any age while others, especially those teaching programming felt that 4th grade was the earliest practical starting place.

Almost all teachers mentioned the role of computer experience in relation to logical thinking. The exercise of step-wise logical thinking was generally valued by teachers. Many teachers felt that the ability to proceed logically was actually being taught while others believe that logical ability was a prerequisite skill which signalled success.

Some saw the ability to "organize their thoughts in better logical progression, to be precise with what they say" as a side benefit. Others reported this as their main objective.

VIII. FINDINGS ON PROFILES OF SUCCESSFUL LEARNERS IN CALEs

Most people would agree that there are some individuals who just don't seem to get along with machines. Since computers are machines, we expected that there would be a group of students who didn't get along well in computer-augmented environments which required their direct participation. Our field research had provided informal confirmation of this hypothesis. Questions 2 and 4 of the teacher interview were specifically included to evoke comment on this issue.

Most teachers, however, could not describe a successful computer experience at first. "It depends on the person" they said, or "all students are successful." Upon further inquiry, most teachers expressed the desire that computers be available and useful to learners of every description. If a certain student could not learn within the CALE as originally presented, the watchful teacher would modify the CALE (usually by adding a more appropriate piece of software) or by enlisting a peer teacher to help out. Often they would suggest a less demanding task to the learner. Thus, "success" was made a constant and the environment a variable. The only teachers who did not use this tactic had high school or college level programming classes. But even at that level, several teachers noted that "punitive" grading or "inflexible" assignments were a bad idea in computer classes.

When prompted to talk more about what those "successful experiences" were that all students have, teachers mentioned:

- o feeling "comfortable" with the computer,
- o enjoying the computer,
- o overcoming any fear they might have had of the machine, and
- o wanting to return.

Said one teacher, a successful experience is "any exposure that leaves the person with a feeling of confidenced over the machine, elevates them over the computer."

Several teachers equated success with being able to approach the computer as a tool for personal projects.

No one offered a predetermined set of goals which had to be achieved before a learner could be called successful.

Question #4 again required the teacher to consider success, this time describing the student instead of the experience. Once the interviewer was satisfied that the respondent had no "secret agenda" for the student, a new twist was addded to the question:

OK, all your kids are successful, but aren't some of them a little more successful? Aren't computers easier for some people? How are those kids different from the others?

This prompt brought responses which included:

- bright kids
- often boys, but some felt girls were better programmers
- people with previous experience in computing
- math and science oriented
- logical or analytical thinkers.
- "risk takers." The kids who "try things in ways they've never tried before."
- people with "stick-to-it-iveness"
- "the creative ones"

One teacher had three criteria for success:

- hands-on
- being in control
- making it do something the student cares about

He recalled one student who never got the hang of programming: he had "trouble attending to logic - connecting output with the program. He couldn't trace back."

When interview notes were sorted into two groups, respondents with three years or less teaching with computers in the first group, those with more than three years experience in the second, one important difference appeared in the way teachers viewed students. Many of the more experienced teachers noted that not only the bright students did well. Kids with undistinguished academic records often blossomed in front of the computer. They might be slower, but they excelled in perseverance, curiosity, and personal initiative. According to one jr. high teacher, her class often attracted "males interested in science fiction, science, math - often with poor language skills". At the game level, she noted it was "boys not interested in sports but not loners, those looking for challenge but not necessarily outstanding students." The girls in her class however, were "serious students, not as social, academically inclined."

In structured CALEs with students at a normal third grade level or above, the major factor affecting success was the appropriateness of the program or course content to the student. Students who didn't understand how to play a game presented on the computer, had no use for an application program, or hadn't expected to do any work in a programming class all tended to drift away, if not quit.

In some CALEs, tasks were quite structured although scheduling time on the computer was not. In this case, the student must be able to take initiative in doing his assigned work. Students who had too many outside interests were not likely to find enough time to accomplish this. If there were not enough terminals to go around, students had to be socially agressive enought to secure a place for themselves. But except for these two considerations the keyboard-screen medium presented few problems.

All students needed to be able to remember a sequence of between 5 and 10 keystrokes to get the computer started running the correct program. They must check the screen for feedback each time they typed a response and they must be able to copy a sequence of letters off the screen acurately.

In these socially structured environments there was usually a peer or adult teachers available to answer questions so the timid individual could ascertain the right answer before typing and can thereby avoid risking a mistake.

In less structured environments, tasks were more free-flowing. Several teachers required a student to initiate a project and finish it, or "explore." Here, willingness to take risks and to make mistakes proved to be an important student characteristic. Ability to tolerate frustration was also necessary since "help" was not always available in an attractive form. Students often chose programming problems their teachers did not know how to solve, and beginners had to learn from preadolescent peer tutors who were ready to monopolize any keyboard which might be vacated. "Timid" or "passive" students were likely to be unsuccessful, teachers reported. But, add a "won't quit" attitude to those who survive, and enough creativity to think up another sequence of keystrokes which might generate the desired result from an uncooperative and undocumented computer, and you had the makings of a genuine computer addict.

Although most teachers noted that high general intelligence increased the liklihood that a learner would be successful in any CALE, several noted that high IQ was not a necessary characteristic. Many students who were considered "slow" benefited personally and could achieve relatively high skill levels if they could engage in step-by-step, logical thinking.

In elementary grades, girls and boys seemed equally able although boys formed a larger portion of the sample. By the jr. high period, girls began to opt out of computer classes. One jr. high teacher noted that the girls who stuck it out were better at programming than the boys. By high school, few girls were involved. Our sample of teachers seemed fairly representative by sex, although there were more female teachers than male. To generate an equal distribution of males and females among computer teachers, a higher percentage of male teachers must choose to go into computing. As yet, there seems to be little in the literature on why girls and women choose CALEs less often than boys and men. We feel this is an exceptionally fertile area for further research.

IX. CONCLUDING COMMENTS

(For a summary of findings and recommendations, see Section I, pp. 5-17.)

A. STUDENT CHARACTERISTICS AND READINESS

Although many characteristics necessary for success in several different CALEs have been cited, we do not feel that a satisfactory classification of learners has been developed to date. This preliminary work may contribute to the development of a constellation of skills and attitudes which could be called "computer readiness" but only the grossest distinctions have been made so far. It is apparent that fear of technology, ability to read, creativity, stick-to-it-iveness, risk-taking, and problem solving ability are all factors. How these factors are related to each other and to the environment remains to be investigated.

B. CALE MODELS

Educators who are unfamiliar with the computers in education movement over the past several years are not generally aware of the extent of the work that has been done in this field. However, many of these same people will have the responsibility for implementing some type of computer-augmented learning activity in their institutions. They are in danger of "reinventing the wheel" many times over unless some effective dissemination takes place.

C. TAXONOMY

The taxonomy could provide a useful structure for comparing existing computer-augmented learning environments and desiging new ones. Further definition and testing of the taxonomy is indicated.

D. INTERCOMMUNICATION

A variety of educational environments with computers in them are found in the San Francisco Bay Area. These environments vary in who uses them, when, how long, under what circumstances, for what purposes. The local computer environments appear to be similar to those found nationwide but systematic comparisons have not been made.

There is a growing body of common experiences among computing teachers and an intense desire for more intercommunication. There are also two distinct types of professional meetings in this field. Many meetings, such as the Asilomar Conference, are crowded by beginning teachers trying to catch up to the state of the art. Less common but equally important are meetings among the leaders in educational computing. These serve as a spawning ground for new concepts or insights in this rapidly changing area. Both types of meetings should be encouraged and supported whenever possible.

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APPENDIX A

DETAILS ON SURVEY OF BAY AREA COMPUTER-AUGMENTED EDUCATION

1. Introduction

Computing and learning are both unique and complex activities. Neither can be fully understood by reading other observers reports and interpretations. Questionnaires only present the information requested and rarely lead to new approaches to a problem. Therefore, we felt some direct observation of teachers and learners using computers was necessary. At this early stage of our project, we were not entirely sure of what to look for or where to look. We chose several on-going activities and locally scheduled meetings and conferences. Then we set out with pen, paper, and open minds to see what we could discover.

2. Reaching Out - The Research Announcement

Many of the people involved in educational computing in the Bay Area keep in regular communication through the meetings and projects sponsored by CUE - Computer Using Educators. This organization has a membership of over 450, all of whom are involved or plan on becoming involved in computers. Therefore, CUE was a logical place to begin to look for contributors and study sites for this research.

A research announcement was distributed in the registration area to everyone who attended the Northern California Math Council's annual conference at Asilomar, CA, in December, 1979. Since a major activity at the conference was a CUE sponsored series of sessions on computers, there were a number of interested respondents. We hoped to develop a list of people who were expressly interested in cooperating in our study. Most respondents indicated an interest in receiving the results of the study, a willingness to participate as a study site. They became an important source of interview subjects for the teachers survey discussed previously.

3. Computer Readiness - Pilot Questionaire

From the inception of the CALEs Project we knew that we would want one segment of it to explore the concept of "Computer Readiness." Readiness is familiar to all primary school teachers. As Goodwin Watson of Columbia University School of Education put it:

> "Readiness for any new learning is a complex product of interaction among such factors as (A) sufficient physiological and psychological maturity. (B) Sense of the importance of the new learning for the learner in his world, (C) mastery of prerequisites providing a fair chance of success, and (D) Freedom from discouragement (expectation of failure) or threat (sense of danger). (Watson, 1963)

Casual observation had led us to wonder why some people developed "computer addiction," (Zimbardo, 1980; Wellemeyer, 1980) while others remain indifferent, even hostile to computers and everything associated with them (Thornburg, 1980). Are there prerequisite skills and attitudes which make some individuals more "ready" to use computers than others? One obvious approach to this question is to ask people who use computers what prior activities helped them become successful with computers.

A pilot questionaire was prepared and distributed to computer users at the West Coast Computer Faire in San Francisco. It was designed to yield some preliminary data on prerequisites for computer success. Respondents were to rate twenty-seven experiences according to their helpfulness in learning to use the computer. Rating categories for those who did not check "insufficient experience to answer," were: 1) not helpful, 2) somewhat helpful, and 3) most helpful.

On Table 1 are listed, in rank order of helpfulness in using computers, the prior experiences of 38 practitioners who responded.

TABLE 1: PERCENT OF PRIOR EXPERIENCES RATED AS BEING HELPFUL FOR USING COMPUTERS

Experience	Percent rated helpful
Writing	82
Programming	76
Reading	76
Typing	75
Teaching	69
Statistical work	63
Algebra or calculus	63
Working puzzles	63
Playing games	63
Sports	62
Editing	56
Working with appliances, machines, or engines	44
Business or accounting	44
Art and drawing	44
Operating calculator	37
English Grammar	37
Language	31
Music	31
Engineering	25
Sorting, filing	25
Tape Recording	19
Talking on the telephone	19
Hi Fi	13
Ham or CB radio	13
Acting	13
Categories added by respondents	06

4. Field Research

Among conferences and sites visited were:

a. Asilomar Math Conference-

The 22nd Annual Conference of the California Mathematics Council (Northern Section) was dominated by computing topics this year (December, 1979). Teachers overfilled all sessions on topics from "My First Computer Lesson" to "a Hands-On Talk with the Computer in Machine Language." This event, orchestrated by CUE (Computer Using Educators) featured presentations by many of the west coast leaders in educational computing. Its overwhelmingly positive reception was an on-the-spot needs assessment for teacher training in this field.

b. Computerland and Other Retail Stores-

Computer stores are excellent research sites. One can determine exactly what hardware and software is readily available to both learners and teachers. One can also assess computer environments expressly designed either to involve the uninitiated computerist or to enhance the knowledge of the novice or expert (thereby increasing his desire to own the latest item).

c. Menlo Park Public Library -

Several class I and II computers are available to the patrons of this small public library. About fifteen games and simulation tapes can be checked out from the reference librarian by anyone who has a "My Computer Likes Me" button. The button is a diploma from a two hour orientation class offered at the library on operating the computer, loading tapes, and playing games. Basic language is always available on these systems for uses in programming.

During a two-hour observation period, the major users of the equipment were adolescent and preadolescent boys, one of whom was the "teacher," i.e., person available to help with technical and social problems in this environment. We saw a total of ten boys, aged 6 to 16 engaged in programming, debugging, running graphic and simulation games, and math drill and practice in a game-like presentation. The youngest was with his mother, who watched but did not participate.

d. Jordan Jr. High School

The Jordan Jr. High School Computer Laboratory is a voluntry pull-out program designed and run by one teacher. Students are scheduled during regular school hours to complete a workbook of lessons on computer operation and beginning programming. Each student takes the six week course under the guidance of a peer teacher. During the succeeding six-weeks each student repeats the same material, this time in the role of peer teacher. Those students who wish to continue studying computing participate in additional after school programs on programming and teaching techniques. One of these programs is specifically set up for girls.

e. CUE Meeting

CUE (Computer Using Educators) is a growing organization of teachers, administrators, and parents who wish to promote the use of computers in schools and other learning environments. CUE puts on lectures, workshops, conferences, and other events to educate new members and enchance the work of seasoned participants.

We attended a small planning meeting at which plans for a permanent software library were being discussed. The library, housed in the resource center at the San Mateo County Office of Education, will contain diskettes cassette tapes of programs which run on the various brands of microcomputers used by local teachers. Teachers may try out the software at the library and copy non-copyrighted programs. Commercially produced programs with copyright restrictions may be reviewed and purchase information will be available.

Most programs available through the library are written by the teachers and contributed for distribution. Volunteers will catalogue each program and modify it if necessary to meet the library's quality and format guidelines.

f. Lawrence Hall of Science

Lawrence Hall of Science provides three different modes of computer access. In the foyer of the museum, several computer terminals offer a choice of computer games and simulations with instructions on posters on the wall explaining their use. School groups visit the museum daily and these terminals are always crowded. In the basement of Lawrence Hall is a large room containing about twenty computer terminals from which a large library of games, simulations, and other programs can be accessed. Anyone entering the museum can puchase computer time on a first come, first served basis during public hours. A college student, familiar with this particular computer system, is on hand in the terminal room to help new users orient themselves to the computer. In addition, Lawrence Hall offers a wide variety of classes in computer games, and programming to the public and through contracts with schools. Some research has been done in these settings but it is difficult to obtain reprints of the findings. A more direct route is to talk to local computer teachers, many of whom have received some or all of their training at the Hall.

APPENDIX B

The taxonomy described so far (see section III, pp. 25-32) results in a static description of a Computer-Augmented Learning Environment (CALE). But learning is a dynamic process, the result of a series of interactions between the static elements and the learner. No taxonomic snapshot can describe what is happening. To solve, in some detail, this problem we analyzed computer learning tasks that had been observed or described.

We began by developing an activity list:

B. ACTIVITY SEGMENTS (LEARNING, USING, TEACHING)

1. LEARNING THE SYSTEM
   a. START UP
   b. LOADING
   c. PROGRAMMING
   d. OTHER

2. PROGRAMMING
   a. IN BASIC - BEGINNING
   b. - INTERMEDIATE
   c. - ADVANCED
   d. IN OTHER HIGH-LEVEL LANGUAGE
   e. IN MACHINE OR ASSEMBLY LANGUAGE

3. APPLICATIONS
   a. GAMING
      (1) CHOOSING A GAME
      (2) LOADING A GAME
      (3) RUNNING GAME
      (4) READING INSTRUCTIONS
      (5) SEEKING HELP
      (6) RESPOND TO GAME
      (7) PROBLEMS ENCOUNTERED
   b. USING COMPUTER TOOLS
      (1) CALCULATOR
      (2) ALGEBRA
      (3) PLOTTING GRAPHS
      (4) STATISTICS
      (5) PERSONAL FINANCE
      (6) ENGINEERING
      (7) ENVIRONMENTAL MODELING

(8) DATA BASE MANAGEMENT
(9) WORD PROCESSING
(10) DATA ENTRY
(11) MACHINE CONTROL
(12) MUSIC
(13) SPEECH GENERATION AND RECOGNITION
(14) OTHER

c. COMPUTER ASSISTED INSTRUCTION (CAI)

d. OTHER

This activity list provides a good context to communicate what is occuring in the learning environment but it sheds little light on why teachers claim the computer is such an important learning tool.

C TEACHER-LEARNER ENVIRONOMENT SITUATION

In order to understand more precisely how the computer environments differ from traditional classrooms a more detailed analysis of teacher-learner environment interactions must be made. We adapted some categories from the work of Lindvall and associates. (Lindvall, 1967.)

1. INDEPENDENT WORK---THE STUDENT IS:

(1) USING PROGRAMMED MATERIAL
(2) INDEPENDENTLY CHECKING HIS WORK
(3) INDIVIDUALLY LISTENING TO A TAPE RECORDER
(4) WORKING INDEPENDENTLY ON A WORKSHEET
(5) READING INDEPENDENTLY
(6) WATCHING/LISTENING (TASK)
(7) RESTING/WATCHING (NON-TASK)
(8) WAITING: FOR TEACHER OR COMPUTER

2. TEACHER-STUDENT WORK

(1) SEEKS ASSISTANCE FROM TEACHER
(2) RECEIVES ASSISTANCE FROM TEACHER
(3) DISCUSSES PROGRESS WITH TEACHER
(4) GIVES FACTS TO TEACHER
(5) GIVES OPINION TO TEACHER
(6) SEEKS INFORMATION FROM TEACHER
(7) SEEK CLARIFICATION
(8) SOCIAL ACTIVITY

3. NONINSTRUCTIONAL USE OF STUDENT TIME

(1) OBSERVES
(2) WAITS FOR TEACHER TO PROVIDE MATERIAL
(3) WAITS FOR PRESCRIPTION
(4) GOES TO GET MATERIAL
(5) WAITS FOR APPROVAL

4. LEARNER-LEARNER ACTIVITY

(1) ASKS PEER ASSISTANCE
(2) GETS PEER ASSISTANCE
(3) TALKS TO PEERS/TASK
(4) TALKS TO PEERS/SOCIAL
(5) GROUP DISCUSSION/TASK
(6) GROUP DISCUSSION/SOCIAL

Unfortunately, this type of research requires more time and resources than we had available. Therefore, the actual collection and interpretation of these data fell beyond the scope of the present study. However, we feel confident that such a procedure would yield valuable results and hope to have the opportunity to pursue it in the future.

D. LEARNER ATTRIBUTES

How to describe the learner is a major dilemma. At the grossest level, learner data should include:

a) age
b) sex
c) grade level (including special status such as learning disabled)
d) whether learner's presence is voluntary or required.

This information yields equally gross results about who benefits from working with computers. It has been observed that bright, pre-adolescent boys generally volunteer for and stick to computer classes- but why? Detailed data along the following lines might yield interesting correlations with performance with and fear of computers:

a) psychology profile
b) achievement profile
c) attitude assessment
d) cognitive assessment

After studying the responses from the teacher interviews, the following modified list of learner attributes was compiled.

1. AGE, SEX, GRADE LEVEL
2. RELATED EXPERIENCE
   a. PROGRAMMING
   b. CALCULATING
   c. OTHER
3. ACHIEVEMENT PROFILE
   a. READING LEVEL
   b. MATH SKILLS
   c. SCIENCE SKILLS
   d. STUDY SKILLS
   e. SOCIAL SKILLS
4. COGNITIVE PROFILE
   a. SEMANTIC SKILLS
   b. SYMBOLIC SKILLS
   c. FIGURAL SKILLS
5. CONATIVE PROFILE
   a. ASPIRATIONS
   b. PERSISTENCE
   c. PRECISENESS

Much of the data to create a learner profile as outlined above exists in the cumulative school files of most students. However, we found no studies in which there was the attempt to match learner profiles with success in specific CALEs. The present study attempts to lay the groundwork for and to provoke such endeavors.

FIGURE 2: TAXONOMY

FIGURE 2. PROVISIONAL TAXONOMY OF COMPUTER-AUGMENTED LEARNING ENVIRONMENTS (CALEs)

- A. ENVIRONMENTAL ELEMENTS
  - 1. TEACHER
    - a. RELATION TO LEARNER
    - b. PERCEPTION OF TASK --TO LEARN:
      - (1) TRADITIONAL CURRICULUM
      - (2) COMPUTER AWARENESS CURRICULUM
      - (3) COMPUTER PROGRAMMING
      - (4) ELECTRONICS
      - (5) DATA PROCESSING (VOCATIONAL)
    - c. USE OF LEARNER OBJECTIVES
    - d. PROVISION FOR MOTIVATION
    - e. RELATION TO SOCIAL ENVIRONMENT
    - f. KNOWLEDGE OF COMPUTER ENVIRONMENT
  - 2. INSTITUTIONAL SETTING
    - (Classification 1)
      - a. HOME
      - b. CLASSROOM
      - c. LIBRARY
      - d. OTHER PUBLIC CENTER
      - e. INDEPENDENT STUDY (IN SCHOOL)
      - f. CLUB
      - g. OTHER
    - (Classification 2)
      - a. FORMAL LECTURE - WITH LAB.
      - b. COMPUTER LAB* IN SCHOOL MEDIA CENTER OR LIB
      - c. ONE TIME DEMO OR SCHOOL FIELD TRIP
      - d. IN OPEN CLASSROOM AS LEARNING STATION
      - e. IN CLASS OR TEACHER - SCHEDULED D * P
      - f. AFTER SCHOOL REC. CLUBS OR DROP-IN CENTERS
      - g. AFTER SCHOOL CLUBS FOR PROGRAMMING
      - h. IN CLASS, SUPPLEMENT OR MOTIVATIONAL
      - i. COMMUNITY CLUB (BOYSCOUTS...)
      - j. PRIVATE HOME
      - k. PUBLIC LIBRARY
  - 3. PHYSICAL SETTING
    - a. DESCRIPTION OF ROOM
    - b. FURNISHINGS
    - c. EQUIPMENT
    - d. ACCESS
    - d. ETC.
  - 4. SOCIAL SETTING
    - a. PEER INTERACTION
    - b. AVAILABILITY OF HELP
    - c. PERCEIVED OBJECTIVES OF LEARNER
    - d. LOCUS OF CONTROL OF ACTIVITIES
    - e. COMPETITION FOR A LEARNING STATION

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5. SOFTWARE

(Classification 1)

- a. DRILL AND PRACTICE
- b. EDUCATIONAL ACTIVITY
- c. TUTORIAL
- d. LOGICAL THINKING/ PROBLEM SOLVING
- e. SIMULATION
- f. EDUCATIONAL GAME
- g. DEMONSTRATION
- h. AUTHORING PROGRAMS
- i. CLASSROOM MANAGEMENT
- j. UTILITY

(Classification 2)

- a. NON-READING GAMES W EASY EYE-HAND COORD
- b. LIMITED READING GAMES
- c. LIMITED MATH GAMES
- d. SPECIFIC DRILL & PRACTICE
- e. NON-READING GAMES WITH ADVANCED E-H COORD
- f. SIMULATIONS - FOR LOGIC AND STRATEGY
- g. SIMULATIONS - FOR CONTENT
- h. INTEGER BASIC
- i. FLOATING POINT BASIC
- j. OTHER HIGH LEVEL LANGUAGES
- k. ASSEMBLY LANGUAGE

6. HARDWARE

- a. FEATURES
  - (1) MANFACTURER OF COMPUTER
  - (2) AMOUNT OF MEMORY
  - (3) PERIPHERALS (DISKS, PRINTERS, ETC.)
  - (4) OPERATING SYSTEM
  - (5) NETWORK AVAILABLITY
  - (6) RELIABILITY
- b. CLASSES
  - (1) CLASS 1: PERSONAL COMPUTERS (PET, APPLE, TRS-80...) WITH 16K OR LESS, INTEGER BASIC ONLY, CASSETTE TAPE STORAGE
  - (2) CLASS 2: PERSONAL COMPUTERS WITH LARGER MEMORY CAPACITY BUT CASSETTE TAPE STORAGE
  - (3) CLASS 3: PERSONAL COMPUTERS (PET, APPLE, TRS-80...) WITH 16K OR LESS, INTEGER BASIC ONLY, CASSETTE (2) CLASSES TAPE DATA STORAGE
  - (4) CLASS 4: PERSONAL COMPUTER WITH NETWORK*, LARGE DISK, OR MULTIPLE LANGUAGES
  - (5) CLASS 5: PERSONAL COMPUTERS DEDICATED TC SOFTWARE
  - (6) CLASS 6: TIMESHARING (WHERE SEVERAL TERMINALS ARE CONNECTED TO A SINGLE MEDIUM OR LARGE COMPUTER ETC, SEE P 24)

- B. ACTIVITY SEGMENTS (LEARNING, USING & TEACHING)
  - 1. LEARNING THE SYSTEM
    - a. START UP
    - b. LOADING
    - c. PROGRAMMING
    - d. OTHER
  - 2. PROGRAMMING
    - a. IN BASIC - BEGINNING
    - b. IN BASIC - INTERMEDIATE
    - c. IN BASIC - ADVANCED
    - d. IN OTHER HIGH LEVEL LANGUAGE
    - e. IN MACHINE LANGUAGE
  - 3. APPLICATIONS
    - a. GAMING
      - (1) CHOOSING A GAME
      - (2) LOADING A GAME
      - (3) RUNNING GAME
      - (4) READING INSTRUCTIONS
      - (5) RESPONDING TO GAME
      - (6) PROBLEMS ENCOUNTERED
    - b. USING COMPUTER TOOLS
      - (1) CALCULATOR
      - (2) ALGEBRA
      - (3) PLOTTING GRAPHS
      - (4) STATISTICS
      - (5) PERSONAL FINANCE
      - (6) ENGINEERING
      - (7) ENVIRONMENTAL MODELING
      - (8) DATA BASE MANAGEMENT
      - (9) WORD PROCESSING
      - (10 DATA ENTRY
      - (11 MACHINE CONTROL
      - (12 MUSIC
      - (13 SPEECH GENERATION AND RECOGNITION
      - (14 OTHER
    - c. COMPUTER ASSISTED INSTRUCTION (CAI)
    - d. OTHER

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TEACHER-LEARNER ENVIRONMENT SITUATIONS *

- 1. INDEPENDENT WORK THE STUDENT IS:
  - a. USING PROGRAMMED MATERIAL
  - b. INDEPENDENTLY CHECKING HIS WORK
  - c. INDIVIDUALLY LISTENING TO TAPE RECORDER
  - d. WORKING INDEPENDENTLY ON A WORKSHEET
  - e. READING INDEPENDENTLY
  - f. WATCHING/LISTENING (TASK)
  - g. RESTING/WATCHING (NON-TASK)
  - h. WAITING: FOR TEACHER OR COMPUTER
- 2. TEACHER-STUDENT WORK
  - a. SEEKS ASSISTANCE FROM TEACHER
  - b. RECEIVES ASSISTANCE FROM TEACHER
  - c. DISCUSSES PROGRESS WITH TEACHER
  - d. TEACHER GIVES FACTS
  - e. TEACHER GIVES OPINION
  - f. SEEKS INFORMATION FROM TEACHER
  - g. SEEKS CLARIFICATION
  - h. PROVIDES SOCIAL ACTIVITY
- 3. NON-INSTRUCTIONAL USE OF STUDENT TIME
  - a. OBSERVES
  - b. WAITS FOR TEACHER TO PROVIDE MATERIAL
  - c. WAITS FOR PRESCRIPTION
  - d. GOES TO GET MATERIAL/RESEARCHES
  - e. WAITS FOR APPROVAL
  - f. PLAYS GAMES
  - g. CREATES
- 4. LEARNER-LEARNER ACTIVITY
  - a. ASKS PEER ASSISTANCE
  - b. GETS PEER ASSISTANCE
  - c. TALKS TO PEERS/TASK
  - d. TALKS TO PEERS/SOCIAL
  - e. GROUP DISCUSSION/TASK
  - f. GROUP DISCUSSION/SOCIAL

D. LEARNER ATTRIBUTES

1. DEMOGRAPHY
   - a. AGE
   - b. SEX
   - c. GRADE LEVEL, ETC.
2. RELATED EXPERIENCE
   - a. PROGRAMMING
   - b. CALCULATING
   - c.
   - d. OTHER
3. ACHIEVEMENT PROFILE
   - a. READING LEVEL
   - b. MATH SKILLS
   - c. SCIENCE SKILLS
   - d. STUDY SKILLS
   - e. SOCIAL SKILLS
4. COGNITIVE PROFILE
   - a. SEMANTIC SKILLS
   - b. SYMBOLIC SKILLS
   - c. FIGURAL SKILLS
5. CONATIVE PROFILE
   - a. ASPIRATIONS
   - b. PERSISTENCE
   - c. PRECISENESS

- a. COMPUTER CONDUCTED DRILL AND PRACTICE
- b. COMPUTER ASSISTED INSTRUTION (CAI)
- c. COMPUTER-MANAGED INSTRUCTION
- d. FULLY COMPUTERIZED INSTRUCTION
- e. USE OF COMPUTERS IN SOLVING PROBLEMS

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E. EDUCATIONAL FUNCTIONS AND LEVELS

1. EDUCATIONAL FUNCTIONS **

f. LEARNING TO CONSTRUCT PROGRAM IN ANY COMPUTER LANGUAGE

g. LEARNING IN AN INFORMATION-TECHNOLOGY-BASED ENVIRONMENT THAT GIVES THE STUDENT BROAD SCOPE OF INITIATIVE

h. PRACTICE IN AN INFORMATION-TECHNOLOGY-BASED ENVIRONMENT THAT SIMULATES A REAL-WORLD TASK

i. LEARNING BY TEACHING HUMAN STUDENTS IN AN INFORMATION-TECHNOLOGY-BASED ENVIRONMENT

j. LEARNING BY TEACHING COMPUTERS

2. EXPERIENCE LEVELS

Most learners proceeded through many of these stages:

a. OVERCOMING FEAR OF TECHNOLOGY IN GENERAL AND COMPUTERS SPECIFICALLY

b. DEVELOPING ENOUGH CURIOSITY AND AWARENESS ABOUT COMPUTERS TO BEGIN "TO QUESTION."

c. UNDERSTANDING THE CAUSE AND EFFECT RELATIONSHIPS BETWEEN KEYBOARD, SCREEN, PROGRAM, AND PROGRAM STROAGE MEDIUM.

d. OPERATING THE COMPUTER "COMFORTABLY" - LOOKING, RUNNING, AND RESTARTING PROGRAMS.

e. USING THE COMPUTER WITH EXISTING PROGRAMS AS A PERSONAL TOOL- TO "BE DEMYSTIFIED ON THE MACHINE, SO THAT THEY VIEW THE COMPUTER AS A TOOL - ONE THAT DOESN'T EXCLUDE OTHER TOOLS."

f. LEARNING TO CONSTRUCT PROGRAMS IN ANY COMPUTER LANGUAGE.

g. PROGRAMMING NEW SOLUTIONS TO MAKE THE COMPUTER A BETTER TOOL.

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* Categories in "C" adapted from Lindvall, 1967.

Classification in "E 1" from Licklider, J.C.R., 1979.

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