An analysis of computer aided instruction for cognitive-psychomotor development

Michael Spangler
Iowa State University

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AN ANALYSIS OF COMPUTER AIDED INSTRUCTION FOR COGNITIVE-
PSYCHOMOTOR DEVELOPMENT

Iowa State University

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300 N. Zeeb Road, Ann Arbor, MI 48106
An analysis of computer aided instruction for cognitive-psychomotor development

by

Michael Spangler

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

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Signature was redacted for privacy.

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INTRODUCTION

In our technology oriented world, integrating information and production is requisite to personal and institutional success. Thus, acquiring information and combining it with production skills defines a functional education. This implies a symbiosis of sorts between the cognitive and psychomotor domains of learning. Exploring these domains is one purpose of educational research particularly in vocational education.

Vocational education is becoming increasingly competitive. Institutions must vie for enrollment and placement of their students. To succeed in this challenging environment, vocational educators must develop curricula which produce quality graduates and maintain student interest or motivation. Meeting these goals while integrating cognitive and psychomotor development is an enormous undertaking. Curricula can be designed using computer assisted instruction to address the rigorous objectives of vocational education.

In psychomotor skill development or dexterity training, computer aided instruction is a new commodity. Instruction has traditionally been focused on laboratory activities, although a knowledge base developed in lecture and classroom discussion is an imperative for understanding certain
concepts. Computer based simulations have been used to hone motor skills and enhance laboratory performance. Using the simulator as a tool for psychomotor development and measuring the effect on cognition is a new horizon for educational research.

The relationship between the cognitive and psychomotor domains is of particular importance to instructors in vocational education and specifically teachers of Industrial Arts or Agricultural Mechanization. These disciplines employ lecture (cognitive) and laboratory (psychomotor) teaching environments. Interdomain transference is a phenomena with potential implications for curriculum development.

A curriculum common to Industrial Arts and Agricultural Mechanization is Metal Forming and Construction. Within this course of study, an essential skill is arc welding. Although it is considered a "hands on" curriculum, a computer generated simulation of an electric arc welder can be used to develop motor skills and explain metalworking concepts which may be difficult to display because of vision or radiation hazards. Additionally, the simulator may be valuable in a cognitive learning environment to improve welding technique and conceptual understanding.
The computer may easily reproduce a static factor such as welder amperage and with interactive equipment may reproduce the dynamic factors of electrode travel speed and arc length. With these capabilities the computer-simulator can present a safe imitation of the actual welding process. The final consideration is the simulator effect on psychomotor skill. Can arc welding bead quality be improved through computer aided instruction? When two groups are given different treatments (traditional practice or computer simulation) will the quality of sample welding beads be different?

Statement of the Problem

The problem of the study is to evaluate the relationship of cognition to psychomotor development in a computer simulation of arc welding techniques for students of vocational education.

Statement of the Purpose

The purposes of this study are:
1. to determine if a relationship exists between cognition and psychomotor development in a vocational training environment.
2. to determine the differences, if any, in cognitive/psychomotor transference between traditional teaching methods and computer based instructional simulations.

3. to develop and test a computerized simulator for arc welding using a machine common to schools of all levels.

Statement of Need

The relationship of psychomotor focused teaching methods and cognitive development is, as yet, undetermined. Transfer of information between psychomotor and cognitive domains is assumed but unsupported by research literature. The need for introducing research in this area is apparent.

The conflict of diminishing educational funding with increased costs of teaching vocational skills, particularly metalworking, demonstrates the need to develop reliable instructional tools. The microcomputer based simulator is a low cost and available teaching tool. Once its utility as an instructional technique is proven and the relationship between simulator performance and laboratory performance is established the computer may represent a significant improvement in vocational and manual arts training.
Statement of the Assumptions

The following assumptions are made in the pursuit of this study:

1. Time on task and instructional content will be the same among groups studied in this project.
2. Weld judges are competent to assess the welds produced using current industry examination standards.
3. Participants in the study are representative of the student population. Randomness is assumed.

Statement of the Limitations

The anticipated limitations of this research study are:

1. The availability of sufficient precedent in conducting a study to assess interdomain transference. Searches of the literature showed no references to effects of psychomotor based teaching systems or environments on cognition.
2. The study will be conducted only in the summer of 1985.
3. The arc welding simulator can reproduce most of the functions of an electric arc welder except for angle of electrode relative to the line of travel. For purposes of this study, only amperage setting and electrode travel speed will be simulated.
Statement of the Hypotheses

**Research hypothesis I**

It is hypothesized that a relationship exists between cognitive learning and psychomotor skill development when using a computer simulation of an arc welder as a student centered tool to improve welding technique.

**Statistical hypothesis I**

\[ \text{Ho: } \rho = 0 \quad \text{There is no relationship between cognition and psychomotor skill acquisition.} \]

\[ \text{Ha: } \rho \neq 0 \quad \text{There is a relationship between cognition and psychomotor skill acquisition.} \]

**Research hypothesis II**

It is hypothesized that use of a computer simulation as an arc welding training tool will result in student weld quality different from the weld quality of traditionally trained students in a laboratory environment.

**Statistical hypothesis II**

\[ \text{Ho: } \mu_s = \mu_t \quad \text{The welding performance of subjects given the computer simulation technique is equal to the performance of those given the traditional instructional technique.} \]
Ha: $\mu_s \neq \mu_t$  The welding performance of subjects given the welder simulation is not equal to the performance of those given the traditional demonstration technique.

Research hypothesis III

It is hypothesized that cognitive test scores of students using an arc welder simulation practice technique are greater than scores of students using traditional practice techniques of welding instruction.

Statistical hypothesis III

$H_0: \mu_s \leq \mu_t$  The cognitive scores for subjects given the simulation practice technique are less than or equal to the test scores of those given the traditional demonstration practice instructional technique.

$H_a: \mu_s > \mu_t$  The cognitive scores for subjects given the arc welder simulation are greater than the test scores of those given the traditional demonstration-practice technique.

Explanation of Welding Process

Arc welding is fusing metals using an electric spark as the heat source. Welders provide current for the process
while the electrode serves as an electrical conductor and source of metal filler material from which the weld is produced. All factors in arc welding focus on a single objective, control of heat at the weld site. Arc welding heat control factors are divided into two categories.

*Static* factors are those which the weldor can not change during the welding process. The three static factors are:

- Welder amperage setting.
- Electrode type and size.
- Metal size and joint type.

*Dynamic* factors are those which are changeable during the welding process. The three dynamic factors are:

- Travel speed.
- Arc length
- Angle of electrode

Arc welding practice develops motor skills for controlling the forward motion of a molten metal pool, sustaining consistent pool diameter and maintaining a fixed arc length during a process where all three are changing. Arc welding practice also provides cognitive training on the relationships of static and dynamic factors with each other and with heat control in general.
Definition of Terms

The following terms are used in this study and require definition.

- **Arc Length** - gap across which the electric arc must travel; distance from the electrode to the welding surface.
- **Arc welding** - fusing metals using an electric arc as the source of heat.
- **Bead** - Appearance of the finished weld; the metal added in welding.
- **Cognitive Domain** - the area of learning which deals with the recall or recognition of knowledge and the development of intellectual ability.
- **Dynamic Welding Factor** - an element of welding heat control which may be changed by the operator during the welding process.
- **Electrode** - conductor rod, often steel with a flux coating, from which the arc is produced in welding; usually melted to form the weld.
- **Electrode Travel Speed** - the rate at which the electrode is moved to form the weld bead.
- **Interdomain Transference** - the phenomena of learning exchange between domains; e.g., crossover of information between cognitive and psychomotor domains.
Psychomotor Domain - the area of learning concerned with acquisition of physical skill, neuromuscular coordinated movement.

Simulation - A computer model or representation of a device or process.

Static Welding Factor - an element of welding heat control which is fixed prior to the welding operation.

Welding Current - the amount of electrical current, measured in amperes, required to develop sufficient heat for metal fusion.
REVIEW OF THE LITERATURE

The literature review is presented in three major sections: (1) Cognition and knowledge acquisition, (2) Psychomotor skill development, and (3) Computer aided instruction.

Upon examination of the literature, one finds a considerable volume of publications with topics neatly discriminated by their position within Bloom's (1956) taxonomy of educational objectives. The phenomenon of interdomain transference or the exchange of information between educational domains is nearly undocumented. The existence of interdomain exchange is acknowledged by educators (Singer, 1972), psychologists (Krathwohl, Bloom, & Masia, 1964) and even taxonomists (Harrow, 1972), but no publications of research on this topic could be found.

Cognition and Knowledge Acquisition

The central problem for a cognitive theory of instruction poses this working hypothesis: "What is the nature of the general cognitive capacity that underlies knowledge acquisition?"

A basic characteristic of human intelligence is the ability to formulate abstract conceptual knowledge about objects and events. Abstract conceptual knowledge is
exemplified when one can deal appropriately with novel instances of a concept, that is, when our knowledge goes beyond just those instances experienced. For example, there is abundant evidence that our knowledge of language must be abstract given the novelty that must be dealt with (Papert, 1980).

The role of novel events in language has long been recognized by linguists. Sentences are almost always novel events. To verify this fact you need only pick at random a sentence in a book and then continue through the book until the sentence is repeated. Unless you have picked a cliche' or a thematic sentence, it is unlikely that the sentence will reoccur. It is readily admitted that most sentences are novel, but what about the elements from which sentences are constructed? Syntactic components must be in a particular order for us to understand sentences. Further examination, however, shows that words too are typically novel events. The apparent physical sameness of words is an illusion supported by the use of printing presses. If handwriting is considered, a great deal of variation in letter and word construction is discovered. The novelty of words becomes even more clear when we think of the same word spoken by different speakers, male and female, child and adult, or by the same speaker when shouting or whispering.
The importance of the argument for novelty is to illustrate that this repetition is not necessary for our understanding of words. Our ability to recognize and understand words or any other information is not a function of having experienced that particular physical event before (Greenburg & Jenkins, 1964).

Due to their generality, abstract concepts apply to a potentially infinite class of instances. This fact poses a serious problem for a cognitive theory bent upon explaining how concepts are acquired. Since one's experience is only a sample of the entire set of events to which such concepts refer, several puzzling questions arise. First, how can experience with a subset of objects or events lead to knowledge of the whole set to which it belongs? The claim that some part of a structure can be equal to the whole structure seems to involve a logical contradiction. A second related question that must be answered, given a precise answer to the first, concerns the nature of the subset providing the knowledge needed to deal with the entire set. Will just any subset of instances do, or must the subset be a certain size or quality? In other words, how do instances of a concept qualify as exemplary cases of the concept? A precise answer to this last question has quite obvious implications for the selection of effective instructional material for teaching concepts.
Such questions have perplexed philosophers for many centuries, leading some to propose that in fact no concept of an infinity class is really possible. Their argument was based upon the belief that since finite abstraction is the means by which all concepts are formed, then the concept of the infinite must refer only to one's ignorance regarding the exact size of a class inexactily surveyed by the senses. Such a belief constitutes a refusal to recognize the creative capacity of human intelligence. One is wrongly led to a theory of knowledge founded upon principles which define knowledge as nothing more than the association of past sensory impressions. Dewey (1939) called products of such a theory "dead" ideas because they have no facility to grow.

Infinite structures can be represented by finite means if the finite means are creative, in the sense that techniques exist to generalize about the whole from some appropriate part (Shaw & Wilson, 1976). For example, it does not take children long to realize that any combination of single digits (0,1,2,...,9) yields a valid natural number. The number 43051 is, of course, a valid instance of the concept of natural numbers, but how does one know this? Has this number been seen before? Is it a familiar or novel instance of the natural number concept? One knows that this
number is a valid instance, presumably because one's knowledge of strings of numerals is as abstract as that for English sentences or any other cognitive matter (Klahr, 1976).

If the above reasoning is valid, then it may be said that people may obtain abstract concepts and not necessarily be able to recognize novel instances of the concept as being novel. That is, events in the sensory generated set of a concept will not always be distinguishable from those instances never before experienced. Therefore, the role of the educator is to expose students to concepts and the novelty of conceptual instances within an experiential learning process.

Gaming is a form of applying concepts and developing new cognitive skill. Considerable attention has been given to study of how humans play games. Less attention, however, has been given to how humans learn to play games. For example, simulation and gaming in training of air-to-air combat tactics is a large military issue. The literature, however, places all the emphasis on how to perform the tactics as opposed to when to perform. The strategic thinking of pilots is either not emphasized in the classroom or is not represented in the unclassified literature. Flight proficiencies are being developed with little thought
given to the accompanying cognitive needs (Bailey, Hughes, & Jones, 1979). Laughery (1984) discusses conceptual acquisition and the development of game playing skills through simulations. One acquires skill at a game or any task by three steps: learning the rules of the game, playing the game, and refining the play. Beginners do not play randomly. After introduction to the task (game) some primitive strategies are developed. As the task is practiced or game played, new strategies are developed, refinements emerge, and their desirability becomes more clear. This process is easily translated from game playing to conceptual acquisition. As a concept is introduced certain preliminary ideas are formed and with practice those ideas are refined to a more thorough conceptual understanding.

Teaching concepts through simulation gaming has been used in management, economics, athletics, sociology, chemistry, law, and many other curricula. Even with all these applications, understanding of the cognitive mechanisms that make simulation an effective instructional medium is still not clear. DeNike (1976) found an interaction between educational cognitive style and the effectiveness of simulation games as a teaching aid. Simulations benefited students relying on peer interaction
and individual thought more than those with different educational styles. The study points out the need for further investigation of cognitive development through simulation gaming.

Pate and Mateja (1979) state that developers of instructional simulations whose general objective is to enhance the acquisition of knowledge as well as its understanding, should select for presentation only key concepts and relationships that can serve for anchoring ideas for further learning. By so doing, they will not only help teachers better instruct these concepts but also improve chances for further learning that will take place when new information is tied to these concepts.

Psychomotor Skill Development

Because of genetic factors, growth and developmental considerations, and prior environmental experiences, learners come to a learning situation with dissimilar probabilities for success. Although educators are typically concerned with the group, or gear instruction for the average individual within the group, there are many reasons why this concern and procedure can be questioned. In support of this approach, it is assumed that principles of learning or laws of behavior generally apply to most
individuals. Doubtless, it is practical to instruct in
groups rather than on an individual basis. If one assumes
the uniqueness of the skill to be learned and a relative
homogeneity of the would-be learners in relevant variables,
group education or training can be defended on reasonable
grounds.

Before designing a behaviorally stated psychomotor
curriculum, certain basic understandings are essential.
Categorizing learner behavior into one of the three learning
domains presents the first problem. To minimize the problem
the educator should ask, "What is the primary concern or
intended educational goal?" If the goal can be labelled as
manipulative or movement behavior change then placement
within the psychomotor domain is appropriate. The educator,
however, must realize that some educational goals will have
cognitive, psychomotor and affective aspects. In this case,
one must be sure to evaluate each aspect of the stated
educational goal (Simpson, 1968).

The second consideration about which the educator
should be aware is that fundamental movements are inherent
to the individual, but there still exists the need for
learning experiences to enhance the development of movement
skills. It is through continued practice and meaningful
experience that the learner enhances abilities (Jones,
1969).
Developmental theories by Hebb and Piaget place quantity of stimulation above quality during the first two years of life. However, the qualitative aspects of stimulation become essential by at least four years of age and are most beneficial if directly related to the behavior to be changed (Ragsdale, 1950). It is then the responsibility of the educator to balance the quantity of motor activity with the quality of skill instruction to produce the most effective psychomotor learning environment.

When developing psychomotor activities an educator must be aware of the specifications of abilities, measures and materials with particular reference to curriculum development. Fleishman and Parker (1962) defined these specifications to include:

- (a) the range of activities that need to be covered in order to be comprehensive in the subject area;
- (b) measures for possible use in assigning or selecting students for particular training efforts or for evaluating progress and proficiency in various areas of psychomotor performance;
- (c) materials and apparatus developed for inclusion in particular psychomotor development and training activity.

In addition to the above specifications, Fleishman and Parker (1962) further distinguished between the concepts of ability and skill.

As we use the term, ability refers to a general trait of the individual which has been inferred from the correlations obtained among performances
of individuals on certain kinds of tasks. Some abilities (e.g., color vision) depend more on genetic than learning factors, but most abilities depend on both to some degree. In any case, at a given stage in life, they represent traits or organismic factors which the individual brings with him when he begins to learn a new task. These abilities are related to performance in a variety of human tasks. For example, the fact that spatial visualization has been found to be related to performance on such diverse tasks as aerial navigation, blue print reading, and dentistry makes this ability somewhat basic.

The term skill refers to the level of proficiency on a specific task or limited group of tasks. As we use the term, it is task-oriented. When we talk about proficiency in flying an airplane, in operating a turret lathe, or in playing basketball, we are talking about a specific skill. Thus, when we speak of acquiring the skill of operating a turret lathe, we mean that this person has acquired the sequence of responses required by this specific task. The assumption is that the skills involved in complex activities can be described in terms of the more basic abilities. For example, the level of performance a man can attain on a turret lathe may depend on his basic abilities of manual dexterity and motor coordination. However, these same basic abilities may be important to proficiency in other skills as well. Thus, manual dexterity is needed in assembling electrical components, and motor coordination is needed to fly an airplane.

Implicit in the previous analysis is the important relationship between abilities and learning. Thus, individuals with high manual dexterity may more readily learn the specific skill of lathe operation. The mechanism of transfer of training probably operates here. Some abilities may transfer to the learning of a greater variety of specific tasks than others. In our culture, verbal
abilities are more important in a greater variety of tasks than are some other types of abilities. The individual who has a great many highly developed basic abilities can become proficient at a great variety of specific tasks (Steinkamp, 1983).

The development of basic abilities has been elaborated by researchers Fleishman (1967) and Gagne and Fleishman (1959). These elaborations included discussions of physiologic bases, the role of learning, environmental and cultural factors and evidence of the rate of ability development during the life span. With this much conceptualization, one can say that an objective has been to describe certain skills in terms of more general ability requirements.

The study of individual differences in motor skills and learning has been understood as a branch of psychological testing. To the experimental psychologist, individual differences are "within group error," background variation against which experimental effects are evaluated. To the differential psychologist, individual differences are the psychomotor tests. For the differentialist, motor skills involve a "continuous interaction of response processes with input and feedback process" (Fitts, 1962). To the rest of psychology, a test consists of items, each one separate and
distinct from the others. When psychologists build tests of intelligence, ability, or personality, they select and weight items. Psychomotor tests, however, may not be constructed in this fashion because they are not made of items. For example, tracking or two-hand coordination, learning to play golf or billiards, and keyboarding are skills which all involve integrated, continuing and active processes. They may be done badly but they must be done in a more or less unitary fashion or not at all.

Skill testing usually involves learning. The test is not administered but practiced, and instead of one total score for each subject we have as many overall scores as there are trials of practice. If there are 16 trials, we have 16 overall scores of performance This complication might be no more than a nuisance were it not that differential composition varies systematically from trial to trial, that different abilities are involved at different stages of practice (Jones, 1969).

Psychomotor behavior is the result of the complex interaction of many factors. Instructional modes vary, depending on the matter to be learned and the stated objectives. Distinctions are made between training and education, with the usual implications that cognitive matter is primarily the concern of education whereas psychomotor skills are connected with training programs. Both training and education are forms of instruction with subtle distinctions and commonalities. The objectives of both are to modify behavior (Singer, 1972).
The most obvious goal of psychomotor instruction is to develop the highest skill levels possible in the learner in the time allocated. This may be a justifiable end in itself or it may serve as a means for contributing to other objectives. For example, many special educators and clinical and developmental psychologists believe that experience in the development of motor skills increases the probability of success in academic endeavors (Clarke, 1982). Ultimately in order to attain proficiency in a skill, a wide selection of variables as presented in this review must be considered.

Computer Aided Instruction

The first use of computers by educational institutions was in the late 1950s when second generation computers first appeared. With the advent of higher level languages, the number and types of users of the computers increased. Major universities began using the new models of machines for accounting, payroll, and student record keeping. At the same time, computers began being used for instructional research. One of the first major instructional research applications was the PLATO project at the University of Illinois. PLATO was designed as a large computer based instructional system. Similar projects were developed at
Stanford University and the Pennsylvania State University (Dennis, 1979). From the mid-1960s through the first half of the 1970s, third generation computers became available in increasing numbers and at lower cost. More school systems and colleges began using computers for administrative functions but only a select few universities had developed any instructional computing programs. Only a small group of corporations and military took any interest in the instructional capacity of the new computers.

In the early 1970s, some new approaches to computer based instruction emerged. Intended for adult learners, the Time-shared Interactive Computer Controlled Instructional Television (TICCIT) system was produced by the MITRE corporation and Brigham Young University. This system allowed students to study lessons presented on a color television and respond through modified typewriter keyboards controlled by a minicomputer. During this period, the PLATO project introduced Plato IV, a large time-shared instructional system. Students study on individual terminals which are connected to a large computer on which all lessons and student data are stored.

Other computer based instruction projects were begun and developed in the early 1970s. Seymour Papert at the Massachusetts Institute of Technology began research on
teaching children by having them program computers. Papert (1980), espousing the educational theory of Jean Piaget, maintained that students can learn many problem-solving skills on their own, given the correct educational environment or "microworlds".

Other institutions and government agencies were developing an increased interest in computer based instruction. Major projects began in the U.S. Navy and U.S. Air Force as well as at many major universities.

A different approach to these university and government projects was taken by the Minnesota Educational Computer Consortium. MECC was oriented toward putting computers and related facilities in the public schools. MECC, like all previous projects, used large and expensive computing machines which inhibited adoption.

In 1977, the first commercially successful microcomputers were mass marketed in the United States. Radio Shack and Commodore Business Machines introduced the TRS-80 and PET computers, respectively. An unknown company also introduced its own computer, the Apple (McManus, 1982).

The introduction of these microcomputers ushered in the microcomputer revolution. Unlike the large machines, the microcomputer was within the budget of many schools and businesses. And unlike the first attempts at
microcomputers, these machines were complete systems with all necessary input, output, memory, processing and storage facilities.

Until this time, experiments in computer-based instruction were the domain of large projects that had the funds necessary for large computing systems. With microcomputers it became possible for the individual public school teacher to purchase a computer and use it for instruction. By 1985, all colleges and universities have microcomputers and most secondary and elementary schools own a machine (DeVault & Harvey, 1985).

Instructional computer programs are referred to by a variety of names. Some of these are:

- CAI - Computer Assisted Instruction
- CBE - Computer Based Education
- CAL - Computer Assisted Learning
- IAC - Instructional Application of Computers
- CBI - Computer Based Instruction

These terms are often used interchangeably. For the purpose of this study, the terminology of choice is computer assisted instruction. This term is chosen to emphasize instruction rather than education in general and to reinforce the use of the computer to assist educators not replace them.
For instruction to be effective, it is necessary that the following four phases be present:

- Presenting information
- Guiding the student
- Practicing the task
- Assessing student learning

These phases are equally important when using a computer assisted instructional approach (Rosenshine, 1983). This is not to say that the computer must always fulfill all the phases of instruction. Computers are one element of the instructional environment along with teachers and other media. The computer may serve any combination of the four phases.

A computer assisted instructional program may belong to one or more of the following types.

- Tutorial
- Drill
- Simulation (Thomas & Boysen, 1984)

Tutorials are designed to satisfy the first two phases of instruction. They present information and then guide the student through initial uses of the information to develop a framework for familiarity or fluency. Tutorials have a broad horizon of application crossing almost all disciplines. They are appropriate for presenting factual
information, for learning rules and principles or for learning problem solving strategies (Gagne, Wager, & Rojas, 1981).

Drills are used primarily for the third aspect of instruction, practice. Computer based drills are criticized for not capitalizing on the power of the computer. This criticism is partly justified in that many of the aspects of a drill may be just as easily accomplished with flashcards or workbooks. However, it is important to note that the computer can be used to produce drills of much greater effectiveness than flashcards or workbooks by incorporating the drill and practice routine with other types of instructional computing strategies (Osgood, 1984).

Another criticism of drills is that they do not teach but merely practice with the assumption the student is already familiar with the information to some degree. This is true.

Drills are not intended to teach. Problems arise when teachers assume a drill is capable of teaching new information and use it as if it should. Drills must be preceded by instructional methods that present the information and guide the student through intitial learning. In computer based instruction this might mean preceding the drill with an appropriate tutorial or simulation. It might also mean preceding the computer based drill with readings in a textbook, a classroom lesson, or a group discussion (Rosenshine, 1983).
A valid criticism is that most computerized drills are of low quality. Most do not incorporate good instructional principles, and most do not collect useful information to show how well the student is progressing. In addition, the response judging procedures are frequently poorly programmed so that reasonable responses are sometimes judged to be incorrect (Osgood, 1984).

A simulation allows a student to learn about some aspect of the world by imitating or replicating it. Students are not only motivated by simulations but also learn by interacting with them in a manner similar to the way they would react in real situations. In almost every instance, a simulation also simplifies reality by omitting or changing details. In this simplified world, the student solves problems, learns procedures, comes to understand the characteristics of phenomena and how to control them, or learns what actions to take in different situations (Dennis, 1979).

Simulations differ from interactive tutorials which help the student learn by providing information and using question-answer techniques. In a simulation, the student learns by actually performing the activities to be learned in a context that is similar to the real world (Thomas, 1970).

Simulations, in contrast with tutorials, may be used for any of the four phases of teaching. Initial presentation, guiding the learner, practice, and assessing learning are all capabilities of a simulation.
Simulations may be divided into four main categories:

- Physical
- Procedural
- Situational
- Process

In a computer based physical simulation, a physical object is displayed on the screen, giving the student an opportunity to use it or learn about it. For example, given a physical simulation of a lathe, the purpose is to learn the components and functions of the equipment as it imitates operation. The physical simulation as a stand-alone instructional tool is little more than a glamorous tutorial.

In most lessons, physical simulations play a secondary role to procedural simulations. The physical simulation exists only as a vehicle for the procedural content. The student learns how the simulated machine works as a means to acquiring skills and actions needed to operate the actual equipment. A program that simulates the important flight instruments of an airplane, for example, is more likely to be used primarily to teach procedures of flying rather than how the instruments work.

The purpose of most procedural simulations is to represent a sequence of actions that constitute a procedure. As previously noted, many physical simulations are also
procedural simulations. The primary focus of such a simulation is usually procedural and the simulation of the various physical objects is therefore necessary to meet the procedural requirements (Pieper, 1984).

In procedural simulations, whenever the student acts, the computer program reacts providing feedback about the effect of the action in the real world. Based on this information, the student takes successive actions and each time obtains more information.

In a learning environment in which procedural simulations are used, there is usually a correct or preferred sequence of steps that the student should learn to perform. There may be many different ways to reach a given outcome, not all of which are equally efficient. A procedural simulation provides the opportunity to explore the different paths and their associated effects (Bronson, 1984).

Situational simulations deal with attitudes and behaviors of people in different situations rather than with skilled performance. Unlike procedural simulations which teach sets of rules, situational simulations usually allow the student to explore the effects of different approaches to a situation or to engage in role playing. The student is an integral part of the simulation. Some games are
classified as situational simulations, particularly adventure and gambling games.

Process simulations are different from other simulations in several ways. The student neither participates in the simulation as with situational simulations nor constantly manipulates it as in physical or procedural simulations. The student selects values of various parameters at the beginning of the exercise and then watches the process occur without intervention. Economists, for example, use process simulations for forecasting. Learning from these simulations occurs by repeating the process a number of times with different input values.

Another distinguishing feature of process simulations is their relationship with time. They are either an accelerated or decelerated version of the real process. Some actions happen too fast to easily measure such as the movement of electrons. Other actions are too slow to afford a perspective of the process such as growth of populations. Process simulations present concepts in a time frame that highlights the changes in reality (Boiteau, Stansfield, & McManus, 1982).

The simulation to be used in this study should be considered both procedural and physical. It will be described in detail in the following chapter.
DESIGN AND METHOD

The primary purpose of this study was to evaluate the effect of psychomotor skill instruction on cognition in a computer assisted vocational training environment. This chapter describes the design, population, sample, treatments, instrumentation, data collection, and analysis techniques used in this study.

Design

The design for this study was a pretest-posttest control-group design with matching using two treatment groups and a control group. The pretest-posttest control group design is described in Borg and Gall's (1979) "Educational Research". The design may be represented graphically as:

\[
\begin{align*}
R & \quad O & \quad X_1 & \quad O \\
R & \quad O & \quad X_2 & \quad O \\
R & \quad O & \quad O \\
R & \quad O & \quad O
\end{align*}
\]

These symbols are explained as follows:

- \(R\) indicates random selection from the population and random assignment to the separate treatment groups or levels.

- \(X_1\) represents the treatment group in which the student uses the arc welder simulator as a psychomotor skill.
skill development tool.

\( X_2 \) represents the treatment group in which the student uses the real arc welder as a psychomotor skill development tool.

\( O \) represents the pretest or posttest examination by the researcher.

Leedy (1980) discussed the matched pretest-posttest control group design:

The pretest-posttest control group design is the "old workhorse of traditional experimentation." In it, we have the experimental group carefully chosen through appropriate randomization procedures and the control group similarly selected. The experimental group is evaluated, subjected to the experimental variable influences and reevaluated. The control group is isolated from all experimental variable influences and is merely evaluated at the beginning and at the end of the experiment. A more optimal situation can be achieved if the researcher is careful to match the experimental against the control group and vice versa for identical correspondences. Certainly, where matching is effected for the factor that is being studied, the design is thereby greatly strengthened.

The matched pretest-posttest control group design was used in this study.
Population

The population for the study consisted of students predominately enrolled in an agricultural discipline and attending Iowa State University during the summer semester of 1985.

Sample

Forty-five subjects were randomly selected from a pool of volunteers solicited from the student population. After pretesting all subjects the groups were established by matching results of the psychomotor skill portion of the pretest.

Each participant received a written and verbal explanation of the purpose of the research project. A complete statement of the activities and any possible hazards was furnished to the subject. Additionally, all participants received instruction for safe operation of arc welding equipment, eye protection, and use of the protective clothing furnished by the researcher. This safety training was identical to that given in the Iowa State University Agricultural Mechanization curriculum.
Treatments and Data Collection

All participants in the study received introductions to the project and safety training in the laboratory. The subjects were then tested to establish foundation scores for both psychomotor and cognitive levels. The psychomotor test was a basic measure of eye-hand coordination. The motor skill pretest was a computer based game which generated a score to be used as an indicator of eye-hand coordination. The cognitive pretest was a 24 item test to determine level of awareness of heat control techniques in arc welding. The two pretest scores were used to match members of the two treatment groups and the control group. An additional demographics survey was furnished to collect nonconfidential personal history information.

After pretesting, all participants received ten minutes of introductory safety instruction and training to start an arc with the AC/DC transformer-rectifier welder. The lesson plan for the introduction and safety training is located in Appendix I. Following this training, the groups received the experiment treatments for learning control of heat in arc welding.

Two treatments were employed by this study. Both treatments involved welding practice techniques for control of electrode travel speed and amperage setting for a flat
position open plate weld. The first group received the traditional demonstration-practice technique as is currently used in teaching arc welding in Industrial Arts, Construction Engineering and Agricultural Mechanization. In this technique, the instructor demonstrated the proper methods of setting the welder amperage, and regulating the travel speed of the electrode. After the demonstration, the student was allowed to practice the skill for ten minutes. The student was then given three pieces of metal on which to weld one bead each with no time constraint. When the welds were completed, the student marked each bead 1, 2 or 3 in order of completion and remitted the labelled product to the instructor. The instructor then submitted the three welds to be evaluated as a unit by a panel of judges using a scale value from 1 to 10 for an overall rating of travel speed control. Complete lesson plans for the demonstration and treatment are available in Appendix J.

The second treatment group received training in setting welder amperage and regulating travel speed by using a computer based arc welder simulator. The simulation used an Apple IIe microcomputer and the Apple Graphics Tablet to reproduce the effects of the welding process. The programs for the simulation are located in the Appendices. The Apple Graphics Tablet presents a thirteen inch square sensitive to
the traces of an attached pen. When the pen is depressed, a signal is transmitted through a circuit board installed in slot four of the Apple IIe. The signal is interpreted and displayed on the monitor as a trace. The pen is used as if it is a writing pen on paper. For the purposes of the simulation, the pen was attached to an electrode holder in the same manner as an electrode. This allows movement similar to the mechanics of moving an electrode and electrode holder. Appendix L shows the simulator user's hand position. In the simulation, the vertical movement of the pen is suppressed and only the horizontal travel is recorded. The resulting movement of the pen is computed to measure the time of travel from one point to the next on the horizontal axis. The product of the computation results in an estimate of travel speed on the horizontal axis and is displayed as an icon representing the type of weld bead which would be produced if all welding factors other than speed and weld current were optimal. Weld current is established at the beginning of the simulation using a computer generated sliding scale showing a range of amperages from which the user may select one. Starting and ending points on the simulated weld are presented and a center line representing the metal joint is displayed. The user is instructed to begin the weld by touching the left
side of the tablet and drag the mock electrode across the simulated weld surface. The computer will display an icon representing the slag covering of the bead. When the weld is finished, the computer will instruct the user to remove the slag by touching a key. The bead will be revealed to show areas of fast, slow, and normal travel speed as well as the effects of excess, insufficient, or normal amperage as in Appendix M. After ten minutes of simulator use, the student was assigned an arc welder and given three pieces of metal to weld in the same manner as the first treatment group. Complete lesson plans for the simulation treatment are located in Appendix K.

Both treatment groups used an American Welding Society classification E7014 electrode which allows the weldor to drag the rod across the metal surface thereby eliminating the factor of arc length maintenance.

All subjects were given a cognitive posttest after the arc welding experience. This instrument was a 24 item form with items identical to those on the pretest.

The control group received no treatment after the initial training and pretesting. Control group subjects were given the cognitive posttest.
Data Analysis

The research variables for which data were gathered include:

- Posttest Score - measured by the 24 item cognitive focused posttest.
- Pretest Score - measured by the 24 item cognitive focused pretest.
- Eye-Hand Coordination - Simple neuromuscular responsiveness as measured by the score on a computer based game.
- Welding Performance - Quality of an arc welding bead as judged by a panel of welding evaluators.
- Computer Experience - Research subject's self-estimation of general experience with computers and computer based games or simulations.
- Sex.
- Age.
- Education level - Expressed in years of formal education.
- Collegiate Major - Chosen from a list of curriculum areas.
- Family Environment - Rural, Suburban or Urban.
- Family Employment Type- Farm, Blue Collar, White Collar, Professional or Other.

Analyses were accomplished using facilities at the Iowa State University Computation Center. The Statistical Package for the Social Sciences (SPSS-X) (SPSS Inc., 1983) was the computer program package used for statistical treatment of the data. The following description of procedures is an overview of the statistical treatments employed.

**Descriptive analysis**

**Analysis of background variables**  
SPSS-X procedure FREQUENCIES was used to describe categorical variables for selected subject characteristics. This procedure produced means, standard deviations and other descriptive statistics for each variable.

**Descriptive analysis of dependent variables**  
Cognitive score and welding performance were analyzed using the SPSS-X procedure FREQUENCIES. The analyses yielded descriptive characteristics of the dependent variables.

**Inferential analysis**  
SPSS-X procedure ANOVA was used to develop an analysis of variance for the dependent variables. SPSS-X procedure REGRESSION was used to develop a multiple regression
equation for predicting welding performance by selected variables. SPSS-X procedure PARTIAL CORR was used to determine relationships between variables.

Summary of Research Procedures

The study was conducted during summer semester, 1985, to evaluate the interdomain transference of psychomotor instruction to cognitive development. Transference was assessed by pretest-posttest difference using 24 item cognitive evaluation instruments. Research subjects participating in the treatment groups were examined for welding performance as well as cognitive differences. Control group members received only the introductory instruction, the pretest and the posttest. Participants in the project were chosen from a pool of volunteers and were given complete safety training prior to any experimental treatment.

The experimental procedures were conducted at the Iowa State University Agricultural Engineering Department in the welding laboratory and adjacent classroom. All protective devices and welding equipment were furnished by the researcher. All data collected were coded and analyzed using computation facilities at Iowa State University.
FINDINGS

The purpose of this study was to evaluate the interdomain exchange of information based on a change in cognitive test scores after psychomotor skill training. To accomplish this purpose volunteer subjects from the student body of Iowa State University were randomly selected to participate in the study. The participants were selected for membership in one of two treatment groups or the control group by matching performances on a computer based game used as a motor skill test and by a cognitive pretest of arc welding heat control knowledge.

Data collected from all participants were as follows: (1) demographic information, (2) eye-hand coordination, (3) pretest score and (4) posttest score. The two treatment groups also provided weld quality scores.

Results of the data analyses are presented in three sections: (1) descriptions and analyses of demographic information, (2) analyses of instruments and judges used in data collection and (3) tests of research hypotheses.

Subject Characteristics

Forty-five subjects were randomly selected from a pool of respondents to advertised requests for research subjects. Written informed consent to research participation was
obtained from each subject (Appendix A). The sample groups were ranked and matched by pretesting to form three groups of 15 subjects each. Assignment of groups to treatments 1, 2, and 3 (welder, simulator, and control, respectively) was random. All subjects completed a demographics survey instrument (Appendix B) from which the following descriptive statistics were developed. Appendix N presents further demographic information of the subject groups.

The average age of all participants was 23.87 years with 24 years the most frequently reported age. Subject ages varied from 18 to 33 years. Mean ages were 24.67, 23.47, and 23.46 years for groups 1, 2, and 3, respectively. An analysis of variance showed no significant differences among the mean ages of the groups.

Participants in the study included 34 males and 11 females, 75.5% and 24.5%, respectively. Distribution among groups by sex could not be analyzed. Two cells (33% of total) did not contain the minimum cell size of five. The simulation, welder, and control groups contained five, two, and four females, respectively.

All participants reported education levels in terms of years of formal schooling. The average number of years of education for the entire sample was 15.97 with 16 years most frequently reported. An analysis of variance showed no
significant difference existed among mean education levels of the research groups.

The chi-square procedure was employed to analyze the distribution of collegiate majors reported by the research subjects. The analysis showed no significant differences in the distributions of majors among the three study groups.

Each subject reported a self-evaluation of general mechanical experience using the following scale:

<table>
<thead>
<tr>
<th>Very limited experience</th>
<th>average experience</th>
<th>Very extensive experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The mean general mechanical level of all participants was 5.22 with 5 the most frequently selected value. An analysis of variance for the mechanical experience scores shows heterogeneity of the group means with a ratio of 4.73 and a probability of 0.01. The Scheffe range test showed groups 2 and 3 (simulator and control) to be homogenous with means of 4.73 and 4.60 respectively. Group 1 (traditional practice) with a mean mechanical experience score of 6.33 was significantly different from the other groups. Any impact of this difference on the dependent variables of this study will be addressed later in the chapter.
A general computer experience score was solicited from all subjects of the study using a scale identical to the one used for mechanical experience. The mean computer experience score for all participants was 3.91 with no significant difference of means among the three study groups.

All subjects were asked to identify their family environment from among the following three choices:

- Rural
- Suburban
- Urban

Thirty (67%) of the subjects identified themselves as coming from a rural environment. Ten (22%) identified themselves as from a suburban environment. Five (11%) selected urban as their family environment. Distributions of the various family environments across the three study groups was such that, using a chi-square procedure, no significant differences among the groups could be found.

All research subjects were asked to identify their family employment category from among the following:

- Farm
- Blue Collar
- White Collar
- Professional
- Other
Twenty (44.4%) of the respondents identified their family employment as farming. One person (2.2%) selected the blue collar employment type. Nine subjects (20%) selected the white collar category. Twelve (26.7%) of the participants chose professional as their family employment type. Three (6.7%) chose the employment category labelled other. No explanation of the last category was requested of the subjects. Distribution of the employment categories across treatment groups was examined. The chi-square procedure showed no significant differences in the distributions among the three groups.

Analyses of Instrumentation and Judging

The first test encountered by all the research subjects was the basic motor skill test. The test of eye-hand coordination was in the form of a video pinball game currently in the public domain. Prior to the study, the game was pilot tested to determine a test-retest reliability. Based on trials of 20 randomly chosen individuals, the statistics in Table 1 were developed.

The next instrument administered to all research subjects was the cognitive pretest (Appendix C). Table 2 contains the pretest item difficulties, discrimination indices (point-biserial correlations) and the test
TABLE 1. Motor skill pilot test results

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trials</td>
<td>20</td>
</tr>
<tr>
<td>Mean score - game 1</td>
<td>28047</td>
</tr>
<tr>
<td>Mean score - game 2</td>
<td>32839</td>
</tr>
<tr>
<td>Pearson product moment correlation</td>
<td>0.77</td>
</tr>
<tr>
<td>Reliability coefficient alpha (standardized scores)</td>
<td>0.87</td>
</tr>
</tbody>
</table>

reliability coefficient alpha (Cronbach, 1951). Coefficient alpha may also be said to be the Kuder-Richardson Formula 20 estimate of reliability since all items were dichotomously scored (Thorndike, 1982).

The posttest (Appendix D) was administered immediately after the treatment and welding exercise. All participants completed the test. Table 3 contains the item difficulties, discriminations and the test reliability coefficient.

The pretest - posttest correlation was highly significant with Pearson product moment correlation of 0.92.

The final measurement was the welding performance of the two experimental treatment groups. No welding was
TABLE 2. Pretest Item Analysis

<table>
<thead>
<tr>
<th>Item number</th>
<th>Difficulty</th>
<th>Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>0.68</td>
<td>0.42</td>
</tr>
<tr>
<td>4</td>
<td>0.40</td>
<td>0.27</td>
</tr>
<tr>
<td>5</td>
<td>0.60</td>
<td>0.78</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.13</td>
</tr>
<tr>
<td>7</td>
<td>0.71</td>
<td>0.15</td>
</tr>
<tr>
<td>8</td>
<td>0.75</td>
<td>0.45</td>
</tr>
<tr>
<td>9</td>
<td>0.62</td>
<td>0.43</td>
</tr>
<tr>
<td>10</td>
<td>0.28</td>
<td>0.48</td>
</tr>
<tr>
<td>11</td>
<td>0.33</td>
<td>0.47</td>
</tr>
<tr>
<td>12</td>
<td>0.18</td>
<td>0.63</td>
</tr>
<tr>
<td>13</td>
<td>0.64</td>
<td>0.47</td>
</tr>
<tr>
<td>14</td>
<td>0.71</td>
<td>0.39</td>
</tr>
<tr>
<td>15</td>
<td>0.58</td>
<td>0.79</td>
</tr>
<tr>
<td>16</td>
<td>0.49</td>
<td>0.54</td>
</tr>
<tr>
<td>17</td>
<td>0.78</td>
<td>0.70</td>
</tr>
<tr>
<td>18</td>
<td>0.78</td>
<td>0.70</td>
</tr>
<tr>
<td>19</td>
<td>0.67</td>
<td>0.39</td>
</tr>
<tr>
<td>20</td>
<td>0.56</td>
<td>0.41</td>
</tr>
<tr>
<td>21</td>
<td>0.42</td>
<td>0.14</td>
</tr>
<tr>
<td>22</td>
<td>0.73</td>
<td>0.32</td>
</tr>
<tr>
<td>23</td>
<td>0.49</td>
<td>0.72</td>
</tr>
<tr>
<td>24</td>
<td>0.78</td>
<td>0.58</td>
</tr>
</tbody>
</table>

\[ \text{alpha} = 0.75 \]

performed by the control group. Welds were evaluated by a panel of three judges. The judges first evaluated each set of welds independently. Using the independent scoring as a guideline, the panel then evaluated each set of welds to produce a composite score. The composite score was to be an
TABLE 3. Posttest Item Analysis

<table>
<thead>
<tr>
<th>Item number</th>
<th>Difficulty</th>
<th>Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.73</td>
<td>0.57</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>0.82</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>0.71</td>
<td>0.24</td>
</tr>
<tr>
<td>5</td>
<td>0.80</td>
<td>0.46</td>
</tr>
<tr>
<td>6</td>
<td>0.40</td>
<td>0.58</td>
</tr>
<tr>
<td>7</td>
<td>0.82</td>
<td>0.13</td>
</tr>
<tr>
<td>8</td>
<td>0.91</td>
<td>0.30</td>
</tr>
<tr>
<td>9</td>
<td>0.51</td>
<td>0.37</td>
</tr>
<tr>
<td>10</td>
<td>0.20</td>
<td>0.72</td>
</tr>
<tr>
<td>11</td>
<td>0.18</td>
<td>0.56</td>
</tr>
<tr>
<td>12</td>
<td>0.40</td>
<td>0.33</td>
</tr>
<tr>
<td>13</td>
<td>0.78</td>
<td>0.18</td>
</tr>
<tr>
<td>14</td>
<td>0.33</td>
<td>0.38</td>
</tr>
<tr>
<td>15</td>
<td>0.71</td>
<td>0.59</td>
</tr>
<tr>
<td>16</td>
<td>0.38</td>
<td>0.54</td>
</tr>
<tr>
<td>17</td>
<td>0.80</td>
<td>0.46</td>
</tr>
<tr>
<td>18</td>
<td>0.53</td>
<td>0.16</td>
</tr>
<tr>
<td>19</td>
<td>0.80</td>
<td>0.25</td>
</tr>
<tr>
<td>20</td>
<td>0.80</td>
<td>0.46</td>
</tr>
<tr>
<td>21</td>
<td>0.27</td>
<td>0.24</td>
</tr>
<tr>
<td>22</td>
<td>0.51</td>
<td>0.35</td>
</tr>
<tr>
<td>23</td>
<td>0.80</td>
<td>0.41</td>
</tr>
<tr>
<td>24</td>
<td>0.53</td>
<td>0.46</td>
</tr>
</tbody>
</table>

alpha = 0.70

integer between 1 and 10. The visual inspection evaluation techniques are similar to those used in welding skills contests as conducted by the Future Farmers of America. An interrater reliability of 0.89 was computed from comparisons of the independent judging scores. SPSS-X procedure
RELIABILITY was used to develop the coefficient alpha reliability estimate.

Tests of Research Hypotheses

Testing hypothesis I

It is hypothesized that a relationship exists between cognitive learning and psychomotor skill development when using a computer simulation of an arc welder as a student centered tool to improve welding technique.

Statistical hypothesis I

Ho: $\rho = 0$ There is no relationship between cognition and psychomotor skill acquisition.

Ha: $\rho \neq 0$ There is a relationship between cognition and psychomotor skill acquisition.

To test hypothesis I, a relational comparison of cognitive learning and psychomotor skill was developed. Cognitive learning may be assessed through the cognitive posttest scores with the effects of previous knowledge (pretest scores) removed. Similarly, psychomotor development may be assessed through weld scores controlled for general motor skill level or eye-hand coordination. To accomplish a correlation under the given constraints, a partial correlation was used with an alpha or significance level of 0.05 for a two tailed test of significance. Based
on the computer program output of the statistics in Table 4, a significant relationship exists between cognitive test scores and psychomotor skill in welding. The null hypothesis must be rejected. A complete correlation matrix of dependent and independent variables is presented in Appendix O.

TABLE 4. Partial correlations of posttest and welding scores

<table>
<thead>
<tr>
<th>Controlling for:</th>
<th>correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Partials</td>
<td>0.77**</td>
</tr>
<tr>
<td>Pretest score only</td>
<td>0.36ns</td>
</tr>
<tr>
<td>Eye-hand coordination only</td>
<td>0.77**</td>
</tr>
<tr>
<td>Both factors</td>
<td>0.38*</td>
</tr>
</tbody>
</table>

*Significant at .05.
**Significant at .01.

**Testing hypothesis II**

It is hypothesized that use of a computer simulation as an arc welding training tool will result in student weld quality different from the weld quality of traditionally trained students in a laboratory environment.
Statistical hypothesis II

**Ho:** $\mu_s = \mu_t$  
The welding performance of subjects given the computer simulation technique is equal to the performance of those given the traditional instructional technique.

**Ha:** $\mu_s \neq \mu_t$  
The welding performance of subjects given the welder simulation is not equal to the performance of those given the traditional demonstration technique.

To test hypothesis II, an analysis of the mean welding performance was developed. Welding performance was measured by the weld scores reported. An analysis of variance was conducted with weld score as the dependent variable and treatment group as the independent variable. The results of the analysis as seen in Table 5 show no significant difference between treatment groups. Based on these results, the null hypothesis can not be rejected. See Appendix N for means and standard deviations.

To further examine the hypothesis, a stepwise multiple regression was performed. Table 6 shows the variables in and out of the equation after two steps. The dependent variable is weld score.

After accounting for the two best predictors (posttest score and sex) in the regression equation, none of the
TABLE 5. Analysis of weld scores by treatment group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>29</td>
<td>199.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>28</td>
<td>181.73</td>
<td>6.49</td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>1</td>
<td>17.63</td>
<td>17.63</td>
<td>2.72ns</td>
</tr>
</tbody>
</table>

remaining variables show potential for significant contribution to the equation. Treatment group is not a significant contributor to prediction of welding performance.

Testing hypothesis III

It is hypothesized that cognitive test scores of students using an arc welder simulation practice technique are greater than scores of students using traditional practice techniques of welding instruction.
TABLE 6. Multiple regression for weld score

<table>
<thead>
<tr>
<th>Variables in the equation</th>
<th>Variables not in the equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>T</td>
</tr>
<tr>
<td>Posttest score</td>
<td>5.12**</td>
</tr>
<tr>
<td>Sex</td>
<td>-3.33**</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.513</td>
</tr>
</tbody>
</table>

**Significant at .01.

**Statistical hypothesis III**

Ho: \( \mu_s \leq \mu_t \) The cognitive scores for subjects given the simulation practice technique are less than or equal to the test scores of those given the traditional demonstration
practice instructional technique.

\[ \text{Ha: } \mu_s > \mu_t \]  

The cognitive scores for subjects given the arc welder simulation are greater than the test scores of those given the traditional demonstration-practice technique.

To test hypothesis III, an analysis of cognitive learning by research groups must be developed. Cognitive learning was measured by the posttest scores after controlling for previous knowledge in the subject area as established by the pretest score. Results of an analysis of variance of posttest scores by research groups without covariance for previous knowledge showed no significant difference in scores among the three research groups (Table 7). The Scheffe test of ranges showed all groups as homogenous subsets of the sample.

Another analysis of variance was performed for hypothesis III with covariates processed before the treatment group main effect. The results in Table 8 show the significance of each covariate and the main effect after covariance. With this procedure, the effect of membership in a treatment group was shown to be significant, showing differences among treatment group performances on the posttest.
TABLE 7. One way analysis of posttest scores by treatment

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>44</td>
<td>690.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within groups</td>
<td>42</td>
<td>681.07</td>
<td>16.22</td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>2</td>
<td>9.73</td>
<td>4.87</td>
<td>0.30ns</td>
</tr>
</tbody>
</table>

The multiple classification analysis in Table 9 provides several measures of association. Category means are expressed as deviations to convey the magnitude of the category effect within the treatment group variable. A correlation ratio, the eta statistic, is associated with the unadjusted category effects. The square of eta indicates the proportion of variance explained by the treatment group effect. The beta statistic is associated with the category effects adjusted for the covariates. Essentially, beta is a standardized regression coefficient. Multiple R is squared to indicate the variance in the dependent variable for which the main effect, covariates and interaction effect are accountable.
TABLE 8. Analysis of posttest score with covariates

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>44</td>
<td>690.80</td>
<td>15.70</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>32</td>
<td>46.53</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor skill</td>
<td>1</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02ns</td>
</tr>
<tr>
<td>Pretest score</td>
<td>1</td>
<td>199.36</td>
<td>199.36</td>
<td>137.09**</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>4.71</td>
<td>4.71</td>
<td>3.24ns</td>
</tr>
<tr>
<td>Education</td>
<td>1</td>
<td>0.85</td>
<td>0.85</td>
<td>0.58ns</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>2.92</td>
<td>2.92</td>
<td>2.01ns</td>
</tr>
<tr>
<td>Major</td>
<td>1</td>
<td>2.25</td>
<td>2.25</td>
<td>1.55ns</td>
</tr>
<tr>
<td>Mechanical</td>
<td>1</td>
<td>10.49</td>
<td>10.49</td>
<td>7.21*</td>
</tr>
<tr>
<td>Computer</td>
<td>1</td>
<td>10.79</td>
<td>10.79</td>
<td>7.42**</td>
</tr>
<tr>
<td>Environment</td>
<td>1</td>
<td>0.17</td>
<td>0.17</td>
<td>0.12ns</td>
</tr>
<tr>
<td>Employment</td>
<td>1</td>
<td>1.76</td>
<td>1.76</td>
<td>1.21ns</td>
</tr>
<tr>
<td>Main effect</td>
<td>2</td>
<td>21.56</td>
<td>10.78</td>
<td>7.42**</td>
</tr>
</tbody>
</table>

*Significant at .05.
**Significant at .01.

All the preceding statistical procedures were developed with SPSS-X, Statistical Package for the Social Sciences (SPSS Inc., 1983).
TABLE 9. Multiple classification analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional method</td>
<td>15</td>
<td>0.60</td>
<td>-0.38</td>
</tr>
<tr>
<td>Simulation method</td>
<td>15</td>
<td>-0.07</td>
<td>1.24</td>
</tr>
<tr>
<td>Control</td>
<td>15</td>
<td>-0.53</td>
<td>-0.86</td>
</tr>
</tbody>
</table>

\eta = 0.12 \quad \beta = 0.23

Multiple R squared = 0.933
Computer aided instruction throughout education and particularly in vocational training is a new technological and instructional frontier. The extent to which a dynamic computer industry and an evolving educational system share their long and short range objectives may dictate the success of both institutions. As the computer engineers develop faster, cheaper and more intelligent machines, the role of the educator to find creative applications for the hardware becomes increasingly critical.

Intrinsic to this project was the objective of exploring a new application of computer technology to garner some new insight to the phenomena of how concepts are acquired and skills are developed. This project may claim some success toward the objective in that the technological research and development phase resulted in a new approach to computer based simulation for manual skills training. New software applications were developed which use equipment readily available and within budgetary constraints of today's schools. The programs are listed in Appendices E, F and G.
One point established in the review of the literature is that authors of instructional objectives tend to discriminate by domain. The treatment by instructional developers implies independence of the cognitive, affective, and psychomotor domains. The data in this study, however, suggest an interdependence between the cognitive and psychomotor domains. The problem of domain identification and independence is examined by Harrow (1972).

Another problem facing educators who are designing curricula is that of categorizing the behavior into one of the three domains. Educators often become confused since everything has a motor origin. In many instances, the primary concern of the educator can be logically categorized as cognitive, but he evaluates with an obvious psychomotor behavior or observable movement that the learner performs to demonstrate his understanding of a special phenomenon. This immediately raises the question: is it a psychomotor activity or a cognitive activity?

A good example of this would be handwriting. When the student is first learning to copy, the educational intents are to provide experiences to improve the child's ability to manipulate the instrument (pencil or crayon), to improve the child's eye-hand coordination, to reinforce the concept of moving from left to right on the paper, and to improve the child's ability to form the letters or figures in legible fashion. This could be categorized as belonging to the psychomotor domain since the teacher is primarily concerned with manipulative skill and perceptual abilities. However, once the learner has mastered, to some degree, these types of skills, would it not be more logical to categorize handwriting as the learner's demonstration of his understanding of letter, word, and sentence formation? The educator must make this kind of decision. If he is measuring the content of the written work, he is obviously concerned with the cognitive aspects of the behavior. If he is measuring the actual
configurations of the letters, his primary concern could well be in the psychomotor domain. This does not imply that an educator cannot be concerned with both the cognitive and the psychomotor aspects of a particular behavior; however, he must be aware of his intended goal or goals and be sure to utilize the appropriate evaluative techniques of measuring.

The information gathered in this study of interdomain learning and transference is summarized in the following discussion of the research hypotheses.

Research hypothesis I

It is hypothesized that a relationship exists between cognitive learning and psychomotor skill development when using a computer simulation of an arc welder as a student centered tool to improve welding technique.

Statistical hypothesis I

\( H_0: \rho = 0 \) There is no relationship between cognition and psychomotor skill acquisition.

\( H_a: \rho \neq 0 \) There is a relationship between cognition and psychomotor skill acquisition.

Conclusion: Reject the null hypothesis.

Based on the statistical analyses developed in the preceding chapter, the above relationship can be shown. This indicates that the null hypothesis may be rejected when the data are examined at the 0.05 level of significance. Although a relationship can be shown from this study, the
weakness of the correlation coefficients gives the researcher the impression that a more robust measurement instrument may strengthen results of future studies.

**Research hypothesis II**

It is hypothesized that use of a computer simulation as an arc welding training tool will result in student weld quality different from the weld quality of traditionally trained students in a laboratory environment.

**Statistical hypothesis II**

\[ H_0: \mu_S = \mu_T \]

The welding performance of subjects given the computer simulation technique is equal to the performance of those given the traditional instructional technique.

\[ H_a: \mu_S \neq \mu_T \]

The welding performance of subjects given the welder simulation is not equal to the performance of those given the traditional demonstration technique.

**Conclusion:** Fail to reject the null hypothesis.

Based on the procedures used to develop the findings of the previous chapter, no significant differences may be shown between welding products of those subjects using the arc welder simulation and those practicing on the actual welding equipment. Knowing that weld quality should not
significantly decrease, instructors may find that the benefits of low cost operation and increased student safety make the simulator highly desirable. Also, though not within the scope of this study, the computer based simulation may alleviate some of the anxieties of welding instruction caused by the noise, heat and radiation that accompany the arc welding process.

Research hypothesis III
It is hypothesized that cognitive test scores of students using an arc welder simulation practice technique are greater than scores of students using traditional practice techniques of welding instruction.

Statistical hypothesis III

$H_0: \mu_s \leq \mu_t$ The cognitive scores for subjects given the simulation practice technique are less than or equal to the test scores of those given the traditional demonstration-practice instructional technique.

$H_a: \mu_s > \mu_t$ The cognitive scores for subjects given the arc welder simulation are greater than the test scores of those given the traditional demonstration-practice technique.

Conclusion: Reject the null hypothesis.
Based on the analysis of variance developed for hypothesis III, the null hypothesis is rejected. The cognitive test scores of subjects given the simulation practice technique are greater than those of subjects given the traditional practice instructional method after covariance of influencing factors. Reasons for the difference between test groups are not obvious. Reasonable assumptions of the causes of difference would be anxiety, physical discomfort, fatigue and differences in perceived abilities. The last factor pertains to the significant difference found between groups in the self-evaluation of mechanical experience. The traditional practice group was shown to have a significantly higher self-estimation of mechanical experience. The precise effect of that difference on cognitive test scores is not within the scope of this research study.

Descriptive statistics

A summary of the statistics shows the 45 test subjects to have an average age of approximately 24 years and an education level of approximately 16 years, equivalent to the senior collegiate year. Sex and college major curriculum were well-distributed throughout the sample with the majority of subjects (74%) being male. Family employment and environment were well-distributed across groups though
the entire sample was dominated by those with rural and farm origins (67% and 44% respectively). Appendix N presents the demographics of the study groups.

**Instrumentation and judging**

Evaluation of the measurement instruments shows workable reliabilities for the pretest and posttest forms although an increase in the number of items would benefit the reliabilities of both tests. Some items on both forms need revision or replacement. Item discriminations were poor for four items of the pretest and posttest.

Additional reliability and validity testing is in order for the motor skill test. The video game (Appendix H) maintained a high test - retest reliability of 0.87. An examination of construct validity by correlation with an established motor skill evaluation instrument would be in order.

The weld judges maintained an inter-rater reliability of 0.89. The similarity of training and background of the welding evaluators resulted in very consistent measurements of travel speed and amperage setting for the welds produced by the research subjects.
Recommendations

1. The equipment used in the study was an Apple IIe and Apple Graphics Tablet. The computer's eight bit microprocessor is too slow for truly realistic and real-time graphics. Interaction with the tablet is also very slow. Delayed interaction confounds the purpose of a real world simulation. The computer's available memory space of 64K was sufficient but a more complex simulation may have exceeded the storage capacity. Machines with 16 or 32 bit processors would be superior for graphic development in a fully functional simulation. Additionally, an articulated electronic graphics pen or a mechanically elevated electrode simulator would allow for a three dimensional effect not present in the research model, thus allowing a more complete simulation effect.

2. A replication of this study should be performed in Iowa and in other states. The replication should include secondary and postsecondary students and a somewhat larger sample size. A wider variety of academic majors should be sampled to include disciplines outside
agriculture, most especially those for which manual dexterity and psychomotor instruction is important. Such disciplines include physical education, art, materials engineering and the construction trades.

3. Studies should be conducted which measure associated factors to cognitive and psychomotor learning such as learner anxiety, attitudes toward physical work skills, sexual predispositions to psychomotor skill training and human physical disabilities in psychomotor training.

4. This study should be replicated with the additional factors of cognitive and psychomotor ability retention over various time intervals. Special consideration should be given to the interval between pretesting and posttesting. In this study the retest interval was somewhat short, approximately 45 minutes.

5. Additional research is needed to examine relationships between cognitive and psychomotor learning, including the directional aspects of cognitive to psychomotor or psychomotor to cognitive transference. The question of the
degree to which the two domains are mutually facilitative is not well addressed by the current body of research literature.
BIBLIOGRAPHY


ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to those who have worked so diligently for the development of this project.

The author is particularly grateful for the exceptional support, patience and unending sources of information provided by Dr. William Miller as advisor and friend.

The author would also like to express appreciation to Dr. Anton Netusil whose open door and open mind were the foundation of a successful graduate program.

Most especially, the author wishes to thank Robin and Caleb Spangler for their love and support even when life was difficult and this project seemed interminable.
APPENDIX A: CONSENT FORM
Research Project Participant
Consent Form

We are asking for your consent to participate in a research project. In this project we are interested in the manner in which knowledge is transferred between mechanical skills and conceptual understanding. As a participant in this project you will be asked to furnish some background information, attend a demonstration of arc welding and welding safety, play a video game to determine your motor skill level, take a fourteen item pretest and posttest and, depending on the group in which you are placed, one of the following:

Group 1 - receive training in arc welding on an arc welder.
Group 2 - receive training in arc welding on a computerized arc welding simulator.
Group 3 - control group - no computer use or welding is performed.

Your responses to items on the demographics survey and the written examinations will be coded and all personal associations will be confidential. All forms with personal identification items will be destroyed immediately following compilation of the results.

Since there is a potential hazard of heat and bright light, you will be given extensive safety training as well as all required safety equipment including gloves, helmet, aprons and industrial quality eye protection.

If you have any additional questions or if you would like to receive information about the results of this project please contact one of the persons listed below. Thank you for your participation in this project.

Michael Spangler
214 Davidson
Iowa State University
294-8607

Dr. William G. Miller
N243 Quadrangle
Iowa State University
294-9464

I am / am not willing to participate in the project.

Your Signature

====================================================================
APPENDIX B: DEMOGRAPHICS SURVEY FORM
DEMOGRAPHICS SURVEY

Please complete the identification portion of the green answer sheet before beginning the survey. Fill in the appropriate blanks for:
NAME (last, first)  BIRTHDATE
SEX  GRADE (years of formal schooling)

* ALL ANSWERS SHOULD BE ON THE GREEN COMPUTER SCORED FORM *

1. Please identify your major field of study.
   A. Agricultural Business
   B. Agricultural Education
   C. Agricultural Journalism/PSA
   D. Agricultural Mechanization
   E. Agronomy/Horticulture/Plant Pathology
   F. Animal Science/Dairy Science
   G. Farm Operation
   H. Fisheries and Wildlife Biology/Animal Ecology
   I. Food Technology
   J. Other

2. Please rate your general experience in mechanical areas (include ANY mechanical skills you possess).

   very limited experience  average experience  very extensive experience
   1 2 3 4 5 6 7 8 9

3. Please rate your general experience with computers (include ANY computer experiences you have had).

   very limited experience  average experience  very extensive experience
   1 2 3 4 5 6 7 8 9

4. Please identify your family environment.
   A. Rural
   B. Suburban
   C. Urban

5. Please identify your family employment type.
   A. Farm
   B. Blue Collar
   C. White Collar
   D. Professional
   E. Other
APPENDIX C: PRETEST FORM
TRUE OR FALSE - Fill in A for TRUE or B for FALSE.

6. Amperage affects the burn-off rate of the electrode and therefore the rate of travel.

7. If the electrode sticks excessively when welding, this may be prevented by raising the amperage setting.

8. Excessive weld spatter may be caused by too high amperage or too long arc.

9. An extremely short arc may result in slag incursions.

10. Flux is the metal chips and particles thrown off in the welding process.

11. A long arc results in excessive bead build-up on the welded metal.

12. Increasing arc length causes an increase in amperage and a decrease in voltage.

MULTIPLE CHOICE - Choose the best answer

13. Proper amperage selection depends on:
   A. type of electrode
   B. size of electrode
   C. position of electrode when welding
   D. thickness of the base metal
   E. all of these

14. A 1/8" electrode should leave a bead width of:
   A. 1/4"
   B. 1/8"
   C. 1/16"
   D. 1/2"
   E. varying size

15. Undercutting is caused by:
   A. low amperage
   B. slow travel speed.
   C. long arc
   D. excessive electrode tilt
Figures:

A  B  C  D

16. The bead in Figure A shows what kind of welding problem?
   A. low amperage
   B. slow travel speed
   C. long arc
   D. excessive electrode tilt

17. The bead in Figure B shows what kind of welding problem?
   A. no problem — normal bead
   B. excessive electrode tilt
   C. unclean base metal
   D. high amperage

18. The bead in Figure C shows what kind of welding problem?
   A. low amperage
   B. slow travel speed
   C. long arc
   D. excessive electrode tilt

19. The bead in Figure D shows what kind of welding problem?
   A. fast travel speed
   B. high amperage
   C. unclean base metal
   D. no problem — normal bead
20. A great deal of light from the arc site means:
   A. excess arc length
   B. slow deposition rates
   C. poor penetration
   D. inadequate electrode tilt

21. Slag is:
   A. an area of molten or melted metal.
   B. metal particles tossed out of the weld site.
   C. a depression in the metal left when the molten pool freezes.
   D. burned flux mixed with impurities.

22. A low amperage setting will result in:
   A. undercutting
   B. bead overlap
   C. excess penetration
   D. all of these

23. Travel speed affects:
   A. penetration
   B. arc length
   C. arc voltage
   D. all of these

24. Travel speed within the body of the bead should:
   A. vary to accommodate change weld surface.
   B. accelerate as the bead lengthens.
   C. decrease at a steady rate.
   D. remain steady.

25. Distortion is directly related to the amount of heat applied to the weld. A long arc will result in:
   A. more distortion.
   B. less distortion.
   C. more or less distortion depending on the type of joint being welded.
   D. no distortion effects.

26. A continuous bead would tend to result in:
   A. more distortion.
   B. less distortion.
   C. more or less distortion depending on the type of joint being welded.
   D. no distortion effects.
27. You are welding 1" plate and your welds show light penetration. You should:
   A. reduce arc length.
   B. increase travel speed.
   C. make a multiple layer bead to gain strength.
   D. do nothing - light penetration is good.

28. You are having trouble striking the arc. You should:
   A. decrease amperage.
   B. increase amperage.
   C. change electrodes.
   D. change travel speed.

29. Preheated base metal:
   A. has no effect on the weld.
   B. will cause excessive spatter during welding.
   C. will result in greater penetration.
   D. all of these.
APPENDIX D: POSTTEST FORM
POSTTEST
* DO NOT WRITE ON THIS FORM *
PLEASE PUT ONLY YOUR NAME ON THE GREEN ANSWER SHEET

TRUE OR FALSE - Fill in A for TRUE or B for FALSE.

1. Amperage affects the burn-off rate of the electrode and therefore the rate of travel.
2. If the electrode sticks excessively when welding, this may be prevented by raising the amperage setting.
3. Excessive weld spatter may be caused by too high amperage or too long arc.
4. An extremely short arc may result in slag incusions.
5. Flux is the metal chips and particles thrown off in the welding process.
6. A long arc results in excessive bead build-up on the welded metal.
7. Increasing arc length causes an increase in amperage and a decrease in voltage.

MULTIPLE CHOICE - Choose the best answer

8. Proper amperage selection depends on:
   A. type of electrode  
   B. size of electrode  
   C. position of electrode when welding  
   D. thickness of the base metal  
   E. all of these

9. A 1/8" electrode should leave a bead width of:
   A. 1/4"  
   B. 1/8"  
   C. 1/16"  
   D. 1/2"  
   E. varying size
Figures:

A  B  C  D

10. The bead in Figure A shows what kind of problem?
A. low amperage
B. slow travel speed
C. long arc
D. excessive electrode tilt

11. The bead in Figure B shows what kind of problem?
A. no problem — normal bead
B. excessive electrode tilt
C. unclean base metal
D. high amperage

12. The bead in Figure C shows what kind of problem?
A. low amperage
B. slow travel speed
C. long arc
D. excessive electrode tilt

13. The bead in Figure D shows what kind of problem?
A. fast travel speed
B. high amperage
C. unclean base metal
D. no problem — normal bead
14. Undercutting is caused by:
   A. low amperage
   B. slow travel speed
   C. long arc
   D. excessive electrode tilt

15. A great deal of light from the arc site means:
   A. excess arc length
   B. slow deposition rates
   C. poor penetration
   D. inadequate electrode tilt

16. Slag is:
   A. an area of molten or melted metal.
   B. metal particles tossed out of the weld site.
   C. a depression in the metal left when the molten pool freezes.
   D. burned flux mixed with impurities.

17. A low amperage setting will result in:
   A. undercutting
   B. bead overlap
   C. excess penetration
   D. all of these

18. Travel speed affects:
   A. penetration
   B. arc length
   C. arc voltage
   D. all of these

19. Travel speed within the body of the bead should:
   A. vary to accommodate change weld surface.
   B. accelerate as the bead lengthens.
   C. decrease at a steady rate.
   D. remain steady.

20. Distortion directly related to the amount of heat applied to the weld. A long arc will result in:
   A. more distortion.
   B. less distortion.
   C. more or less distortion depending on the type of joint being welded.
   D. no distortion effects.
21. A continuous bead would tend to result in:
A. more distortion.
B. less distortion.
C. more or less distortion depending on the type of joint being welded.
D. no distortion effects.

22. You are welding 1" plate and your welds show light penetration. You should:
A. reduce arc length.
B. increase travel speed.
C. make a multiple layer bead to gain strength.
D. do nothing - light penetration is good.

23. You are having trouble striking the arc. You should:
A. decrease amperage.
B. increase amperage.
C. change electrodes.
D. change travel speed.

24. Preheated base metal:
A. has no effect on the weld.
B. will cause excessive spatter during welding.
C. will result in greater penetration.
D. all of these.
APPENDIX E: SIMULATION ACTUATOR PROGRAM
1 REM ************************************************************************
2 REM MENU FOR SIMULATOR ACTUATION
3 REM ************************************************************************
100 DATA
120 DATA ARC WELDER SIMULATION
130 DATA MENU ALIGNMENT
140 DATA QUIT
990 DATA
1000 REM APPLE HELLO PROGRAM
1005 NOTRACE : NORMAL
1010 TEXT : HOME : D$ = CHR$ (4): DIM IN$(20)
1020 PRINT D$;"NOMON C,I,O":
HOME : HTAB 16: PRINT "APPLE ]"; CHR$ (91)
1030 PRINT D$;"BLOAD GRAPHICS TABLET LOGO,A$2000"
1040 POKE - 16297,0: POKE - 16302,0: POKE - 16304,0
1100 READ A$: HTAB.21 - INT ( LEN (A$) / 2):
VTAB 23: PRINT A$
1110 POKE - 16368,0: VTAB 1: GET A$:
IF LEN (A$) THEN A = ASC (A$): IF A < > 27 THEN 1110
1120 TEXT : HOME : POKE - 16298,0
1200 IN = IN + 1: READ IN$(IN): IF LEN (IN$(IN)) THEN 1200
1210 IN = INT (22 / IN)
1300 GOSUB 61000: PRINT " ==> ";
1310 GOSUB 60000: IF IN = - 1 THEN HOME :
RESTORE : IN = 0: GOTO 1040
1320 IF IN < 1 THEN PRINT CHR$ (7);: GOTO 1310
1330 IF IN = 3 THEN HOME : PRINT CHR$ (4);"BRUN BHI"
1340 HOME : VTAB 12: HTAB 8:
PRINT "LOADING PROGRAM FROM DISK."
1350 IF IN = 3 THEN HOME : PRINT CHR$ (4);"BRUN BHI"
1400 PRINT : PRINT CHR$ (4);"RUN ";IN$(IN)
1410 END

REM INPUT SUBROUTINE
60000 IN = 0:IX = PEEK (36) + 1:
IY = PEEK (37) + 1: POKE - 16368,0
60020 GET IN$:AS = 0: IF LEN (IN$) THEN AS = ASC (IN$):
IF AS = 3 THEN 60020
60030 IF AS = 13 THEN GOSUB 60090: RETURN
60040 IF AS = 27 THEN NORMAL :
IN = - 1: CALL - 868: RETURN
60050 IN = 0: CALL - 868
60060 IN = IN + 1: IF IN$(IN) = "" THEN IN = 0:
PRINT CHR$ (7);: GOTO 60020
60070 IF LEFT$(IN$(IN),1) < > IN$ THEN 60060
60080 FLASH : PRINT IN$(IN);: VTAB IY: HTAB IX: GOTO 60020
60090 NORMAL : IF IN > 0 THEN PRINT IN$(IN);
60100 VTAB IY: HTAB IX: RETURN
61000 REM MENU SUBROUTINE
61010 IX = 0: NORMAL : PRINT
61020 IX = IX + 1: IF IN$(IX) = "" THEN 61036
61030 PRINT " .................................TYPE ";
LEFT$(IN$(IX),1);: HTAB 2: PRINT IN$(IX);:
FOR IY = 1 TO IN: PRINT : NEXT : GOTO 61020
61036 VTAB 17:
PRINT " YOU MUST ALIGN THE MENU BEFORE USING":
PRINT " THE ";: INVERSE :
PRINT "ARC WELDER SIMULATION":: NORMAL : PRINT " PROGRAM"
61040 VTAB 24: HTAB 5:
PRINT " SELECT PROGRAM, THEN PRESS RETURN":;
VTAB 22: HTAB 1: RETURN
1 REM ****************************
2 REM SIMULATION ACTUATOR
3 REM ****************************
5 DIM PLACE(250)
7 PRINT CHR$ (4)"BLOAD BEADSHAPE"
8 PRINT : PRINT : GOSUB 10000
9 GET A$: PRINT : PRINT
10 IF ASC (A$) = 27 THEN PRINT CHR$ (4)"RUN HELLO"
15 GOSUB 700
20 AL = 25: SCALE= 1:FIRST = 0
30 HOME : FOR I = 1 TO 250:PL(I) = 0: NEXT I
50 HGR : HOME : VTAB (23):
PRINT " TOUCH THE PEN NEAR THE":;
FLASH : PRINT " LEFT ";: NORMAL : PRINT "BORDER"
60 PRINT " TO STRIKE THE ARC": VTAB (1)
99  \texttt{D$ = CHR$ (4)}
104  \texttt{PRINT D$;"IN#4": INPUT X,Y,Z: PRINT D$;"IN#0"}
106  \texttt{X = 5}
107  \texttt{GOSUB 1000: GOSUB 1530}
108  \texttt{VTAB 1:D$ = CHR$ (4)}
110  \texttt{PRINT D$;"IN#4": INPUT XO,YO,ZO: PRINT D$;"IN#0"}
114  \texttt{HCOLOR = 0}
115  \texttt{HPLOT X + 5,81 TO X + 15,45 TO X + 17,48}
116  \texttt{GOSUB 1500}
117  \texttt{IF X < 240 THEN HCOLOR = 3: GOTO 120}
118  \texttt{GOSUB 3000}
119  \texttt{RUN}
120  \texttt{X = XO; Y = YO; Z = ZO; TIMER = TIMER + 1}
122  \texttt{X = X / 11: PLACE(X) = TIMER + PL(X)}:
124  \texttt{IF X > 240 THEN X = 240}
140  \texttt{HPLOT X,81 TO X - 5,70}
150  \texttt{HPLOT X + 5,81 TO X + 15,45}
190  \texttt{POKE - 16368,0}
200  \texttt{GOTO 108}
599  \texttt{END}
700  \texttt{TEXT : REM AMP INPUT}
710 HOME : VTAB (12): XI = 19
715 PRINT "USE LEFT OR RIGHT ARROWS TO"
720 PRINT "ENTER THE WELDER AMPERAGE SETTING"
725 PRINT
730 INVERSE : PRINT "LOW";: NORMAL :
PRINT "=================================";
735 HTAB (35): INVERSE : PRINT "HIGH"; NORMAL
740 HTAB (10): VTAB (24): PRINT "PRESS ";:
INVERSE : PRINT "RETURN";: NORMAL : PRINT " TO ACCEPT"
750 VTAB (15): HTAB (XI): PRINT "ĉ";
760 VTAB (16): HTAB (XI): GET A$
765 VTAB (15): HTAB (XI): PRINT " "
770 IF ASC (A$) = 21 THEN XI = XI + 1: GOTO 800
780 IF ASC (A$) = 8 THEN XI = XI - 1: GOTO 800
790 IF ASC (A$) = 13 AND XAMPS > 0 THEN 900
795 GOTO 750
800 IF XI > 39 THEN XI = 39
801 IF XI < 1 THEN XI = 1
805 XAMPS = 50 + XI * 5:
XB$ = STR$ (XAMPS): IF XA < 100 THEN XB$ = " " + XB$
810 VTAB (18): HTAB (16): INVERSE : PRINT "AMPS = ";XB$;
820 NORMAL : GOTO 750
900 RETURN
999 END
1000 REM SET UP GRAPHIC
1005 HGR : HCOLOR= 7: HOME
1010 HPL0T 5,80 TO 260,80 TO 260,83 TO 5,83 TO 5,80
1020 VTAB (22): HTAB (10): PRINT "AMPERAGE ==> ";XAMPS
1030 HPL0T 100,0 TO 180,0 TO 180,40 TO 100,40 TO 100,0
1035 FOR I = 35 TO 5 STEP - 5: HPL0T 100,1 TO 94,1: NEXT I
1040 GOTO 1500
1050 RETURN
1500 REM SUB TO SHOW ARC LENGTH
1505 HCOLOR= 0:
1510 HPL0T 150,0 TO 90 + AL,AL TO 98 + AL,AL TO 158,0
1510 AL = AL - .10
1520 IF Z = 2 OR Z = 12 THEN AL = AL + 4:
1530 IF AL > 40 THEN AL = 39
1540 IF AL > 38 THEN PL(X) = PL(X) - 1000
1550 IF AL < 30 AND AL > 22 THEN PL(X) = PL(X) + 1000
1560 IF AL < 23 THEN GOSUB 1750
1700 RETURN
1750 REM BROKEN ARC SUB
1760 HOME : VTAB 23:
PRINT "THE ARC LENGTH IS TOO GREAT TO MAINTAIN"
1770 LOX = X
1790 X = 250: RETURN
3000 REM SUB TO SH0 BEAD
3005  VTAB 24
3006  PRINT " PRESS ANY KEY TO CHIP OFF SLAG";
3007  VTAB (1): PRINT : PRINT : GET A$
3010  FOR I = 45 TO 150:
3012  HCOLOR= 0: HPL 0,1 TO 279,1: NEXT I: HCOLOR= 3
3020  HPL 5,80 TO 260,80 TO 260,83 TO 5,83 TO 5,80
3030  IF LOX = 0 THEN LOX = 240
3040  HPL LO,81 TO LO + 5,70
3050  TO LO + 10,77 TO LO + 10,83 TO LO + 5,90 TO LO,81
4000  ROT= 32:SH = 1
4010  DRAW 1 AT AF,94:
4020  FOR I = AF - 5 TO LOX STEP 3: HPL I,69: HPL I,93: NEXT I
4025  FOR I = AF TO LOX:
4030  IF PL(I) = 0 THEN ZERO = ZERO + 1: GOTO 4065
4035  IF ZERO > 2 THEN SH = 2: GOTO 4060
4040  IF ZERO < 1 THEN SH = 3: GOTO 4060
4045  SH = 1
4050  ZERO = 0
4055  M = M + 1: IF M < 8 THEN 4070
4060  M = 0
4065  IF SH = 2 THEN CH = 2
4068  DRAW SH AT 12 + I,94 + GH
4070  GH = 0: NEXT I
4075  IF XAMPS < 85 THEN HCOLOR= 0:
4080  FOR I = 9 TO 15: HPL 6,81 + I TO LOX,81 + I:
97

HPLOT 6,81 - I TO LOX,81 - I: NEXT I: HCOLOR= 3

4090 IF XAMPS > 140 THEN FOR I = 5 TO LOX STEP 20:

DRAW 4 AT I,94: NEXT I

5000 FOR I = AF TO LOX STEP 3

5005 IF PL(I) > 999 THEN AW = 1 + AW: IF AW = 3 THEN AW = 1

5010 IF PL(I) > 999 THEN

ROT = ( INT ( RND (1) * 8 - 4)) + 32:

SCALE = AW: DRAW 4 AT I,114: ROT = 32

5015 SCALE = 1

5020 IF PL(I) < - 999 THEN DRAW 3 AT I,94:

XDRAW 1 AT I + 7,94

5030 NEXT I: HCOLOR = 0

5035 FOR I = 118 TO 135:

HPLOT 0,1 TO 190,1: NEXT I: HCOLOR = 3

5040 HOME: VTAB 23:

PRINT " EXAMINE THE WELD THEN PRESS ANY KEY":

PRINT " TO START OVER OR <ESC> TO QUIT";

5044 INVERSE

5045 HTAB 1: VTAB 21:

PRINT "NORMAL FAST SLOW SHORT-ARC LONG-ARC": VTAB 1

5046 NORMAL

5047 GOSUB 8000

5050 GET A$:

IF ASC (A$) = 27 THEN PRINT CHR$ (4) "RUN HELLO"

5060 RETURN
8000  REM  ICONS
8010  DRAW 1 AT 35,155
8020  DRAW 2 AT 80,157
8030  DRAW 3 AT 130,155
8040  DRAW 3 AT 185,155: XDRAW 1 AT 192,155
8050  DRAW 1 AT 245,155:
SCALE= 2: XDRAW 4 AT 245,179: SCALE= 1
8100  RETURN
10000  REM  INTRO SUBROUTINE
10005  TEXT
10010  HOME : PRINT " Welcome to the ARC WELDER SIMULATION"
10020  PRINT : PRINT :
PRINT " This is a practice tool for learning"
10030  PRINT " how to control heat with an arc welder"
10040  PRINT :
PRINT "=================================================================="
10050  PRINT " You are to run an arc welding bead "
10060  PRINT : PRINT " using the pen on the APPLE GRAPHICS"
10070  PRINT :
PRINT " TABLET as a 1/8 inch electrode and the"
10080  PRINT :
PRINT " TABLET as the 1/4 inch metal surface."
10090  PRINT : PRINT " To run the bead press the pen to the"
10100  PRINT :
PRINT " tablet. To change arc length lift the"
10110 PRINT :
PRINT "pen then press it down again quickly."
10120 INVERSE
10130 VTAB 24:
PRINT "TOUCH ANY KEY TO BEGIN OR <ESC> TO QUIT";
10140 NORMAL
11000 RETURN
APPENDIX F: MENU ALIGNMENT PROGRAM
10 REM ************************
20 REM * MENU ALIGNMENT
30 REM ************************
32 DATA 160,3,162,186,173,0,193,189,0,200,202,136,48,13
34 DATA 217,41,96,240,244,238,06,
96,173,06,96,201,200,173,06,96
36 DATA 41,07,141,44,96,173,
255,207,144,216,96,32,106,202,0
40 D$ = CHR$ (4)
60 FOR I = 1 TO 45; READ X: POKE (24575 + I),X: NEXT I
70 HOME : TEXT : CALL 24576: T = PEEK (24620):
IF T < 1 OR T > 8 THEN HOME :
VTAB 12: HTAB 5:
PRINT "NOT DETECTING INTERFACE CARD!!!": PRINT : END
75 HOME ; VTAB 10 : HTAB 9 : FLASH :
PRINT " INTERFACE IN SLOT # ";T;
PRINT " ": NORMAL : FOR I = 1 TO 2000: NEXT ;SL = T
80 XOFF = 0; YOFF = 0; SCAL = 20: TEXT : HOME :
VTAB 2: HTAB 14: PRINT "MENU ALIGNMENT":
HTAB 14: PRINT "----------------": PRINT : PRINT : POKE 34,5
90 PRINT D$;"PR#0": HOME :
A$ = "PLACE MENU OVERLAY IN CENTER": GOSUB 670:
A$ = "OF GRAPHICS TABLET RECESSED AREA": GOSUB 670: PRINT
100 A$ = "THEN TAPE UPPER-LEFT CORNER": GOSUB 670:
A$ = "OF OVERLAY TO TABLET":

GOSUB 670: PRINT : PRINT : PRINT
110 PRINT : A$ = "PRESS THE SPACE BAR TO ACKNOWLEDGE":
GOSUB 670: A$ = "THAT YOU HAVE PERFORMED THIS":
GOSUB 670: PRINT : PRINT
120 HTAB 10: INVERSE :
PRINT "SPACE BAR": NORMAL: PRINT : PRINT
130 HTAB 20: GET A$: IF A$ < > "" THEN 130
135 HOME : A$ = "OK": GOSUB 670: FOR I = 1 TO 1000: NEXT
140 HOME : VTAB 8: A$ =
"TAKE THE TABLET PEN AND PRESS IT": GOSUB 670:
A$ = "DOWN AT THE UPPER-LEFT CORNER": GOSUB 670:
A$ = "OF THE RESET COMMAND BOX":
GOSUB 670: GOSUB 540: VTAB 20: PRINT
150 PRINT D$; "PR#"; SL:
PRINT "T1,X"; XOFF; "Y"; YOFF; "S"; SCAL; "R,C,N"
160 PRINT D$; "IN#"; SL
170 GOSUB 610: HX = X: REM SAVE X-COORD
180 IF Z < 0 THEN GET A$:
IF A$ = CHR$ (27) THEN PRINT : GOTO 90
190 IF Z < > 2 THEN 140
200 PRINT : PRINT D$; "PR#0": HOME :
IF X > 60 OR Y > 60 THEN HTAB 13:
PRINT "NO! TRY AGAIN!":
FOR XX = 1 TO 1000: NEXT XX: GOTO 140
210 PRINT D$; "IN#0": A$ = "GOOD. NOW...":

GOSUB 670: FOR XX = 1 TO 1000: NEXT XX: HOME

220 PRINT : PRINT : A$ = "PRESS THE PEN DOWN AT THE LOWER-LEFT": GOSUB 670:
A$ = "CORNER OF THE WORK AREA.":
GOSUB 670: GOSUB 570: VTAB 13: PRINT

230 GOSUB 610: IF Z < 0 THEN GET A$:
IF A$ = CHR$ (27) THEN PRINT : GOTO 90

235 IF Z < 0 THEN VTAB 20: PRINT : GOTO 230

240 IF X = HX THEN 300

250 VTAB 12: A$ = "SWING THE BOTTOM OF THE MENU AS":
GOSUB 670: A$ = "INDICATED UNTIL PRESSING THE PEN DOWN":
GOSUB 670: A$ = "AT THIS POINT SHOWS ALIGNED": GOSUB 670

260 VTAB 18: CALL - 958: GOSUB 540: VTAB 18:
PRINT CHR$ (7): IF X < HX
THEN A$ = "SWING THE MENU RIGHT": GOTO 280

270 A$ = "SWING THE MENU LEFT.

280 VTAB 18: GOSUB 670: GOSUB 610: IF Z < 0 THEN GET A$:
IF A$ = CHR$ (27) THEN PRINT : GOTO 90

290 IF HX < > X THEN 260

300 HOME : VTAB 12: A$ = "ALIGNED": GOSUB 670: GOSUB 570:
VTAB 15: A$ = "TAPE MENU IN PLACE": GOSUB 670: A$ = "AND":
GOSUB 670: A$ = "PRESS THE SPACE BAR TO ACKNOWLEDGE":
GOSUB 670: VTAB 19: HTAB 10:
INVERSE : PRINT " SPACE BAR

310 GOSUB 610: IF Z = > 0 THEN HOME :
A$ = "ONCE ALIGNED, DON'T CONFUSE ME!":
GOSUB 670: FOR XX = 1 TO 1000: NEXT XX: HOME : GOTO 220
320 GET A$: IF A$ = CHR$ (27) THEN 90
330 IF A$ < > " " THEN VTAB 20: PRINT : GOTO 310
340 HGR : PRINT :
PRINT D$;"PR#";SL: PRINT "M1,X0,Y0,S2,R,C"
350 VTAB 21: CALL - 958:
A$ = "PRESS DOWN WITH THE PEN AT THE FOUR": GOSUB 670:
A$ = "Corners of the Overlay as Indicated." : GOSUB 670
360 VTAB 24: HTAB 10: PRINT "PRESS ESC TO RE-START.";
VTAB 1: POKE - 16297,0: POKE - 16301,0:
POKE - 16300,0: POKE - 16304,0
362 HCOLOR= 3:
H PLOT 63,12 TO 215,12 TO 215,148 TO 63,148 TO 63,12
363 XX = (215 - 63) / 22: FOR I = 1 TO 21:
YY = 63 + XX * I: H PLOT YY,12 TO YY,24: NEXT
365 H PLOT 63,24 TO 215,24: H PLOT 63,18 TO 215,18
370 HCOLOR= 3 : P = 12: GOSUB 720: GOSUB 610:
HCOLOR= 0: GOSUB 720: IF Z < 0 THEN 680
380 X1 = X: Y1 = Y: GOSUB 710: HCOLOR= 3:
GOSUB 740: GOSUB 610:
HCOLOR= 0: GOSUB 740: IF Z < 0 THEN 680
390 X2 = X: Y2 = Y: GOSUB 710: HCOLOR= 3 : P = 148:
GOSUB 740: GOSUB 610:
HCOLOR= 0: GOSUB 740: IF Z < 0 THEN 680
105

400 X3 = Y: Y3 = Y: GOSUB 710: HCOLOR = 3:
GOSUB 720: GOSUB 610:
HCOLOR = 0: GOSUB 720: IF Z < 0 THEN 680
410 X4 = X: Y4 = Y: GOSUB 710
420 IF ABS (X1 - X4) > 30 OR
ABS (X2 - X3) > 30 OR
ABS (Y1 - Y2) > 30 OR ABS (Y3 - Y4) > 30 THEN 690
425 IF ABS (X1 - X2) < 50 OR ABS (Y2 - Y3) < 50 THEN 690
430 X1 = INT ((X1 + X4) / 2): Y1 = INT ((Y1 + Y2) / 2):
X2 = INT ((X2 + X3) / 2): Y2 = INT ((Y3 + Y4) / 2)
440 HOME: PRINT D$;"PR#0": TEXT:
HOME: VTAB 12:
A$ = "CREATING TABLET INFORMATION FILE." : GOSUB 670
450 ONERR GOTO 480
460 PRINT D$;"VERIFY TAB.INFORMATION,D1"
470 PRINT D$;"UNLOCK TAB.INFORMATION"
480 ONERR GOTO 800
490 PRINT D$;"OPEN TAB.INFORMATION"
500 PRINT D$;"WRITE TAB.INFORMATION"
510 PRINT SL: PRINT X1: PRINT Y1: PRINT X2: PRINT Y2
520 PRINT D$;"CLOSE TAB.INFORMATION"
525 PRINT D$;"LOCK TAB.INFORMATION"
530 PRINT: PRINT D$;"RUN HELLO"
540 REM ***********************
550 REM * ALIGNMENT RESTART COMMAND
560 REM **********************
570 VTAB 22: HTAB 5:
PRINT "IF MENU COMES LOOSE FROM TABLET,":
PRINT : HTAB 9: PRINT "PRESS ";
INVERSE : PRINT "ESC";:
NORMAL : PRINT " KEY TO RE-TAPE"; RETURN
580 REM **********************
590 REM * SINGLE PEN-INPUT ROUTINE
600 REM **************************
610 PRINT D$;"PR#";SL: PRINT "N": PRINT D$;"IN#";SL:
INPUT X,Y,Z: IF Z = > 0 THEN IF Z < > 2 THEN 610
620 PRINT D$;"PR#0": PRINT D$;"IN#0": RETURN
630 REM **************************
640 REM * STRING CENTER AND PRINT
650 REM * WITH CR
660 REM **************************
670 HTAB 21 - ( LEN (A$) / 2):
PRINT A$:Z1 = FRE (0): RETURN
680 GET A$: IF A$ = CHR$ (27) THEN PRINT : GOTO 80
690 PRINT : PRINT D$;"PR#0": TEXT : HOME : VTAB 2:
A$ = "EITHER YOU WERE NOT VERY CAREFUL, OR": GOSUB 670:
PRINT :A$ = "DID NOT FOLLOW INSTRUCTIONS, OR":
GOSUB 670: PRINT :
A$ = "THE MENU IS NOT ALIGNED.": GOSUB 670: PRINT : PRINT
700 A$ = "TRY IT AGAIN": GOSUB 670:
FOR XX = 1 TO 2500: NEXT XX: GOTO 340

710 VTAB 17: PRINT D$;"PR#0":
PRINT CHR$ (7): PRINT D$;"PR#";SL: PRINT "N": RETURN

720 REM * RIGHT ARROW *
730 HPlot 50,P TO 61,P:
HPlot 56,P - 5 TO 60,P TO 56,P + 5: RETURN

740 REM * LEFT ARROW *
750 HPlot 217,P TO 228,P:
HPlot 222,P - 5 TO 218,P TO 222,P + 5: RETURN

800 TEXT : HOME : VTAB 10:
PRINT " UNABLE TO WRITE DISK INFORMATION FILE."
PRINT : PRINT

810 HTAB 8: PRINT "CORRECT PROBLEM WITH MEDIA"
PRINT : HTAB 11: PRINT "AND THEN TYPE 'RUN'.


APPENDIX G: TABLET CODE PROGRAM
1 REM ****************************
2 REM TABLET CODE
3 REM ****************************
20 LOMEM: 25392
30 D$ = CHR$ (4): PRINT D$;"CLOSE GRAPhICS TABLET SOFTWARE"
40 ONERR GOTO 2610
50 D$ = CHR$ (4): PRINT D$;"OPEN TAB.INFORMATION,D1": PRINT D$;"READ TAB.INFORMATION":
60 INPUT SL: INPUT XL: INPUT YL: INPUT XH: INPUT YH
70 ONERR GOTO 2650
80 EP% = PEEK (753) * 256 + PEEK (752):M% = 800
90 DIM Y%(M%),X%(M%)
100 PRINT D$;"BLOAD UTILITIES,A$6000,D1"
110 XA = XH - XL:YA = YH - YL:
120 LT = INT ((XA + YA) / 2):PI = INT (LT / 11)
130 SO = INT (XA / 11 + .5)
140 MD = INT (PI / 2):XM = XL:YM = 2 * MD + YL
150 HGR2 :PC = 3:BC = 0: HCOLOR= PC:W = 1:DF = 1
160 X1 = XM * 2;Y1 = YM * 2:
170 X2 = ( INT ((XH * 2 - X1) / 280 + .5) * 280):
180 Y2 = INT (X2 * 192 / 280):X5 = X1:X6 = X2:Y5 = Y1:Y6 = Y2
190 D% = - 2:SM = S2: GOSUB 1070:RD = 0
200 CM = 0:N% = 1: CALL EP%:
210 CD = PEEK (700): ON CD + 1 GOTO 190,200,170,170
180 GOTO 170
190 PRINT: PRINT D$;"PR#0":
PRINT D$;"IN#0": GET A$: IF ASC (A$) < > 27 THEN 200
192 TEXT: HOME: VTAB 12: HTAB 13:
INPUT "QUIT? (Y OR N) ";A$:
IF A$ = "Y" THEN HOME: VTAB 12: HTAB 10:
PRINT "LOADING HELLO PROGRAM": POKE 104,8:
POKE 103,1: PRINT D$;"RUN HELLO,D1": STOP
194 GOSUB 1130: GOTO 170
200 IF PEEK (640) < > 2 THEN 170
210 POKE 640,0
220 XF = XL * 2:YF = YL * 2:SF = SO:
GOSUB 2590: REM SENSE MENU
230 PRINT: PRINT D$;"IN#":SL
240 INPUT X,Y,Z: IF Y > 1 THEN GOSUB 1130: GOTO 170
250 IF Y < = 1 AND Y > = 0 THEN PRINT D$;"PR#0":
PRINT CHR$ (7): PRINT:
PRINT D$;"PR#":SL: PRINT "N": ON Y + 1 GOTO 280,290
260 GOTO 230
270 TEXT: PR# 0: PRINT "ERROR": STOP
280 ON X + 1 GOTO 140,300,890,620,1460,550,1150,2160,
1380,650,290,1580,1680,1740,1840,570,
330,420,2330,2330,1970,2070
290 GOSUB 1130: GOTO 170
300 IF XT = X3 AND YT = Y3 AND X4 = XE AND
Y4 = YB THEN HCOLOR= BC: HPLLOT 0,0: CALL 62454: GOTO 520
310 HCOLOR= BC: HPLLOT X3,Y3: FOR T1 = Y3 TO Y4:
    HPLLOT X3,T1 TO X4,T1: NEXT:
    HCOLOR= PC: GOSUB 1130: GOTO 170
330 TEXT : PRINT D$;"PR#0": HOME : VTAB 7: HTAB 6:
    PRINT "PLEASE TYPE THE PICTURE NAME.": PRINT :
    HTAB 7: PRINT D$;"IN#0":
    INPUT "==> ";B$: IF B$ = "" THEN GOSUB 1130: GOTO 170
340 VTAB 9: HTAB 37: CALL - 868: HTAB 1: GOSUB 530
345 B$ = "PIC." + B$: ONERR GOTO 400
350 PRINT D$;"BLOAD ";B$;",A$4000,VO,D";C$
360 S2 = PEEK (16632) * 256 + PEEK (16633):
    IF S2 < =0 THEN 150
370 X1 = PEEK (16504) * 256 + PEEK (16505):
    X2 = PEEK (16506) * 256 + PEEK (16507):
    Y1 = PEEK (16508) * 256 + PEEK (16509):
    Y2 = PEEK (16510) * 256 + PEEK (16511)
380 ONERR GOTO 2650
390 HOME : GOTO 520
400 B$ = RIGHT$ (B$,( LEN (B$) - 4)): ONERR GOTO 2650
410 PRINT D$;"BLOAD ";B$;",A$4000,VO,D";C$: GOTO 150
420 TEXT : PRINT D$;"PR#0": HOME : VTAB 7: HTAB 3:
    PRINT "PLEASE TYPE A NAME FOR THIS PICTURE."": PRINT :
    HTAB 7: PRINT D$;"IN#0":
    INPUT "==> ";B$: IF B$ = "" THEN GOSUB 1130: GOTO 170
112

430 VTAB 9: HTAB 37: CALL - 868: HTAB 1: GOSUB 530
440 GOSUB 1330: HCOLOR= BC: GOSUB 1040:
H = INT (X1 / 256): POKE 16504,H: POKE 16505,X1 - H * 256:
H = INT (X2 / 256): POKE 16506,H: POKE 16507,X2 - H * 256:
H = INT (Y1 / 256): POKE 16508,H: POKE 16509,Y1 - H * 256:
450 H = INT (Y2 / 256): POKE 16510,H:
POKE 16511,Y2 - H * 256:
H = INT (S2 / 256): POKE 16632,H: POKE 16633,S2 - H * 256
460 B$ = "PIC." + B$: ONERR GOTO 490
470 HCOLOR= PC:
PRINT D$;"VERIFY ";B$","D";C$: ONERR GOTO 2650
480 VTAB 21: HTAB 1:
PRINT "A PICTURE ALREADY EXISTS WITH THAT NAME.":
PRINT : HTAB 12:
INPUT "CONTINUE (Y OR N) ";E$: IF E$ < > "Y" THEN 510
490 ONERR GOTO 2650
500 PRINT D$;"BSAVE ";B$","A$4000,L$1FF8,VO,D";C$
510 HOME : PRINT D$;"PR#";SL: PRINT "H2,N"
520 GOSUB 1090: PRINT D$;"IN#";SL: GOTO 170
530 VTAB 10: CALL - 958: PRINT : HTAB 16:
PRINT "DRIVE # ? (DEFAULT=";DF;")":
HTAB 25: INPUT " ";C$:
IF C$ < > "1" AND C$ < > "2" THEN C$ = STR$ (DF)
540 DF = VAL (C$): VTAB 11:
HTAB 24: CALL - 958: PRINT C$: RETURN
550 REM *** SOFT RESET COMMAND ***
560 GOSUB 1330: GOSUB 1090: D% = - 2: GOTO 170
570 TEXT: PRINT D$: "PR#0"
HOME: PRINT D$: "IN#0": GOSUB 530
580 HOME: HTAB 7:
PRINT "PRESS SPACE BAR TO CONTINUE.": POKE 34, 2
590 PRINT D$: "CATALOG D"; C$
600 POKE - 16368, 0: GET A$: IF A$ < > " " THEN 600
610 GOSUB 1130: GOTO 170
620 REM *** BACKGROUND AND PEN COLOR ***
630 T1 = PC: GOSUB 670:
IF PC = 8 THEN PC = T1: GOSUB 1130: GOTO 660
640 BC = PC: PC = T1:
HCOLOR= BC: HPLOT 0, 0: CALL 62454: GOTO 520
650 T3 = PC: GOSUB 670: GOSUB 1130: IF PC = 8 THEN PC = T3
660 ON CM + 1 GOTO 170, 1580, 1680, 1740, 1840, 2330
670 XF = XM * 2; YF = YM * 2; SF = INT ((XH - XM) / 140)
680 PRINT D$: "PR#0": TEXT: HOME: PRINT D$: "PR#": SL:
PRINT "G1, R, X"; XF; ", Y"; YF; ", S"; SF: GR:
HOME: VTAB 22: HTAB 9: PRINT "CONSTRUCTING COLOR MENU."
690 COLOR= 5: FOR ZZ = 0 TO 39: HLIN 0, 39 AT ZZ: NEXT
700 X8 = 9: Y8 = 17: X9 = 2: Y9 = 2: C9 = 0:
GOSUB 880: X9 = 11: Y9 = 2: C9 = 12: GOSUB 880:
X9 = 20: Y9 = 2: C9 = 3:
GOSUB 880: X9 = 29: Y9 = 2: C9 = 15: GOSUB 880
114

720 HOME: VTAB 22: HTAB 7:
PRINT "USE THE PEN TO PICK A COLOR."
PRINT: PRINT D$; "PR#"; SL: PRINT "N"
730 PRINT D$; "IN#"; SL: INPUT X, Y, Z:
IF Z < 0 THEN PRINT D$; "IN#0"
GET A$: X = 0: Y = 0: PRINT:
IF ASC (A$) = 13 THEN PC = 8: RETURN
740 IF Z <> 2 THEN 730
750 X = INT (X / 7): Y = INT (Y / 4)
760 IF Y < 2 OR Y > 37 OR Y = 19 OR Y = 20 OR X < 2 OR X > 37 THEN 730
770 PRINT D$; "PR#0": PRINT CHR$ (7):
IF Y > 1 AND Y < 19 THEN
ON INT ((X - 2) / 9) + 1 GOTO 790, 800, 810, 820
780 ON INT ((X - 2) / 9) + 1 GOTO 830, 840, 850, 860
790 PC = 0: B$ = "BLACK1": GOTO 870
800 PC = 1: B$ = "GREEN": GOTO 870
810 PC = 2: B$ = "VIOLET": GOTO 870
820 PC = 3: B$ = "WHITE1": GOTO 870
830 PC = 4: B$ = "BLACK2": GOTO 870
840 PC = 5: B$ = "ORANGE": GOTO 870
850 PC = 6: B$ = "BLUE": GOTO 870
860 PC = 7:B$ = "WHITE2"
870 HOME : VTAB 22: HTAB (40 - LEN (B$)) / 2: PRINT B$: FOR ZZ = 1 TO 500: NEXT : HCOLOR= PC: HOME : RETURN
880 COLOR= C9: FOR ZZ = 1 TO X8: VLIN Y9,Y9 + Y8 - 1 AT X9: X9 = X9 + 1: NEXT : RETURN : REM COLOR BOX LO-RES DRAW
890 REM *** WINDOW COMMAND ***
900 PRINT : PRINT D$;"PR#";SL: PRINT "T1,F,C": PRINT D$;"PR#0"
PRINT "CORNERS OF THE ACTIVE": PRINT : HTAB 11: PRINT "TABLET AREA DESIRED."
920 PRINT D$;"PR#";SL: PRINT "N,C": PRINT D$;"IN#";SL: INPUT X,Y,Z: IF Z < 0 THEN PRINT D$;"IN#0": GET A$: IF ASC (A$) = 68 THEN GOSUB 1330: HCOLOR= BC:
GOSUB 1040;X1 = X5:X2 = X6: Y1 = Y5:Y2 = Y6: GOSUB 1070: GOTO 170
930 IF Z < 0 THEN IF ASC (A$) = 13 THEN GOSUB 1130: GOTO 170
940 IF Z < > 2 THEN 920
950 PRINT D$;"PR#0": IF X < XM * 2 OR Y < YM * 2 THEN VTAB 22: HTAB 4:
PRINT CHR$ (7);"PLEASE STAY WITHIN THE WORK-AREA."
FOR ZZ = 1 TO 500: NEXT ZZ: VTAB 22: CALL - 868: GOTO 920
116

960 VTAB 11: CALL - 868: HTAB 8:
PRINT "UPPER-LEFT AND ";:
INVERSE : PRINT "LOWER-RIGHT": NORMAL
970 PRINT D$;"PR#";SL: PRINT "N,C":
INPUT TX,TY,Z: IF Z < 0 THEN PRINT D$;"IN#0":
GET A$: IF ASC (A$) = 68 THEN GOSUB 1330:
HCOLOR= BC: GOSUB 1040:X1 = X5:X2 = X6:
Y1 = Y5:Y2 = Y6: GOSUB 1070: GOTO 170
980 IF Z < 0 THEN IF ASC (A$) = 13 THEN GOSUB 1130:
GOTO 170
990 IF Z < > 2 THEN 970
1000 PRINT : PRINT D$;"PR#0":
IF TX > XH * 2 OR TY > YH * 2 THEN VTAB 22: HTAB 4:
PRINT CHR$ (7);"PLEASE STAY WITHIN THE WORK AREA.":
FOR ZZ = 1 TO 500: NEXT ZZ: VTAB 22: CALL - 868: GOTO 970
1010 IF TX < X OR TY < Y THEN VTAB 22: HTAB 5:
PRINT CHR$ (7);"PLEASE SPECIFY POINTS CORRECTLY!":
FOR ZZ = 1 TO 500: NEXT ZZ: GOTO 910
1020 X1 = X:X2 = TX - X1 + 1:Y1 = Y:Y2 = TY - Y1 + 1
1030 GOSUB 1330:
HCOLOR= BC: GOSUB 1040: GOSUB 1070: GOTO 170
1040 XT = INT (GF):
XB = 279 - XT:YT = INT (HF):YB = 191 - YT:
   IF XT > = 2 THEN HPLOT XT - 1,YT TO XT - 1,YB:
   HPLOT XT - 2,YT TO XT - 2,YB:
HPLOT XB + 1,YT TO XB + 1,YB: HPLOT XB + 2,YT TO XB + 2,YB
1050 IF YT >= 1 THEN HPLOT XT,YT - 1 TO XB,YT - 1:
HPLOT XT,YB + 1 TO XB,YB + 1
1060 RETURN
1070 T1 = X2 / 280:T2 = Y2 / 192:
IF T1 < T2 THEN S2 = T2:
IF INT (T2) < T2 THEN S2 = INT (T2) + 1
1080 IF T1 >= T2 THEN S2 = T1:
IF INT (T1) < T1 THEN S2 = INT (T1) + 1
1090 RD = 0: GOSUB 1130:
HCOLOR= 0: IF BC = 0 OR BC = 4 THEN HCOLOR= 3
1100 GOSUB 1040: HCOLOR= PC:B1 = INT (XT / 256):
B2 = XT - B1 * 256:B3 = INT ((XB + 1) / 256):
B4 = (XB + 1) - B3 * 256:B5 = YT:B6 = YB + 1:
X3 = INT (XT):X4 = INT (XB):Y3 = INT (YT):Y4 = INT (YB)
1110 GOSUB 1330:
HCOLOR= PC:WM = 1:W$ = "": ONERR GOTO 2650
1120 BX = 3089: POKE BX,B2: POKE BX + 1,B1:
POKE BX + 2,B4: POKE BX + 3,B3:
POKE BX + 4,B5: POKE BX + 5,B6: RETURN
1130 IF RD > 0 THEN GOSUB 1400: RETURN
1140 GF = (280 - X2 / S2) / 2:HF = (192 - Y2 / S2) / 2:
XF = INT (X1 - GF * S2):
YF = INT (Y1 - HF * S2):SF = S2: GOSUB 2590: RETURN
1150 REM *** VIEWPORT COMMAND ***
1160  HCOLOR= 3: IF BC = 3 OR BC = 7 THEN  HCOLOR= 0
1170  GOSUB 1330: XF = INT (X1 - GF * S2):
      YF = INT (Y1 - HF * S2): SF = S2: GOSUB 2590
1180  GOSUB 1290: GOSUB 1310
1190  IF Z < 0 THEN PRINT D$; "IN#0": PRINT :
      GET A$: IF ASC (A$) = 13 THEN GOSUB 1130:
      GOSUB 1330: HCOLOR= PC: GOTO 170
1200  IF Z < 0 THEN IF ASC (A$) = 68 THEN GOSUB 1090:
      GOTO 170
1205  IF Z < 0 THEN GOTO 1180
1210  IF XT > X OR XB < X OR YT > Y OR YB < Y THEN 1180
1220  T1 = X - 1; T2 = Y - 1; H = 0; X8 = T1; Y8 = T2: GOSUB 1350
1230  GOSUB 1280: GOSUB 1310:
      IF Z < 0 THEN GOSUB 1350: GOTO 1190
1240  IF XT > X OR XB < X OR YT > Y OR YB < Y THEN 1230
1250  IF X < T1 OR Y < T2 THEN GOSUB 1350: PRINT D$; "PR#0":
      TEXT : HOME : VTab 12: HTAB 5:
      PRINT "PLEASE SPECIFY POINTS CORRECTLY":
      GOSUB 1300: GOSUB 1140: GOTO 1180
1260  WM = 1: W$ = "": GOSUB 2590: RD = 0
1270  X3 = T1 + 1; Y3 = T2 + 1:
      X4 = X; Y4 = Y; H = 0: GOSUB 1350:
      GOSUB 1330: B1 = INT (X3 / 256): B2 = X3 - B1 * 256:
      B3 = INT ((X4 + 1) / 256): B4 = (X4 + 1) - B3 * 256:
      B5 = Y3: B6 = Y4 + 1: GOSUB 1120: HCOLOR= PC: GOTO 170
1280 PRINT : PRINT D$;"PR#0":
GOSUB 2300: PRINT D$;"PR#";SL:
PRINT "M2": VTAB 23: HTAB 15: POKE 41, PEEK (41) + 4:
PRINT CHR$ (7);"LOWER-RIGHT":
FOR T3 = 1 TO 500: NEXT :
PRINT D$;"PR#";SL: PRINT "N,H2": RETURN
1290 PRINT : PRINT D$;"PR#0":
GOSUB 2300: PRINT D$;"PR#";SL:
PRINT "M2": VTAB 23: HTAB 15: POKE 41, PEEK (41) + 4:
PRINT CHR$ (7);"UPPER-LEFT":
FOR T3 = 1 TO 500: NEXT :
PRINT D$;"PR#";SL: PRINT "N,H2": RETURN
1300 FOR H = 1 TO 1000: NEXT H: RETURN
1310 PRINT D$;"IN#";SL:
INPUT " ",X,Y,Z: IF Z = 2 OR Z < 0 THEN RETURN
1320 GOTO 1310
1330 POKE 233,99: POKE 232,32:
HCOLOR= 0: IF BC = 0 OR BC = 4 THEN HCOLOR= 3
1340 H = 0:X8 = X3 - 1;Y8 = Y3 - 1: GOSUB 1350
H = 16:X8 = X4 + 1;Y8 = Y3 - 1: GOSUB 1350:H = 32:
X8 = X4 + 1;Y8 = Y4 + 1: GOSUB 1350:
H = 48:X8 = X3 - 1;Y8 = Y4 + 1: GOSUB 1350: RETURN
1350 IF X8 > = 0 AND X8 < 280 AND Y8 > = 0 AND Y8 < 192 THEN ROT= H: SCALE= 1: XDRAW 1 AT X8,Y8
1360 RETURN
1380 RD = RD + 1: IF RD > 1 THEN RD = 0:
GOSUB 1130: GOTO 660

1390 GOSUB 1400: GOTO 660

1400 IF X4 = X3 OR Y4 = Y3 THEN 1440

1410 T1 = ((XH * 2) - (XM * 2)) / (X4 - X3): T2 =
((YH * 2) - (YM * 2)) / (Y4 - Y3):
SF = INT (T1): IF T2 < T1 THEN SF = INT (T2)

1420 XF = INT ((XM * 2) - (SF * X3)):
YF = INT ((YM * 2) - (SF * Y3)):
IF ABS (XF) > 27000 OR ABS (YF) > 27000 THEN GOTO 1440

1430 GOSUB 2590: RETURN

1440 PRINT D$;"PR#0": GOSUB 2300: PRINT :
PRINT D$;"PR#",SL: PRINT "M2,C": VTAB 23: HTAB 14:
POKE 41, PEEK (41) + 4:
PRINT "NOT POSSIBLE.":RD = 0: GOSUB 1300: GOSUB 1130: RETURN

1460 PRINT : PRINT D$;"PR#",SL:
PRINT "T1,C": PRINT D$;"PR#0": PRINT D$;"IN#0": TEXT

1470 HOME : PRINT :
HTAB 9: PRINT "FAST-DRAW DELTA SETTING":
VTAB 5: HTAB 7:
PRINT "CURRENT DELTA SETTING IS "; ABS (D%);"."
PRINT :A$ = "ON.": IF D% < 0 THEN A$ = "OFF."

1480 HTAB 10: PRINT "AUDIO FEEDBACK IS ";A$

1490 VTAB 18: CALL - 958: HTAB 11:
INPUT "NEW DELTA EQUALS ";A$: IF A$ = "" THEN 1530
1500 IF VAL (A$) < 1 OR VAL (A$) > 127 THEN 1490
1510 IF D% < 1 THEN D% = - VAL (A$): GOTO 1530
1520 D% = VAL (A$)
1530 VTAB 20: CALL - 958: HTAB 9:
INPUT "TURN AUDIO FEEDBACK ";A$: IF A$ = "" THEN 1560
1540 IF LEFT$ (A$,2) < > "ON" AND
LEFT$ (A$,3) < > "OFF" THEN 1530
1550 D% = ABS (D%):
IF LEFT$ (A$,3) = "OFF" THEN D% = - D%
1560 GOSUB 1130: GOTO 170
1580 GOSUB 1130: PRINT D$;"IN#";SL:CM = 1
1590 RT = 2: INPUT X,Y,Z:
IF Z <> 2 THEN POKE - 16368,0: GOTO 1590
1600 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4 THEN GOSUB 1940:
IF RT = 1 THEN 220
1610 IF RT = 0 THEN 1590
1620 HPOLT X,Y
1630 RT = 2: INPUT X,Y,Z: IF Z < > 2 THEN POKE - 16368,0: GOTO 1630
1640 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4 THEN GOSUB 1940: IF RT = 1 THEN 220
1650 IF RT = 0 THEN 1630
1660 HPOLT TO X,Y: GOTO 1630
1680 GOSUB 1130: PRINT D$;"IN#";SL:CM = 2
1690 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE -16368,0: GOTO 1690
1700 IF X < X3 OR X > X4 OR
Y < Y3 OR Y > Y4 THEN GOSUB 1940: IF RT = 1 THEN 220
1710 IF RT = 0 THEN 1690
1720 HPLOT X,Y: GOTO 1690
1740 GOSUB 1130: PRINT D$;"IN#";SL:CM = 3
1750 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE -16368,0: GOTO 1750
1760 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4
THEN GOSUB 1940: IF RT = 1 THEN 220
1770 IF RT = 0 THEN 1750
1780 HPLOT X,Y:TX = X:TY = Y
1790 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE -16368,0: GOTO 1790
1800 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4
THEN GOSUB 1940: IF RT = 1 THEN 220
1810 IF RT = 0 THEN 1790
1820 HPLOT X,Y TO TX,Y TO TX,TY TO X,TY TO X,Y: GOTO 1750
1840 GOSUB 1130: PRINT D$;"IN#";SL:CM = 4
1850 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE -16368,0: GOTO 1850
1860 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4
THEN GOSUB 1940: IF RT = 1 THEN 220
1870 IF RT = 0 THEN 1850
1880 HLOT X,Y:TX = X:TY = Y
1890 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE -16368,0: GOTO 1890
1900 IF X < X3 OR X > X4 OR
   Y < Y3 OR Y > Y4 THEN GOSUB 1940: IF RT = 1 THEN 220
1910 IF RT = 0 THEN 1890
1920 IF Y < TY THEN FOR H = Y TO TY:
   HPLOT X,H TO TX,H: NEXT : GOTO 1850
1930 FOR H = TY TO Y; HPLOT X,H TO TX,H: NEXT : GOTO 1850
1940 IF (Y * SF + YF - YL * 2) / SO < 2 THEN RT = 1 : RETURN
1950 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#";SL:
   PRINT "M2": VTAB 23: HTAB 3: POKE 41, PEEK (41) + 4:
   PRINT "POINT OUTSIDE VIEWPORT. RESPECIFY.":
   GOSUB 1300: PRINT D$;"PR#";SL: PRINT "N,H2":RT = 0: RETURN
1970 GOSUB 1130:N% = 1:
1975 IF N% = 1 THEN 1970
1980 HLOT X%(1),Y%(1) TO X%(N% - 1),Y%(N% - 1):
   GOSUB 1990: GOSUB 1130: GOTO 170
1990 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#";SL:
   PRINT "M2": VTAB 23: HTAB 14:
   POKE 41, PEEK (41) + 4:
   PRINT CHR$ (7);"CALCULATING...":
   IF N% = 2 THEN AR = 0: GOTO 2020
2000 AR = 0: FOR T1 = 2 TO N% - 1:
DX = X%(T1) - X%(T1 - 1):
DY = (Y%(T1) + Y%(T1 - 1)) / 2: AR = AR + DX * DY: NEXT T1
2010 AR = AR + (X%(1) - X%(N% - 1)) *
((Y%(1) + Y%(N% - 1)) / 2):
AR = ABS (AR) / WM + 2:
IF AR < 999999999 THEN AR = ( INT (AR * 100)) / 100
2020 GOSUB 2300: VTAB 23:B$ = "AREA IS ":
POKE 41, PEEK (41) + 4:
GOSUB 2030: GOSUB 1300: GOSUB 1300: RETURN
2030 B$ = B$ + STR$ (AR) + " SQUARE " + W$ + ":"
HTAB 21 - INT ( LEN (B$) / 2): PRINT B$: RETURN
2070 GOSUB 1130:N% = 1: CALL EP%:CD = PEEK (700):
ON CD + 1 GOTO 190,2075,2080,2080
2075 IF N% = 1 THEN 2070
2080 GOSUB 2090: GOSUB 1130: GOTO 170
2090 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#":SL:
PRINT "M2": VTAB 23: HTAB 14: POKE 41, PEEK (41) + 4:
PRINT CHR$ (7);"CALCULATING...":
IF N% = 2 THEN DT = 0: GOTO 2110
2100 DT = 0: FOR T1 = 2 TO N% - 1:DX = X%(T1) - X%(T1 - 1):
DY = Y%(T1) - Y%(T1 - 1):
DT = DT + SQR (DX * DX + DY * DY): NEXT :
DT = DT / WM: IF DT < 999999999 THEN
DT = ( INT (DT * 100)) / 100
2110 GOSUB 2300: VTAB 23:B$ = "THE DISTANCE IS ":
POKE 41, PEEK (41) + 4:
GOSUB 2120: GOSUB 1300: GOSUB 1300: RETURN

2120 B$ = B$ + STR$ (DT) + " " + W$ + ".":
HTAB 21 - INT (LEN (B$) / 2): PRINT B$: RETURN

2160 GOSUB 1130
2170 GOSUB 2310
2180 PRINT D$;"IN#";SL: INPUT X,Y,Z:
IF Z < 0 THEN PRINT D$;"IN#0":
GET A$: IF ASC (A$) = 13 THEN GOSUB 1130: GOTO 170
2190 IF Z < > 2 THEN PRINT: GOTO 2180
2200 IF X3 > X OR X4 < X OR Y3 > Y OR Y4 < Y THEN 2170
2210 GOSUB 2320
2220 PRINT D$;"IN#";SL: INPUT TX,TY,Z:
IF Z < 0 THEN PRINT D$;"IN#0":
GET A$: IF ASC (A$) = 13 THEN GOSUB 1130: GOTO 170
2230 IF Z < > 2 THEN PRINT: GOTO 2220
2240 IF TX < X3 OR TX > X4 OR TY < Y3 OR TY > Y4 THEN 2210
2250 PRINT D$;"PR#";SL: PRINT "T1,C": TEXT: HOME:
T1 = TX - X + 1:T2 = TY - Y + 1:
DX = SQR (T1 * T1 + T2 * T2):
VTAB 10: HTAB 6:
PRINT "DISTANCE IS "; INT (DX);" SCREEN UNITS.":
PRINT D$;"IN#0"
2260 VTAB 18: CALL - 958: HTAB 8:
INPUT "YOUR NUMBER OF UNITS -> ";A$:
IF A$ = "" THEN W = DX: GOTO 2280

2265 IF VAL (A$) > 999999999 THEN 2260

2270 W = VAL (A$): IF W = 0 THEN 2260

2280 VTAB 20: CALL - 958: HTAB 8:
INPUT "TYPE OF UNITS -> "; W$: IF LEN (W$) > 10 THEN 2280

2290 WM = DX / W: GOSUB 1130: GOTO 170

2300 FOR T4 = 21 TO 24: VTAB T4:
PRINT " NEXT T4:
PRINT : RETURN

2310 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#": SL:
PRINT "M2": VTAB 23: HTAB 13: POKE 41, PEEK (41) + 4:
PRINT CHR$ (7); "BEGINNING POINT?":
FOR T3 = 1 TO 500: NEXT :
PRINT D$;"PR": SL: PRINT "N,H2": RETURN

2320 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#: SL:
PRINT "M2": VTAB 23: HTAB 14: POKE 41, PEEK (41) + 4:
PRINT CHR$ (7); "ENDING POINT?":
FOR T3 = 1 TO 500: NEXT :
PRINT D$;"PR#": SL: PRINT "N,H2": RETURN

2330 REM CIRCLE MODE***

2340 GOSUB 1130: PRINT D$;"IN": SL: CM = 5

2350 RT = 2: INPUT X,Y,Z:

IF Z < > 2 THEN POKE - 16368,0: GOTO 2350

2360 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4
THEN GOSUB 1940: IF RT = 1 THEN 220
2370 IF RT = 0 THEN 2350
2380 HPLOT X,Y;TX = X;TY = Y
2390 RT = 2: INPUT X,Y,Z:
IF Z < > 2 THEN POKE - 16368,0: GOTO 2390
2400 IF X < X3 OR X > X4 OR Y < Y3 OR Y > Y4 THEN GOSUB 1940: IF RT = 1 THEN 220
2410 IF RT = 0 THEN 2390
2420 R = SQR ((X - TX) + 2 + (Y - TY) + 2)
2425 ONERR GOTO 2480
2430 FOR TH = 0 TO .7854 STEP 1 / R
2440 DX = R * SIN (TH):DY = R * COS (TH):X = TX:Y = TY
2450 HPLOT X + DX,Y + DY: HPLOT X + DX,Y - DY:
HPLOT X - DX,Y + DY: HPLOT X - DX,Y - DY
2460 HPLOT X + DY,Y + DX: HPLOT X + DY,Y - DX:
HPLOT X - DY,Y + DX: HPLOT X - DY,Y - DX
2470 NEXT TH: ONERR GOTO 2650
2475 GOTO 2340
2480 PRINT D$;"PR#0": GOSUB 2300: PRINT D$;"PR#":SL:
PRINT "M2": VTAB 23: HTAB 12:
POKE 41, PEEK (41) + 4:
PRINT "CIRCLE OFF SCREEN. RESPECIFY."
2485 GOSUB 1300: PRINT D$;"PR#":SL:
PRINT "N,H2": ONERR GOTO 2650
2490 GOTO 2340
128

2590 PRINT: PRINT D$;"PR#"; SL
2600 PRINT "D,S"; SF; "H2,X"; XF; "Y"; YF; ":R,N": RETURN
2610 TEXT: HOME: PRINT: HTAB 7:
PRINT "TABLET INFORMATION FILE DOES":
PRINT: HTAB 16: PRINT "NOT EXIST."
2620 VTAB 7: HTAB 8: PRINT "MAKE SURE THE MASTER DISK":
PRINT: HTAB 11: PRINT "IS NOT PROTECTED AND":
PRINT: HTAB 12: PRINT "THEN PRESS RETURN."
2630 VTAB 14: HTAB 5:
PRINT "THE MENU ALIGNMENT ROUTINE WILL":
PRINT: HTAB 17:
PRINT "BE RUN. ": GET A$: IF ASC (A$) < > 13 THEN 2630
2635 POKE 104, 8: POKE 103, 1
2640 PRINT: PRINT D$; "RUN MENU ALIGNMENT,D1": STOP
2650 REM * ERROR HANDLER *
2660 TEXT: HOME: T7 = PEEK (222):
PRINT D$: "PR#O":
IF T7 = 8 THEN VTAB 12:
HTAB 16: PRINT "I/O ERROR." : GOTO 2700
2670 IF T7 = 6 THEN VTAB 12: HTAB 11:
PRINT "PICTURE NOT ON DISK." : GOTO 2700
2680 IF T7 = 4 OR T7 = 9 OR T7 = 10 THEN VTAB 12: HTAB 8:
PRINT "THE PICTURE IS LOCKED, OR":
HTAB 5: PRINT "THE DISK IS FULL, OR PROTECTED." : GOTO 2700
2685 IF T7 = 13 THEN VTAB 12:
PRINT "FILE REQUESTED IS NOT A PICTURE FILE."; GOTO 2700
2690      VTAB 12: HTAB 9: PRINT "PROBLEM --> PEEK(222)=";T7
2700      VTAB 20: HTAB 8: PRINT "PRESS SPACE BAR TO RETRY.";
                    PRINT : HTAB 11: PRINT "PRESS <CR> TO ABORT."
2710      VTAB 24: HTAB 20:
GET A$: IF A$ = " " THEN VTAB 20: HTAB 1:
CALL  - 958: HTAB 15:
PRINT "RETRYING..."; IF T7 = 6 THEN GOTO 345
2715      IF A$ = " " THEN RESUME
2720      IF ASC (A$) = 13 THEN PRINT :
PRINT D$; "CLOSE ";B$: GOTO 290
2730      GOTO 2710
APPENDIX H: MOTOR SKILLS TEST - GAME SCREEN DISPLAY
APPENDIX I: INTRODUCTION AND SAFETY LESSON PLAN
OBJECTIVES: On completion of this lesson the student should:

1) have basic understanding of SMAW terms and basic principles
2) understand advantages and limitations of SMAW
3) be familiar with safety rules and procedures

INTRODUCTION AND MOTIVATION:

We are asking for your consent to participate in a research project. In this project we are interested in the manner in which knowledge is transferred between mechanical skills and conceptual understanding. As a participant in this project you will be asked to furnish some background information, attend a demonstration of arc welding and welding safety, play a video game to determine your motor skill level, take a twenty-four item pretest and posttest and, depending on the group in which you are placed, one of the following:

Group 1 - receive training in arc welding on an arc welder.
Group 2 - receive training in arc welding on a computerized arc welding simulator.
Group 3 - control group - no computer use or welding is performed.

Your responses to items on the demographics survey and the written examinations will be coded and all personal associations will be confidential. All forms with personal identification items will be destroyed immediately following compilation of the results.

Since there is a potential hazard of heat and bright light, you will be given extensive safety training as well as all required safety equipment including gloves, helmet, aprons and industrial quality eye protection.

If you would now please read and sign the consent form and hand them back. Please remember that you are free to withdraw from this project at any time. If you have a question at any time during the project, please feel free to ask.

Now, let's begin.
Terms and definitions:
A. Shielding - any procedure or device for protecting an in-process weld from contaminants in the air or from chemical reactions in a base metal.
B. Air contaminants - Oxygen and nitrogen in air.
C. Deposition rate - The weight of filler metal placed onto or into a weld in a given time period.
D. Slag - A combination of flux and impurities drawn from the air and molten metal that forms a covering over a weld to protect it as it cools.

Advantages of SMAW:
A. Equipment is relatively inexpensive.
B. Equipment is portable because the welding machines can be powered with gasoline or diesel powered engines.
C. Applications are relatively simple and can be adapted to many job requirements.
D. Is well suited for maintenance and repair work in small shops, on farms, and in garages.

Limitations of SMAW:
A. As electrodes are used, work has to stop for electrode replacement and this reduces actual welding time.
B. High amperages used with semi-automatic and automatic welding processes are difficult to work with in SMAW and the deposition rate with SMAW is lower than with other processes.
C. As the electrodes burn off, the ends or stubs become waste that adds to the welding cost factor.

Principles of SMAW:
A. An electric arc is struck between a grounded base metal and a flux-covered electrode held in a holder and manipulated by hand.
B. The heat of the arc melts the base metal and the metal in the electrode so that the two fuse together to create the weld.
C. Flux contained on the electrode covering is also melted or vaporized to provide shielding that protects the weld from contaminants in the air, hence the name shielded metal arc welding.

Relationships of arc, base metal, electrode, and flux:
A. The arc stream is created by holding the electrode 0" to 1/8" away from the base metal.
B. The arc stream creates a molten pool or crater that tends to flow away from the arc and cool and solidify as it moves.
C. Flux from the electrode covering forms as slag on the top of the weld to protect it from contaminants during cooling. (Figure 1)
How Flux Coated Electrodes Work:

A. Flux-covered electrodes have a core of metal wire with a baked on chemical covering, and both parts of the electrode have specific functions.

B. The wire core melts in the arc stream and droplets of metal are transferred across the arc to make the molten puddle and provide the filler metal to fill the gap or groove between two base metals.

C. The flux covering also melts in the arc stream to help stabilize the arc, to provide a vapor around the arc to keep it free from atmospheric impurities, and to form a slag covering to protect the weld.

SAFETY:

Terms:

Oxygen displacement - a reduction of oxygen in the breathing zone around a welding activity caused by any arc or flame.

Toxic hazards - poisonous gases, fumes and vapors produced by chemical reactions in certain welding processes.

Contaminants - impurities formed from chemical reactions between base metals, flux, and electrodes, and usually present in fumes and vapors.

Electrical Safety:

A. All electrical equipment should have an earth ground for safety reasons, and this ground should not be confused with the work lead to workpiece ground that completes the welding circuit.
B. Keep electrical connections tight, clean, and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

C. Keep work area, equipment, and clothing dry because even a slight amount of moisture can conduct enough electricity to cause a severe shock.

D. Never dip an electrode holder in water to cool it.

E. When working with welding machines set up for multiple operation, be very careful not to touch hot parts of the electrode holders because open-circuit voltages from two machines are increased and can cause a severe shock.

F. Remove electrode from electrode holder when work is finished.

G. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

H. Keep welding cables as close to the work area as possible and do not connect cables to building framework because current can be directed through lifting chains and cables and weaken them.

I. When working in high places, carefully examine work area for electrical hazards because a shock in such conditions could cause a fall and severe injury.

J. Keep welding cables free of conduits, mostors, and any other equipment that could cause a short circuit.

K. Keep ground as close to the arc as possible.

Important Rules for Handling Welding Cables

A. Never drag cables through dirt or oil, and never pull on a cable to force it over an obstruction.

B. Use only clean dry rags to clean welding cables, never use gasoline or an oily rag for the job.

C. When not in use, keep welding cables coiled free of kinks and properly stored.

D. Never drape a welding cable over any type of gas cylinder, and NEVER strike an arc on a gas cylinder.

Rules for Handling Hollow Castings or Containers

A. Hollow castings or containers should be vented before any heating, cutting, or welding activity.

B. Tanks, drums, and containers should not be heated, cut, or welded.

(CAUTION: Some containers can be safely purged, but the rule for beginners is to never attempt such an activity).

Hazards associated with arc rays

A. A welding arc produces ultraviolet and infrared radiation that can severely burn eyes that are unprotected. [note: A welding helmet protects the head from flying sparks, but the shaded lens is also required for eye protection.]
B. Radiation from a welding arc is strong enough to sunburn or sometimes blister bare skin if the exposure is intense or for an extended period, so arms, legs, and torso should be covered with durable flame-resistant clothing.

C. Work stations and work areas should be shielded to prevent an arc flash from injuring nearby workers or visitors.

Welding Helmets:

A. Stationary filter lens - this type hood has a fixed lens housing with the shaded lens held in by a spring retainer from where a lens can be slipped out and replaced as welding requires.

B. Flip-front filter lens - This type hood has a lens housing with a front side that can be flipped up so that it leaves a clear glass lens that permits the hood to be worn while chipping. (Figure 2)
Steps in Selecting a Safe Lens Shade for SMAW:

A. Determine electrode size and amperage range for the electrode.

(NOTE: In oxyacetylene welding and cutting, lens shade requirements are based on metal thickness, but in SMAW, lens shade requirements are based on electrode size and amperage range of the electrode).

<table>
<thead>
<tr>
<th>Electrode Size</th>
<th>Amperage</th>
<th>Shade #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 to 75</td>
<td>8</td>
</tr>
<tr>
<td>1/16-5/32</td>
<td>75 to 200</td>
<td>10</td>
</tr>
<tr>
<td>3/16-1/4</td>
<td>200 to 400</td>
<td>12</td>
</tr>
<tr>
<td>5/16-3/8</td>
<td>400+</td>
<td>14</td>
</tr>
</tbody>
</table>

B. Select lens shade according to the lens manufacturer's selection chart, but never select less than a #8 lens shade for SMAW.

(NOTE: When you remove your hood after arc welding and you see white spots or white blotches as after images, it means that you are getting too much light through the lens and you should switch to a shade at least one number darker, or check the seal on your lens).

C. A general rule of thumb is that the larger the diameter of the electrode, the higher the number required for a lens shade.

Protective Clothing:

Shirts and pants - do not wear clothing made from synthetic materials, clothing should be heavy, long sleeve shirt with cuffless pants that are not frayed at the bottom, and shirt pockets should have flaps.

Leather jackets and aprons - should be worn for additional protection, especially when welding out of position or in confined areas where flying sparks present an increased hazard.
Boots - should be made of heavy leather with uppers that reach above the ankle to help prevent burns from sparks and spatter, and although steel-toed boots are not required, they are highly recommended.

Gloves - heavy leather gloves with gauntlets are required for all welding and cutting activities.

Safety glasses - should have nonmetal frames, impact-resistant lenses with side shields to protect from flying objects, and should be worn at all times in the shop area. (NOTE: Safety glasses should meet both industry and OSHA specifications).

Face shield - should be a clear-plastic type to provide good visibility when chipping or grinding and still provide protection from particles of slag or metal.

Environmental Safety Requirements:

A. Ventilation - many welding activities produce toxic fumes and vapors that are hazardous to breathe, and every work station should be equipped with ventilation or an exhaust system capable of safely removing dangerous and irritating smoke and contaminants. (CAUTION: Always position your head to the side of rising fumes).

B. Respirators - in confined areas where the hazard of toxic fumes is increased, a weldor should wear an air-supplied respirator or a self-contained breathing apparatus, not a filter-type mask that cannot compensate for oxygen displacement.
Now I will demonstrate how to place the electrode in the jaws of the holder, turn on the power to the machine, and strike an arc.
[Place E7014 electrode in holder, show to class]
[Switch on power]
[Strike arc 6 to 8 times - Do not establish a bead.]
Are there any questions?
Now place your helmet on your head and adjust.
Put on gloves.
Take one electrode and practice striking an arc for the next 2 minutes.
[Time - 2 minutes]
Now you will start the pretesting.
Please go to the computer room and play one game. The game is already running on each computer. The only control you will need will be the open and closed apple keys on either side of the space bar.
[After all are seated at the computers]
Are there any questions about the game?
[After each person has completed the game hand out the pretest form]
[When all pretests are received]
Thank you, if you will wait 5 minutes, I will prepare you for the next phase of the project.
[Match scores and pretest results - rank participants]
The following persons will go to these groups:
   Welding
   Simulator
   Control

[When all treatment group personnel have finished, administer post test] Thank you for your help with this project. If there are any last questions please feel free to ask.
APPENDIX J: WELDING PRACTICE LESSON PLAN
WELDING LESSON PLAN

You have been selected to participate in the traditional instruction group for this project. This means that you will be taught to weld a flat bead using the arc welder.

The amperage control shows a range of settings from which you must select. Amperage setting is based primarily on thickness of the metal to be welded and diameter of the electrode. You will be dealing with 1/4 inch steel and 1/8 inch electrode which require an amperage setting of 110 to 150 amps. Exactly where in that range will be your task during the practice time coming soon.

The electrode you will be using is the E7014. This electrode is very easy to run. Just touch it to the plate to strike the arc and hold the electrode down on the metal surface. No arc length will be required. The only concern you will have while you are welding will be maintaining a consistent travel speed that will form a solid weld.

If your travel speed is inconsistent then you will have parts of the weld running too fast or too slow. Bead width should be 2 to 3 times the width of the wire in the electrode. Generally, use 2 inches of electrode to produce 1 inch of bead. Avoid any weaving of the electrode, a straight line will produce the best results.

Your goal in the next 10 minutes is to practice the welding technique you have been shown and learn to control the speed of travel of the electrode. You must also fine tune your welders, which are set for your use. When the practice time has expired, I will blow a whistle and you must stop welding. Then I will give you three pieces of steel on which you will weld one bead each. The judges will then score the welds as a single composite score.

Are there any questions?

[Hand out scrap metal for practice]

[After 10 minutes, hand out three pieces to each student]

[Collect weld scores and send students back to computer lab to complete posttest]
APPENDIX K: WELDING SIMULATION LESSON PLAN
SIMULATOR LESSON PLAN

You have been selected to participate in the computer simulator instruction group for this project. This means that you will be taught to weld a flat bead using the Apple computer and graphics tablet as an arc welder.

[Start program display]

The amperage control shows a range of settings from which you must select. Amperage setting is based primarily on thickness of the metal to be welded and diameter of the electrode. You will be dealing with 1/4 inch steel and 1/8 inch electrode which require an amperage setting of 110 to 150 amps. Exactly where in that range will be your task during the practice time coming soon.

The electrode you will be using is the E7014. This electrode is very easy to run. Just touch it to the plate to strike the arc and hold the electrode down on the metal surface. No arc length will be required. The only concern you will have while you are welding will be maintaining a consistent travel speed that will form a solid weld. On the simulator, all you have to do is hold the stylus to the tablet surface and drag it across to form the bead.

[Demonstrate a normal weld]

If your travel speed is inconsistent then you will have parts of the weld running too fast or too slow. Bead width should be 2 to 3 times the width of the wire in the electrode. Generally, use 2 inches of electrode to produce 1 inch of bead. Avoid any weaving of the electrode, a straight line will produce the best results. The simulation will form the bead automatically. The weld surface will be produced as a function of your travel speed and amp setting.

[Demonstrate fast and slow weld]

Your goal in the next 10 minutes is to practice the welding technique you have been shown and learn to control the speed of travel of the electrode. You must also fine tune your the amp setting on the simulator, which has a preset range for your activity. When the practice time has expired, I will blow a whistle and you must stop the simulation. You will then be taken to the welding shop,
given a real arc welder which has been prepared for your use. You will be instructed to put on the safety equipment. Then I will give you three pieces of steel on which you will weld one bead each. The judges will then score the welds as a single composite score.

Are there any questions? Begin the simulations.

[AFTER 10 MINUTES, HAND OUT THREE PIECES TO EACH STUDENT]

[COLLECT WELD SCORES AND SEND STUDENTS BACK TO COMPUTER LAB TO COMPLETE POSTTEST]
APPENDIX L: SIMULATOR TABLET AND STYLUS
APPENDIX M: WELDING ICON SCREEN DISPLAY
SCREEN DISPLAY

NORMAL  FAST  SLOW  LOW AMPS  HIGH AMPS

EXAMINE THE BEAD THEN PRESS [RETURN]
APPENDIX N: GROUP DEMOGRAPHICS
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COORDINATION SCORE</th>
<th>PRETEST SCORE</th>
<th>POSTTEST SCORE</th>
<th>AGE</th>
<th>YEARS SCHOOL</th>
<th>MECHANICAL ABILITY</th>
<th>COMPUTER ABILITY</th>
<th>WELD SCORE</th>
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<tbody>
<tr>
<td>MEAN - WELDING</td>
<td>38698</td>
<td>14.87</td>
<td>15.33</td>
<td>24.67</td>
<td>15.93</td>
<td>6.33</td>
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<tr>
<td>Standard Deviation</td>
<td>19618</td>
<td>4.03</td>
<td>4.01</td>
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<td>1.63</td>
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<td>MEAN - SIMULATION</td>
<td>41342</td>
<td>13.80</td>
<td>14.66</td>
<td>23.46</td>
<td>16.00</td>
<td>4.73</td>
<td>3.60</td>
<td>5.00</td>
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<tr>
<td>Standard Deviation</td>
<td>18984</td>
<td>4.36</td>
<td>4.32</td>
<td>4.45</td>
<td>1.51</td>
<td>1.87</td>
<td>1.84</td>
<td>2.69</td>
</tr>
<tr>
<td>MEAN - CONTROL</td>
<td>29042</td>
<td>14.93</td>
<td>14.20</td>
<td>23.46</td>
<td>16.00</td>
<td>4.60</td>
<td>3.73</td>
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<tr>
<td>Standard Deviation</td>
<td>12822</td>
<td>3.84</td>
<td>3.72</td>
<td>3.56</td>
<td>1.30</td>
<td>1.59</td>
<td>2.12</td>
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<td>MEAN - TOTAL</td>
<td>36372</td>
<td>14.53</td>
<td>14.73</td>
<td>23.86</td>
<td>15.97</td>
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<td>3.91</td>
<td>5.76</td>
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<td>Standard Deviation</td>
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<td>4.02</td>
<td>3.96</td>
<td>3.57</td>
<td>1.32</td>
<td>1.85</td>
<td>1.86</td>
<td>2.62</td>
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### Variable: Sex

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<tr>
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<th>Female</th>
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<tbody>
<tr>
<td>Welder</td>
<td>14 (31.2%)</td>
<td>1 (2.2%)</td>
</tr>
<tr>
<td>Simulation</td>
<td>9 (20.0%)</td>
<td>6 (13.3%)</td>
</tr>
<tr>
<td>Control</td>
<td>11 (24.4%)</td>
<td>4 (8.9%)</td>
</tr>
<tr>
<td></td>
<td>34 (75.6%)</td>
<td>11 (24.4%)</td>
</tr>
<tr>
<td></td>
<td>45 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

### Variable: Curriculum

<table>
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<tr>
<th>Group</th>
<th>Ag</th>
<th>Ag</th>
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<tbody>
<tr>
<td></td>
<td>Ag</td>
<td>Science Related</td>
</tr>
<tr>
<td>Welder</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Simulation</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Control</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>23</td>
</tr>
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</table>

\[
alpha = 0.05 \quad \text{chi square} = 1.24
\]

\[
\text{critical value of chi square at 2 df } = 5.99
\]
Variable: Family Environment

<table>
<thead>
<tr>
<th>Group</th>
<th>Urban/</th>
<th>Rural</th>
<th>Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welder</td>
<td>9</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Simulation</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Control</td>
<td>11</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>15</td>
<td>45</td>
</tr>
</tbody>
</table>

\[ \alpha = .05 \quad \text{chi square} = 0.60 \]
\[ \text{critical value of chi square at 2 df} = 5.99 \]

Variable: Family Employment

<table>
<thead>
<tr>
<th>Group</th>
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<th>White Collar/</th>
<th>Blue Collar</th>
<th>Prof &amp; Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welder</td>
<td>8</td>
<td>7</td>
<td>15</td>
<td></td>
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<tr>
<td>Simulation</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>8</td>
<td>7</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>24</td>
<td>45</td>
<td></td>
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</tbody>
</table>

\[ \alpha = .05 \quad \text{chi square} = 1.61 \]
\[ \text{critical value of chi square at 2 df} = 5.99 \]
### Variable: Computer Ability

**Analysis of Variance**

<table>
<thead>
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<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
<th>Prob</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>44</td>
<td>153.64</td>
<td></td>
<td></td>
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<tr>
<td>Within groups</td>
<td>42</td>
<td>148.13</td>
<td>3.52</td>
<td></td>
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<tr>
<td>Between groups</td>
<td>2</td>
<td>5.51</td>
<td>2.76</td>
<td>.78</td>
<td>.46</td>
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### Variable: Education Level

**Analysis of Variance**

<table>
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<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
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<th>Prob</th>
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<tbody>
<tr>
<td>Total</td>
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<td>76.98</td>
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<tr>
<td>Within groups</td>
<td>42</td>
<td>76.93</td>
<td>1.83</td>
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<td></td>
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<tr>
<td>Between groups</td>
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<td>.04</td>
<td>.02</td>
<td>.01</td>
<td>.99</td>
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</table>

### Variable: Age

**Analysis of Variance**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
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<tbody>
<tr>
<td>Total</td>
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<td>563.20</td>
<td></td>
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Variable: Mechanical Ability

Analysis of Variance

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Scheffe' Procedure Results

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* denotes pairs of groups significantly different at the .05 level
APPENDIX O: CORRELATION MATRIX
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</table>

* Significant at the .05 level
** Significant at the .01 level
APPENDIX P: HUMAN SUBJECTS COMMITTEE APPROVAL FORM
1. Title of project (please type): An Analysis of Computer Aided Instruction for Cognitive-Psychomotor Development.

2. I agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects are properly protected. Additions to or changes in procedures affecting the subjects after the project has been approved will be submitted to the committee for review.

   Michael Spangler 25 July 85
   Typed Named of Principal Investigator Date Signature of Principal Investigator
   214 Davidson 4-8607
   Campus Address Campus Telephone

3. Signatures of others (if any) Date Relationship to Principal Investigator
   Michael 26 July 85 Major Professor
   Signed
   26 July 85 Major Professor

4. ATTACH an additional page(s) (A) describing your proposed research and (B) the subjects to be used, (C) indicating any risks or discomforts to the subjects, and (D) covering any topics checked below. CHECK all boxes applicable.

   □ Medical clearance necessary before subjects can participate
   □ Samples (blood, tissue, etc.) from subjects
   □ Administration of substances (foods, drugs, etc.) to subjects
   □ Physical exercise or conditioning for subjects
   □ Deception of subjects
   □ Subjects under 14 years of age and (or) □ Subjects 14-17 years of age
   □ Subjects in institutions
   □ Research must be approved by another institution or agency

5. ATTACH an example of the material to be used to obtain informed consent and CHECK which type will be used.

   □ Signed informed consent will be obtained.
   □ Modified informed consent will be obtained.

6. Anticipated date on which subjects will be first contacted: Month Day Year
   Anticipated date for last contact with subjects:
   8 5 85
   8 6 85

7. If Applicable: Anticipated date on which audio or visual tapes will be erased and (or) identifiers will be removed from completed survey instruments: N/A
   Month Day Year

8. Signature of Head or Chairperson Date Department or Administrative Unit
   7/29/85

9. Decision of the University Committee on the Use of Human Subjects in Research:
   □ Project Approved □ Project not approved □ No action required
   Name of Committee Chairperson Date Signature of Committee Chairperson