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Iowa State University  Ph.D.  1984

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Interaction of field dependence independence with computer-assisted instruction structure in an orthographic projection lesson

by

Ronald Duane Dahl

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

Major: Industrial Education and Technology

Approved:

Signature was redacted for privacy.
In Charge of Major Work

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Iowa State University
Ames, Iowa

1984
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CHAPTER 1. INTRODUCTION

Some of the most important changes which have occurred in society throughout time have had their base in technology. Changes such as the way we travel, communicate and in some instances, the way we think—all brought about by technology—can have positive and negative effects. Frequently, the attitude concerning the changing effects relates to perspective. An example of this is atomic energy. In the form of a power plant, the purpose is positive and constructive. In the form of an atomic bomb, the purpose is negative and destructive from the perspective of many people.

The technology of computerization is a rare form of technology in the respect that most people seem to view the computer as positive and constructive. This is exemplified by the fact that Time, Inc. magazine honored the computer as "Man of the Year" for 1982. The computer is not new, but yet its effective application is still in its infancy. This may make the honor bestowed by Time, Inc. somewhat premature.

Computers are being used today in a wide variety of applications. As Shane (1982) points out, a large portion of the Western culture could already be classified as a computerized society. Hardly a day can pass without a citizen of the United States coming in contact with some form of computer application. It may be with the automatic teller machine at their bank or possibly their telephone. Many people are completely unaware when they do come in contact with computer technology.

The past trends of computerization will likely continue in the future. Expansion and application in areas where computers were not
used previously will likely occur. It is projected that by the 1990s, computer technology will expand to areas such as home health care systems and "smart highways" for semi-automatic driving (Long, 1982). These are only two of the many future applications of the computer we can expect.

A key element to the success of any new technology is the application in an effective manner. The researcher was most concerned with the effective application of computers in education. Just as computers are not new to business or industry, computers are not new to education. Almost as soon as computers were developed, attempts were made to apply the technology to education. The early success of computers in education was primarily in administrative procedures. This included student record keeping, bookkeeping, et cetera, essentially the same applications which had been successful in business and industry. Most of the applications of the computer in instruction were not very effective. This early development in computer-assisted instruction (CAI) amounted to nothing more than page turning. Page turning in this context is the use of a computer screen or line printer similar to a page in a book, displaying information such as text, graphics, and tables (Clegg, 1976). This application proved to be no better and in some instances worse than present instructional methods. Some studies do show evidence of superiority but are questionable in their research methods.

Research has continued in CAI and as a result much has been learned about how to use this tool. This continued research has resulted in the realization that the computer is not a substitute for a book page.
Instead, it is a valuable tool to assist students in concept formation on an individual basis.

Problem of the Study
The problem of the investigation was to examine the relationship between the cognitive style of field dependence and two forms of computer-assisted instruction: a drill and practice CAI strategy and a simulation CAI strategy.

Purpose of the Study
The purpose of the study was twofold:
1. To assist educators in identifying which computer-assisted instruction strategy (drill and practice or simulation) will provide the greatest assistance to students in the acquisition of specific materials.
2. To identify the effect field dependence has in relation to the computer-assisted instruction strategies of this study in the acquisition of specific materials.

Need for the Study
A wide variety of instructional strategies using the computer have evolved since the development of the computer. Some of these strategies presented by Edwards et al. (1978) are drill and practice, tutorial, and simulation. These strategies have collectively come to be called computer-assisted instruction (CAI). As Hooper (1982) points out, past research with CAI has put great effort into establishing classification
schemes and to measure achievement. Little has been done, though, to investigate the quality or depth of learning that occurs from CAI.

A large portion of the research has centered on the feasibility of CAI. These attempts have demonstrated nothing more than the possibility to learn from the computer. Attempts to show the superiority of CAI over other traditional forms of instruction frequently fall short of their goal. In most cases, the researcher demonstrates student scores using CAI were no different than the scores of students using traditional instructional methods (Boettcher et al., 1981; Green and Mink, 1973). There were some advantages cited for CAI over traditional methods, such as savings in time and a way to extend the scope of the lab work (Jones, 1972). These advantages would have to be weighed against such factors as instructor computing ability, software development and computer expense. Few studies previous to 1980 were able to demonstrate a true advantage of CAI.

These studies have failed to demonstrate an actual advantage of CAI. They have shown the computer can be used as an instructional aid but have not gone beyond this. It has been suggested by Kearsley (1977) that CAI research explore such topics as kinds of applications, student populations and subject areas where CAI can best be applied. He goes on to question: What should CAI really be trying to accomplish when used for instructional purposes? Hall (1979) feels CAI research should be conducted along the line of instructional design and evaluation of CAI strategies.

Haste must not be made in the research of instructional methods for
CAI. Hickey (1974) says that if necessary research is not done soon, control of the instructional process may well be lost by educators to either engineers, programmers or possibly even students. There already is evidence that the development of CAI is well along this path. We must work quickly and efficiently to avoid the same problems for CAI which plague other technologies we use today. The time is now to conduct research in CAI strategies which will provide the essential methodological direction.

Aptitude-treatment-interaction (ATI) is an area of research where the incorporation of the computer in instruction could possibly make an important contribution. ATI is the attempt to evaluate individual student difference and develop specific instructional methods for these differences (Becker, 1970). The computer could be very effective in this respect because the instructional methodology could be adapted to each student's learning style. This kind of methodology is virtually impossible in large groups which frequently are encountered in the traditional educational setting.

Although a large amount of ATI research has been conducted, not much has been incorporated with CAI. This is surprising, given the potential adaptability of CAI to different student learning styles.

In an ATI/CAI study conducted by Hooper (1982), instructional sequence (order of instructional activities used in teaching) and cognitive style (field dependence) were investigated. Hooper hypothesized that field independent students who received CAI previous to instruction would achieve better scores on the posttest and transfer test. Both
instructional treatments used the computer. The students who received CAI previous to teaching instruction received a pre-instructional activity (preorganizer). The students who received CAI after teaching instruction received the equivalence of a drill and practice strategy. A posttest and a transfer test served as measures of the study's dependent variable.

Results of Hooper's study failed to support her hypothesis that instructional sequence has an effect upon posttest scores or transfer scores. The study also failed to show an interaction of field dependence and CAI strategy upon posttest scores. She did show a significant interaction between field dependence and CAI strategy on transfer test scores. Indicated was field independent students of the less-structured CAI treatment performed better on the transfer test than the field independent students of the more structured treatment. The field dependent students of more structured strategy performed better on the transfer test than the field dependent students on the unstructured strategy.

These results support the aspect of field dependence and the amount of structure associated with the instructional strategy.

In another ATI/CAI study conducted by Boysen (1980), the above hypothesis was not supported. Boysen hypothesized that field dependent learners would achieve better under highly structured material while field independent learners would achieve better using less structured material. The structuring of material dealt with explicit and implicit feedback styles. Both instructional treatments used the computer to provide drill and practice exercises to supplement conventional
instruction. Treatments varied only in the type of feedback provided. Posttest and transfer test scores were used as the dependent variables for the study.

The results of this study were exactly opposite those predicted. The field dependent students performed better on the less structured CAI and those students who performed better on the structured CAI were identified as field independent. Boysen attempts to explain these results through the use of the CAI in the drill and practice mode. She says since all students were first exposed to similar lectures, field independent students may have preferred the structured program because they had already attained the appropriate problem-solving strategies from the lecture.

The results of these two studies leads one to ask the question: What effect does structure have upon learning outcomes of field dependent independent students?

Hypotheses

The variables of the study were:

\[ Y = \text{posttest score} \]
\[ X_1 = \text{pretest score} \]
\[ X_2 = \text{CAI strategy, 0 or 1; 0 = computer controlled CAI, 1 = learner controlled CAI} \]
\[ X_3 = \text{degree of field dependence} \]
\[ X_4 = \text{sex, 0 or 1; 0 = female, 1 = male} \]
\[ X_5 = \text{past exposure to course, 0 or 1; 0 = no past exposure, 1 = has had exposure} \]
\( X_6 = \text{class rank} \)

The hypothesized model of behavior for the study is:

\[
\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_2 X_3 + \beta_8 X_2 X_4 + \beta_9 X_2 X_3 X_4
\]

The statistical hypothesis to be examined in this study was:

\[
H_{0j} : \beta_j = 0 \text{ for } j = 2, 4, 7, 8, 9 \quad H_{Aj} : \beta_j \neq 0 \text{ for } j = 2, 4, 7, 8, 9
\]

Assumptions for the Study

The overall assumptions made by this study are:

(1) The two computer-assisted instructional strategies developed for this study represented a drill and practice CAI strategy and a simulation CAI strategy.

(2) Students who enrolled in freshman Engineering 166X, during the Spring semester, 1984, at Iowa State University were representative of all freshman engineering students.

(3) Field dependence is an important cognitive style which has an effect upon the way individuals learn new material.

(4) Students completed only the computer-assisted instruction treatment which was assigned to them.

Limitations of the Study

The limitations of this study are:

(1) The subjects which were used for this study were engineering students at Iowa State University enrolled in freshman Engineering 166X during the Spring semester 1984.
(2) The concept of cognitive style used for this study was the construct of field dependence.

(3) The problem-solving skills investigated were those related specifically to orthographic projections.

(4) The treatments of the study were designed to be completed on an individual basis. The possibility for lack of independence of error does exist, but this degree of error was considered negligible for the present study.

Definition of Terms

Cognitive Style  The characteristic ways in which individuals conceptually organize the environment. Emphasis is on how cognition is organized rather than what knowledge is available (Goldstein and Blackman, 1978).

Computer-assisted instruction (CAI)  The utilization of a computer in the educational process to assist in the acquisition of material to be learned.

Drill and practice CAI  A computer-assisted instruction strategy that consists of a series of exercises or problems which route the student in a way which optimizes performance (Kearsley, 1977).

Field dependence  Field dependent students find it difficult to restructure a situation in order to solve a problem or to impose structure on material when structure is lacking (Adams and McLeod, 1979).
<table>
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<th>Field independence</th>
<th>Field independent students are more capable of taking a critical element out of context and restructuring a problem in order to use the elements in a different way (Adams and McLeod, 1979).</th>
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<td>Group Embedded Figures Test (GEFT)</td>
<td>An instrument developed by Herman A. Witkin and Associates to measure field dependence/independence.</td>
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<tr>
<td>Simulation CAI</td>
<td>A representation of an actual process or system which allows students to direct their own inquiry by arranging the sequence of important characteristics and allows students to manipulate the major variables of the system to give them life-like problem-solving experiences (Clegg, 1976; Kearsley, 1977).</td>
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CHAPTER 2. LITERATURE REVIEW

The review of literature is organized in the following manner: first, different strategies of CAI were investigated and discussed. The second section of this review focused upon cognitive style and its relationship to field dependence independence. The final part of this section addressed the aspect of structure and its relationship to field dependence independence. In the next section, a strategy that uses computers to build intuitive structures through heuristic strategies was examined. The final section of this review investigated the use of computers in engineering drawing courses.

CAI

Computer-Assisted Instruction (CAI) is the utilization of a computer to assist in the learning process. Attempts to utilize the computer in this manner are not new. Many forms or strategies of CAI have evolved during the past twenty years. Although many strategies of CAI have been developed, there are still many discrepancies concerning its effectiveness. This has led to skepticism in many people, hindering development and adaptation of CAI.

Even though a wide acceptance of CAI has not occurred at this time, efforts have not ceased. CAI has been developed for a wide variety of subject areas and grade levels. These content areas include college math (Orr, 1982), police training (Brightman, 1971), physics (Bork, 1981a), foreign language (Olsen, 1980), and chemistry (Johnson, 1981), to name only a few.
In a study conducted by Boettcher et al. (1981), two lessons in psychopharmacological nursing were developed. This study addressed learning objectives in the cognitive categories of knowledge and application as described by Bloom (1956). A comparison was made between CAI and printed programmed instructions (PI). The subjects were 83 baccalaureate nursing students who were randomly assigned to either the CAI or PI treatments. The CAI group received instruction on PLATO, programmed logic for automatic teaching operators, a CAI system developed at the University of Illinois. The results of this study indicated no difference between the treatment groups on the cognitive domain measures.

Lawler (1972) conducted a study comparing CAI and traditional classroom instruction (CI). He used 167 undergraduate students in a health education course at Florida State University. The students were divided into four groups, one CI group which was the control and three CAI groups. The CAI group received 14 modules throughout the course. The results of this study demonstrated a general superiority of the CAI groups over the CI groups on the final examination performance.

A comparison between CAI and traditional instruction was investigated by Green and Mink (1973). Simulations of experiments in eyelid conditioning were conducted as part of an introductory psychology course. A total of 120 students participated in 11 groups. The groups were composed on measures of factual content, skills of experimental design and analysis, attitudes toward science and computers and evaluation of learning experience. The results of this study indicated no significant difference among groups on mastery of factual content. Students did
indicate a more favorable attitude toward the CAI than the instructor-led seminars.

Brightman (1971) conducted a study where CAI and traditional classroom instruction were compared. The purpose of this study was two-fold: first, to develop a CAI system for training in the area of search and seizure and rules of evidence; second, to evaluate the effectiveness of CAI with conventional classroom instruction. The results of this study indicated a significant difference between the two methods of instruction, favorable in the direction of the CAI for all parts of the study.

The results of the studies presented here are typical of most findings of CAI studies. The reasons for this lack of clarity for CAI's superiority has led to much of the confusion surrounding it. The most likely solution to this problem probably revolves around learning styles rather than the computer itself. As Auner et al. (1980) point out:

Studies which contrast computer based instruction (CBI) with classroom instruction are seldom of value in justifying the use of CBI even when superior learning is found for the CBI conditions. The superiority ascribed to the use of instructional approaches, such as self-pacing, which could be provided just as well by media other than CBI. The potential for true superiority of CBI can only be demonstrated when an instructional approach unique to (or most economically provided by) CBI is shown to produce better learning than instructional approaches supported by alternative media (p. 115).

Although no single theory of learning has general acceptance, most theorists suggest that it is better for students to have an active rather than passive role in the learning process (Bork, 1982a). This may be why many of the CAI strategies have been ineffective; the learner
remains passive. The developers for much of CAI courseware use the computer for page turning. According to Dyer (1976), the automated textbook aspect of CAI illustrates what needs to be further explored. The systematic, innovative features of CAI must be related to the larger field of instruction.

Stephan T. Barry (1982) and others expressed two obstacles to CAI which are entrenched in the computer culture. The first is the historical tendency to force computer users to conform to the machine logic (Dean, 1982). The second is the pervading inability of those who understand computers to clearly and effectively transmit that understanding to others. These obstacles are now slowly giving way to a new emphasis on ease of learning. Another obstacle expressed by Barry (1982) to the development of CAI materials requires two sets of skills which are seldom found within the same individual. These skills are the technical expertise of computer programming and skill and the art of explaining and teaching.

Given these obstacles to the successful implementation of CAI, research and development continue largely because of several advantages. These are the computer's ability for interaction and the possibility of giving the student individual attention (Bork, 1981a). A third attribute of the computer expressed by Bork (1982a) is that it can be highly modular in form. In other words, students need only study or complete modules where they need additional practice or study. Yet another advantage is the recent development of microcomputers and their lower cost. Evans (1982) says once their development receives a commercial
impetus, the production line will roll them off by the millions. He goes on to say each unit will be as cheap as the calculators of today.

The element of one-to-one interaction, the so-called socratic dialogue, has long been recognized as a superior method of instruction. Unfortunately, this kind of interaction is not practicaly in today's schools. Large class sizes and a wide variety of materials to cover all contribute to this problem. Bork (1981a) points out that the computer programmed with good interactive lessons allows every student an opportunity to play an active role in the learning process. This is in contrast to the passive role that is characteristic for most students when material is presented in lecture and textbook formats. The computer is constantly asking the student to do something and is much closer to what goes on in a student-tutor interaction than what goes on in the lecture environment (Bork, 1982a).

Individualized instruction also shows much promise for CAI. The computer has the ability to respond immediately to input made by the student. The computer response is based upon an analysis of the student input. This can be simple such as right or wrong, or the computer can branch to remedial exercises if needed. This has the advantage of providing instruction necessary to achieve the desired level for each student. Alfred Bork says (1981a):

It is common knowledge among educators that students are different; not all students have the same background and not all students learn in the same way. But many of our conventional approaches to education use a lock-step procedure for all students and do not allow us to take these differences into account. The computer can give us some of the advantages of individualized instruction in an affordable manner.
Along the line of individual instruction is the design of the instructional programs into modules. Each module contains a topic related to the subject. This is similar to chapters in a book. These designs can be machine controlled based upon some pre-diagnostic test or they can be completely operator controlled. Judd et al. (1970) suggest that while selection of topics may be effective for areas of study in which the student has demonstrated some competence, a degree of program control that leads the student to the topic may be preferable in situations where the student has shown to have little competence. If material is organized in many short modules, then students can follow different paths through these modules, depending upon individual needs (Bork, 1982a).

Initially CAI was developed with emphasis on computer capabilities rather than on instruction (Schwartz and Hanson, 1982). This contributed to many of the difficulties currently experienced by CAI. Schwartz and Hanson (1982) indicate designers of computer systems have changed their emphasis from demonstrating computer technology to focusing on the ability of the computer to help instruct the students. This is demonstrated by the development as such languages of PASCAL, PILOT and DAL, all of which were designed for greater computing power and efficiency.

The task of solving the problems confronting us with CAI is not small. Dwyer (1974) says the source of these difficulties with CAI is pinpointed in the words of Piaget (1970): "The heart-breaking difficulty in pedagogy, as indeed in medicine and in many other branches of knowledge that partake at the same time of art and science, is in fact,
that the best methods are also the most difficult ones." Dwyer (1974) goes on to say that this is precisely the challenge which those who engaged in the development of technological innovation for education ought to embrace as their own. We must examine not only the technology of CAI but also the learning theories.

Cognitive Style

Research concerned with adapting instructional treatments to individual differences among student aptitudes had been termed aptitude treatment interaction (ATI) (Tobias, 1976). ATI studies have examined numerous aptitudes, attributes and personality traits and their effect upon the educational processes but only recently have begun examining cognitive style aptitudes (Hooper, 1982).

In reviewing the literature, this researcher found several definitions and explanations of cognitive style. According to Messick (1970), cognitive styles are defined as information processing habits which represent the learners' typical modes of perceiving, thinking, remembering and problem solving. Messick states that they are stable in the manner or form of cognition. Ausubel (1968) believes cognitive style refers to both individual differences in cognitive organizational and various self-consistent personal tendencies that are not reflective of human cognitive functioning in general. He also views style as enduring individual differences.

Hill's definition of cognitive style represents the manner in which an individual seeks meaning from his environment (DeLoach et al., 1971).
It is defined as the cartesian product of four sets: (1) symbols and their meaning, (2) cultural determinants, (3) modalities of inference, and (4) memory-concern. Hill (1970) believes that the cognitive style of an individual can be changed by the process of training and education.

Cognitive style, according to Kogan (1972), is "individual variations in modes of perceiving, remembering, and thinking, or as distinctive ways of apprehending, storing, transforming and utilizing information" (p. 244). Cognitive styles are contrasts of one kind of performance versus another which is different but not necessarily opposite; there is not a value differential. Cognitive styles thus appear to have some of the same properties as abilities, but cognitive styles give greater weight to the manner and form of cognition; abilities concern level of skill (Martens, 1975).

Witkin et al. (1977) assess cognitive style in four parts. First, they are concerned with form rather than content of cognitive activity. Cognitive style is cast into process terms in this respect because it concerns itself with how we perceive, think, solve problems, learn, relate to others, et cetera. Second, they cut across the boundaries traditionally used to compartmentalize the human psyche. As a result, this helps restore the psyche to its proper status as a holistic entity. Considering the pervasiveness of cognitive style, they can be assessed by perceptual methods which can then be used to identify an individual's cognitive style. The third characteristic is that cognitive styles are stable over time. This does not imply they do not change, but they
should remain stable from day to day, month to month. Finally, cognitive styles are bi-polar. Each pole has adaptive value under specified circumstances and may be judged positive in relation to those circumstances.

Field Dependence Independence

A cognitive style which has received a great deal of attention in ATI research is field dependence (field dependence independence). This characteristic was first investigated by Witkins and his colleagues. The early research of this cognitive style dealt with how people locate the upright in space. Presently, even though this concept is thought to be part of the perceptual dimension of the analytic/global construct, the term field dependence persists (Hooper, 1982).

In Witkins' earliest work to explain the nature of field dependence independence, he was concerned with how people located the upright in space. The complex visual world we live in was eliminated and the visual and bodily standards were separated. The substitute visual framework was a luminous square frame presented in front of the subject in a completely darkened room. The frame could be rotated about its center clockwise or counterclockwise. Pivoted at the same center was a luminous rod which could also be tilted clockwise or counterclockwise independently of the frame. The subject's task was to position the rod upright independent of the frame which remained stationary. Individuals who place the rod upright regardless of the frame were said to be field independent. Those who positioned the rod upright in relation to the frame were labeled field dependent.
Witkins' next investigations revolved around the issue of the position of the body itself in space. The subject was seated in a chair which could be tilted. This chair was then projected into a small room which could also be tilted. The subject was to adjust the chair to a position where it was upright. The individual differences from the body-adjustment situation were very similar to those findings of the rod and frame situation.

In the third situation, investigated subjects were shown a simple geometric figure and asked to find it in a more complex figure. This test is known as the Embedded Figure Test (EFT). A modified form of this test is used by most researchers today when investigating the cognitive style of field dependence independence.

In identifying field independent persons, Witkin and Moore (1974) describe these individuals as able to "experience parts of the field as discrete from the surrounding field, even when the field is so organized to strongly embed the part" (p. 2). Witkin and Moore (1974) describe field dependent persons as "guided by the organization of the field as a whole, so that any part of the field is experienced as continuous with its surround."

In the research, several characteristics have been observed by individuals who are characterized as either field dependent or independent. Below is a summary of these characteristics which have been reviewed by the researcher.

(1) A relatively field independent person is likely to overcome the organization of the field when presented with a field
having a dominant organization (Witkin et al., 1977; Adams and McLeod, 1979).

(2) A relatively field dependent person in defining his/her own attitude, attributes and sentiments, is likely to take into account the points of view of others (Witkin and Moore, 1974).

(3) Field dependent people are likely to use global defenses such as repression and denial while field independent individuals will rely on such things as intellectualization and isolation (Witkin and Moore, 1974).

(4) Numerous studies have shown that there are positive relationships between field independence and verbal, mathematical and special abilities (Martens, 1975).

(5) Field dependent persons are more passive and less analytic in their processing of a stimulus and tend to preserve holistic nature of an encountered field (Threadgill, 1979).

(6) A number of studies have shown a positive relationship between field independence and intelligence (Goldstein and Blackman, 1978).

Additional information on the cognitive style of field dependence independence can be obtained by reviewing these additional sources written by Witkin et al. (1967, 1971, 1974, 1977), Bieri et al. (1958), Nebelkopf and Dreyer (1970), and McLeod et al. (1978).

A very important aspect of the field dependence independence cognitive style focuses on how individuals process information. This is particularly important with respect to education. By identifying how
individuals structure their information processing, we can then provide these individuals an optimum degree of structure.

Witkins' rod and frame test (R&F), body-adjustment test (BAT) and Embedded Figure Test (EMT) were all originally designed to identify individual differences in perception. Those individuals who were successful in these tests were labeled field independent. These individuals had the ability to impose structure upon the unstructured material. Individuals who were unable to identify the upright or embedded figure were labeled field dependent. These persons were unable to impose structure to the field. It became clear as research continued that this ability dealt with a broad dimension of individual differences which extended across both perceptual and intellectual activities.

Because field dependence cuts across intellectual as well as perceptual activities, it has many implications for education. The most important is the way field dependent individuals use external referents. Frequently in education, the material to be learned lacks clear directions (structure). This means the students must impose this structure themselves. Field dependent students will likely have greater difficulty doing this than field independent students. This, of course, leaves the field dependent student at a great disadvantage. When the material to be learned is presented in an already organized form so that structuring is not necessary, field dependent and field independent students perform equally (Witkin et al., 1977). Several studies may be cited to illustrate this.

In a study conducted by Fleming et al. (1968), lists of words were
shown to field dependent and field independent subjects. The subjects were then asked to recall the words on the list. Two lists were used, one which had a superordinate to subordinate sequence (e.g., animal, vertebrate, man) or vice versa. When the superordinate items came first, the words were given inherent organization from the beginning. This organization was not present when the subordinate list was presented. As would be expected, the field dependent subjects had great difficulty with the latter list, being able to recognize less words than the field independent subjects. When the superordinate list was used, there was no difference between the individuals' ability to recall words.

In another study, Koran et al. (1971) investigated individual differences in the acquisition of a teaching skill form written and video-modeling procedures. These treatments were found to be differentially effective for field dependent and field independent intern teachers. Field dependent interns were found to benefit more from the video-modeling and the field independent interns benefited equally or more from written modeling. The authors suggest that the more field dependent interns were unable to generate a behavioral representation which was provided in the video-modeling treatment. This is why the video-modeling treatment was superior for the field dependent interns over the written modeling.

Studies such as these by Fleming (1968) and Koran et al. (1971) suggest that to facilitate acquisition of material by both field dependent and field independent persons, the structure should be clear. Witkin and Moore (1974) suggest that:
There are probably many learning situations where, because the material to be learned is not clearly organized, the field dependent student may be at a disadvantage. Field dependent students may need more explicit instruction in problem-solving strategies or more exact definition of outcome performance than field independent students, who may even perform better when allowed to develop their own problem-solving strategies. Careful attention to cognitive-style differences in learning under more structured or less structured conditions, and detailed analysis of the problem-solving skills and strategies assumed for different learning tasks, are necessary to better define instructional procedures facilitating learning for each kind of student (p. 12).

Seymour Papert and CAI Strategy

The contributions the computer can make to education have only just begun to be investigated. Yet, as Dwyer (1974) points out, many educational programs involved with computer technology prefer to accept the safe but shallow waters of drill and practice, frame-oriented tutoring, computer-aided testing, and other traditional management-of-student applications. The computer's versatility enables it to perform other instructional tasks which may be more valuable than these "shallow" approaches to CAI. Seymour Papert (1980a) is one person who believes computers can be the vehicle for new ways of learning. Papert's (1980b) dream is of using this powerful new technology not to improve the schools we have always known, but to replace them with something better.

The fundamental problem Papert (1980b) sees is not how to improve schools, but to discover why schools are necessary. He asks the question, why is some knowledge picked up so easily from culture while other knowledge seems to require deliberate organized instruction? The LOGO group of Massachusetts Institute of Technology (MIT) Artificial
Intelligence Laboratory has been guided by the idea of creating computer-based environments in which areas of formal learning can be learned in a natural fashion much as a child learns to speak. By striving to make the computer's processes as transparent as possible and creating activities in which children program computers in a well-structured, procedural language like LOGO, they have attempted to put children in control of their own learning.

In his work at MIT, Papert was involved with the design and development of the computer language LOGO. This language has been used with an electronic turtle to assist elementary students gain mathematical concepts. The goal of these students was to make the turtle draw by programming its motion. The turtle had only the properties of position and heading. To draw pictures, the student had to break each picture into its elementary geometric shapes. The student thus entered the world of math through the computer in their attempts to draw figures.

Papert claimed that turtle geometry exposed children at an early age "to the idea of using heuristic knowledge." The student was learning to think of formal mathematics as rooted in intuitive body-mathematics. They learn to use mathematics not as a ritual to be learned by rote, but as an instrument to be used for personal ends (Papert, 1980b). Papert predicted that these formulated structures would assist the student much later in life as new mathematical concepts were formally introduced.

A key concept of Papert (1980a) involves the concept common to computerists' term of bugs or debugging. In a computing concept,
debugging refers to the identification or isolation of a part or parts of a program which keeps it from working. Papert (1980a) makes the statement:

Surely "debugging" strategies were developed by successful learners long before computers existed. But thinking about learning by analogy with developing a program is a powerful and accessible way to get started on becoming more articulate about one's debugging strategies and more deliberate about improving them (p. 23).

The instructor in the LOGO environment does not provide answers to questions but instead introduces the child to methods for solving problems of a larger class. This method is summed up in the phrase "play turtle". For example, if a student desired to form a circle, the student would be instructed to act out how the turtle could form a circle. The aim is to subdivide the problem into natural parts so that problems for each separate part can be debugged. By working with small parts, the bugs can be identified more easily and solved. This is referred to as structured programming. The method tries to establish a firm connection between personal activity and the creation of formal knowledge.

The approach suggested by Papert seems to have implications for field dependent individuals. It has been noted that cognitive style appears to be stable over time. However, many behaviors that emanate from cognitive style are far more malleable (Witkin et al., 1977). By encouraging or cueing field dependent students to use a structured programming approach to problem solving when appropriate, their concept formation may be more closely aligned with field independent individuals. Thus, even though field dependent persons tend to favor a spectator
approach to concept attainment, the process of "play turtle" would require the student to adopt more of a hypothesis testing style of concept formation. It, therefore, seems plausible to induce field dependent persons to use a hypothesis testing approach by engaging them in the activity. Although some suggestions exist in the experimental literature to the usability of cues to assist in concept attainment, much research is left to be done before specific conclusions can be made.

Studies which are examining the effects of turtle geometry also are continuing. The initial data of these studies seem to suggest and support Papert's claim that the computer provides a unique learning environment which not only strengthens intuitive mathematical structures, but facilitates higher levels of cognitive thinking as well.

CAI in Engineering Drawing

The development of the computer was followed quickly by its introduction into industry and manufacturing. This application has been widely varied and in most cases very effective. The advent of the computer on the industrial scene has accelerated the pace of industrial operations greatly, but has also brought deep implications for the utilization of human resources (Quy and Covington, 1982). While the machine efficiency has been greatly improved, the technical skills of workers have been threatened with obsolescence.

This characteristic is being observed not only by individuals who are in the job market, but by many who are just entering. There are
many reasons for this lag of training, but a major one is that industry is creating a need for technically trained personnel with skill sets not envisioned ten years ago (Palko and Hata, 1982). Because financial assistance to educational institutions is greatly limited, the direction in curriculum must be studied carefully to assure the greatest benefit from available funds. This has greatly added to the lag which exists in many of the high technology areas.

An area of computer development which has recently received a great deal of attention is computer-aided design (CAD) and computer-aided manufacturing (CAM). The reason for this attention is summed up by Tchogovadze (1982):

> It is not an exaggeration to say that the sophistication of most industrial capacities and/or equipment has far surpassed the level at which it is still possible to employ traditional "manual" methods of design.

Because industry has reached this level of sophistication, it is necessary for technical education to provide comparable exposure.

Although exposure to computers has long been part of the technical curriculum at most post secondary and many secondary schools, the introduction of CAD has been very limited. The research concerning the effectiveness of CAD as an appropriate CAI methodology is even more limited. Essentially, the literature at this time involves the description of the curriculum or courses and some very limited attitude surveys.

Two articles which address the use of computers in architectural instruction were reviewed (Dvorak, 1974; Forwood, 1979). These articles do not address the effectiveness of computers to teach concepts in
the area of architecture. They are more concerned with the introduction of the computer into the curriculum because industry has done this. Dvorak (1974) does comment upon the fact that those students who had exposure to the PLATO system did receive a slightly higher average than non-PLATO users, although non-PLATO users had more As.

In other articles by Cooley (1979) and Mosillo (1977), attempts have been made to develop CAD systems which are intended to be forms of CAI. Here the attempt was not made to demonstrate the power of the computer in a CAD application so much as to teach engineering drawing concepts. Unfortunately, both of these systems fall short of good CAI because they lack true interaction with the student and generally amount to sophisticated forms of page turning.

The researcher observed a real danger in the development of CAI for the area of engineering drawing. Because the area is closely allied with CAD, the developers of CAI for this area must keep their basic objective clear. This should be to develop good interactive programs which allow the learner to control the learning. Because of the high degree of sophistication associated with most CAD systems, this objective could be easily lost. A great deal of research needs yet to be done in the area of CAD and how effective it is as a form of CAI.
CHAPTER 3. METHODOLOGY

Subjects

The subjects for this study consisted of all students enrolled in freshman Engineering 166X during the Spring semester, nineteen eighty-four at Iowa State University, Ames, Iowa. Iowa State University is a land grant college with the majority of its students coming from Iowa, but having representation from every state and more than one hundred foreign countries. The academic program has an orientation around science and technology with a strong emphasis on the humanities and the arts.

The initial sample size was ninety-four students but was reduced to eighty-four students as a result of students withdrawing from the course. Sixteen of the final students were female, sixty-eight of the students were male. Students enrolled in this course were selected on a random basis from a pool of two hundred and fifty-six students who had pre-registered for the course. Seventy-four of the students were freshmen, seven sophomores, and three were juniors.

During the Spring semester, nineteen eighty-four, there were four instructors and four sections of freshman Engineering 166X. Two sections met from 8:00 a.m. until 11:00 a.m. and two sections met from 2:10 p.m. until 5:00 p.m. on Tuesday and Thursday. The sections scheduled at the same time met in the same room with a common lecturer. Students were segregated by class section; one section sat on one side of the class and the other section on the opposite side. While students worked on in-class assignments, the instructor for the specific section was available
for assistance. Assignments were completed both during class time and outside class time.

The classroom for freshman Engineering 166X had twenty-four student workstations. Each workstation consisted of two drawing tables with a drafting machine. Between each drawing table was a GIGI micro-computer and a high resolution color monitor. This was used for class demonstrations during lecture and for student assignments throughout the semester. The main lecture podium also had a GIGI micro-computer which was connected to three video monitors in front of the classroom. This was used for demonstrations during lecture.

Freshman Engineering 166X, "Engineering Graphics with Computer Application," is an engineering graphics course with applications of computer graphics to the analysis and solution of problems. Graphics coverage included orthographic projections, pictorials, and three-dimensional geometry with applications to engineering drawings. Free-hand, instrument, and computer graphics drawing programs were used for problem solving. Computer graphics hardware and software were introduced to students and used interactively by students for this course.

Instructors for all four sections of freshman Engineering 166X volunteered to participate in this study, making it part of the regular course requirements. A description was read by the primary investigator to each section on the first day of class pertaining to the purpose of the present study. A copy of the description can be seen in Appendix A. Approval to conduct the study was also received from the Iowa State University Human Subjects Committee. A copy of this approval form
signed by the committee can be found in Appendix B.

Measuring Instruments

Four instruments were used to collect data and measure dependent and independent variables. The Group Embedded Figures Test (GEFT) was commercially available and purchased by the researcher. Tests eight and nine of the Multiple Aptitude Test (MAT) were out of print. Permission to reproduce these tests for this study was granted by the publisher. The letter of permission can be seen in Appendix C. The final instrument was developed by the researcher to collect biographical information about each student who participated in the study. These instruments are described below.

The cognitive style of field dependence independence was measured by the Group Embedded Figures Test (GEFT). The GEFT is an adaptation of the original Embedded Figures Test (EFT) which makes group administration possible. With the GEFT, scores for many individuals may be obtained in a single twenty minute administration. The GEFT contains eighteen complex figures, seventeen of which were taken from the EFT.

The GEFT is a perceptual test where, in the strictest interpretation, scores reflect the extent of competence at perceptual disembedding. Simple form embedding on the GEFT is accomplished by light shading of similar sections. The student is prevented from seeing simultaneously the simple form and complex form by printing the simple form on the back cover of the test booklet. During administration of the test, students are allowed to look back at the simple form as frequently as desired.
The GEFT contains three sections: the first section is for practice. The second and third sections consist of two equivalent forms with nine items each. The score is the total number of simple forms correctly traced in the second and third sections. Students were allowed five minutes to complete each of these sections. The possible scores range from 0 to 18. Students with high scores on the GEFT are considered field independent, while those with low scores are considered field dependent.

The preliminary norms available for the GEFT to date are based upon men and women college students from an Eastern liberal arts college. The method for estimating reliability was the correlation between the nine item second section scores and the nine item third section scores. Correction by the Spearman-Brown Prophecy formula produced a reliability estimate of .82 for both males and females.

Validity of the GEFT was assessed by comparing it to other measures of field independence. These other measures included the parent form of the test, the EFT, the Portable Rod and Frame Test (PRFT), and the Articulation of Body Concept Test (ABC). The correlation coefficients range from -.82 for males on the EFT to -.34 for females on the PRFT. The correlation coefficients on the EFT and PRFT are negative because they are scored in reverse fashion from the GEFT. According to the GEFT manual (Witkins et al., 1971, p. 29):

The combined evidence suggests that the GEFT may prove to be a useful substitute for the EFT when individual testing is impractical. It must be considered a research instrument, however, until more extensive direct
and construct data are collected from a wider variety of groups.

The score from test eight of the Multiple Aptitude Test (MAT) was used to measure the independent variable of spatial visualization abilities. Each of the twenty-five items of this test consists of a row of figures with a completed figure on the left and four groups of pieces to the right. One of these figures can be fitted together exactly to form the figure shown on the left. The student is asked to indicate which group of pieces could be fitted together to form the figure. According to Segel and Raskin, "This is one of the best types of tests to measure the spatial visualization factor" (1959a). All of the items for this test are two dimensional. The Kuder-Richardson (K-R) Formula 21, reliability coefficient of .87 is very acceptable (Segel and Raskin, 1959b). Comprehensive normative data for grades seven through thirteen by sex are available. A copy of test eight can be found in Appendix D.

Test nine of the MAT was used as the dependent measure of spatial relations. All twenty-five items of this test involve visualization in three dimensions. Each item consisted of a row of figures, with the object on the left being drawn in perspective as a three dimensional object. The four patterns on the right are in two dimensions, one which could form the object on the left. The student was asked to visualize the objects and indicate the object which would form exactly the object on the left. Test nine of the MAT was administered one week after the due date of the computer-aided instruction assignments. The K-R Formula 21 reliability coefficient for test nine of the MAT was
an acceptable .78 (Segel and Raskin, 1959b). Comprehensive normative data were also available for test nine. A copy of test nine can be found in Appendix E.

The correlation coefficient between test eight and nine of the MAT was reported as .44 for males and .41 for females for combined scores of grades seven through thirteen (Segel and Raskin, 1959b). According to Buros (1965), the tests of the MAT battery are undoubtedly as good as most of their kind; the correlational data are exceeded by those of few tests. The psychometrics are impressive and in terms of content, analyses and supplementary materials, this battery is excellent.

Scoring of tests eight and nine of the MAT was accomplished in the same manner. A correction-for-guessing formula was used to increase the size of the standard deviations. This yields more effective discrimination between individuals, higher reliability and more predictive power in general. To score these tests, the number of right answers minus one-third of the wrongs was used. Items which were left blank were not scored as right or wrong. The maximum possible score was twenty-five and the minimum score possible was minus eight.

The final data collection instrument used for this study was a biographical information form. This instrument was designed to measure three independent variables of primary interest to the researcher. Questions one, two and three were designed to determine the amount of past experience each student had relative to the topic which this study was concerned. Questions five and six were asked to determine the class standing of each student when they graduated from high school.
Question seven was used to identify the independent variable of the student's sex. The other questions on this instrument were used for population description data or post hoc statistical analyses. A copy of the biographical information form can be seen in Appendix F. Each student completed this form on the first day of class.

Research Design

The experimental design for this study was a two-group pretest-posttest design. The content of the treatments was to solve orthographic projection problems. One treatment was designed as a drill and practice lesson, while the other was a simulation lesson. The pretest was administered on the first day of class. The purpose of this test was to measure the students' spatial visualization at the beginning of the course. Test eight of the MAT served as the pretest. Test nine of the MAT was administered one week after the CAI treatment due date. This served as the posttest for the study.

Students from the four sections of freshman Engineering 166X were pooled together and randomly assigned to either the drill and practice or simulation lesson. Both lessons were presented through the Iowa State University (ISU) computation system using the Virtual Address Extension (VAX) computer. VAX is a Digital Equipment Corporation (DEC) super minicomputer capable of dealing with a multitude of user environments.

Students completed their lessons using a GIGI microcomputer which was attached to VAX via the COMmunications SWITCH processor (ComSwitch) (Hutchison and Struss, 1983). The GIGI is a graphics terminal which
has a high resolution color monitor and a typewriter keyboard. The source programs for the two lessons were written in the Digital Authoring Language (DAL).

The two treatments presented on VAX differed in the required response of the student. For the drill and practice lesson, the student was presented the top and front views of an orthographic projection. Four alternative right side views identified by either A, B, C, or D were also presented. The student was asked to indicate which of the four alternative right side views went with the top and front views. Those students completing the simulation lesson were required to actually generate the missing view. The top and right side views of an orthographic projection were presented. The student was then required to generate the missing view using the GIGI microcomputer. Both lessons were designed to require about forty-five minutes to complete.

Drill and Practice Lesson

This lesson required the student to identify the correct right side view from four alternative right side views for the given top and front views of an orthographic projection. This treatment was referred to as "drill and practice" because one problem after another in random order was presented to the student. When we speak of drill and practice, we mean more than the opportunity to work examples. Implicit in the term is that the student receive feedback which indicates when a problem has been correctly solved (Bork, 1981b).

When the students logged-on to execute this lesson, they first were
presented with the instructions to complete the lesson. The instructions can be seen in Figure 1. After reading the instructions, the student was then presented with one of the twenty problems in this lesson. The order the problems were presented to each student was random. This prevented students from sharing the correct responses. An example problem is shown in Figure 2. The students then responded to the query and their response was evaluated. If their response was incorrect, this was indicated. They were required to respond until the correct view was indicated. When the correct view was indicated, the next problem was presented. An example of an incorrect response can be seen in Figure 3 and a correct response in Figure 4. Upon completion of all twenty problems, the student's score was indicated with a message indicating if additional practice was needed. The percent score and number of correct responses on the first attempt was recorded by the computer for each student.

Simulation Lesson

This lesson simulates the process a student would go through while drawing the missing view of an orthographic projection on paper. The lesson then gave immediate feedback in regard to the correctness of the solution and provided assistance to arriving at the desired solution after each incorrect response.

When the students logged-on to execute the lesson, they would first see a title screen followed by the instructions to complete the lesson. After reviewing the instructions, the student was given the opportunity
For this lesson you will be presented with the top and front views of an object. Four alternative right side views will also be presented. You must select which right side view is correct for the top and front views.

To select the appropriate right side view enter either A, B, C, or D. Your response will be evaluated and you will be instructed what to do next.

This lesson requires that you complete all twenty problems before the lesson can be terminated. The time required to complete the lesson is from 30 to 45 minutes.

Figure 1. Drill and practice lesson instructions

![Diagram of top and front views with four right side views A, B, C, D]

Which right side view should be used with the given views? Enter either A, B, C, or D and press RETURN.

Figure 2. Drill and practice lesson problem
Which right side view should be used with the given views? RETURN and try again.

Figure 3. Drill and practice incorrect response

Figure 4. Drill and practice correct response
to review the instructions a second time. Once the student had reviewed
the instructions, the first of six problems was presented. A top and
right side view of an orthographic projection were presented. The
student was to generate the front view using the GIGI microcomputer.
An example of what the student would see is shown in Figure 5. A block
with a brief description of all key operations was presented on the
screen for all problems. A description of the key operators is shown
in Table 1.

To produce the missing view, the student would move the cursor to
the desired location and produce hidden or visible lines. These lines
could then be deleted if the student later desired. Circles and curved
surfaces were not included for the problems of this lesson. Once the
student had generated a solution, it was compared with the correct
solution. The student accomplished this by pressing the "C" key on the
GIGI terminal. The program would then check the solution and indicate
the correctness of the solution.

If the solution was correct, the next problem was presented to the
student. If the solution was incorrect, the same problem was presented
again, this time with a prompt or hint to assist the student in arriving
at the desired solution. The first time an incorrect solution was ar-
rived at, a screen similar to the one shown in Figure 6 would be pre-
sented. Essentially the same screen for the first attempt is presented
except dots appear only where there are intersecting lines on the cor-
rect solution. The purpose of this was to delimit possible solutions
for the student.
Please complete the front view of this object.

Figure 5. Simulation lesson screen 1

The intersection of lines will occur only at the dot locations.

Figure 6. Simulation lesson screen 2
Table 1. Key operations used for simulation lesson

<table>
<thead>
<tr>
<th>Key</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="left_arrow" alt="Left Arrow" /> <img src="up_arrow" alt="Up Arrow" /> <img src="down_arrow" alt="Down Arrow" /> <img src="right_arrow" alt="Right Arrow" /></td>
<td>The arrow keys were used to move the cursor around the monitor in 25 unit increments. The cursor moved in the direction indicated by the arrow.</td>
</tr>
<tr>
<td><img src="c" alt="C" /></td>
<td>When the students wanted their solutions checked, they would press this key.</td>
</tr>
<tr>
<td><img src="delete" alt="Delete" /></td>
<td>This key was used to remove the most recently created line from the student's solution.</td>
</tr>
<tr>
<td><img src="h" alt="H" /></td>
<td>To produce a hidden (dashed) line, this key was pressed.</td>
</tr>
<tr>
<td><img src="r" alt="R" /></td>
<td>When lines were deleted, the dots which correspond to those locations also were removed. This key allowed the student to replenish those dots.</td>
</tr>
<tr>
<td><img src="s" alt="S" /></td>
<td>To begin a line, either hidden (dashed) or visible (solid), the starting location had to be identified. The cursor was moved to the starting location, and this key was pressed. The cursor was then moved to the end point of the line, and either the or key was pressed to produce the desired line.</td>
</tr>
<tr>
<td><img src="v" alt="V" /></td>
<td>To produce a visible (solid) line, this key was pressed.</td>
</tr>
</tbody>
</table>
The student would then attempt the same problem for the second time. The procedures for producing the missing view and checking it remain the same. If the student's second attempt was incorrect, the third screen would include projection lines from the top and right side views. The purpose of this was once again to assist the student in producing the correct solution. This prompt was used to teach the technique of projecting the other views onto the missing view. An example of the third screen can be seen in Figure 7. Note that all previous prompts remain on the current screen.

In the event the student's third attempt was incorrect, the fourth screen was presented with an isometric view of the desired object. The isometric drawing was presented in the upper right hand corner of the screen. Those lines which correspond on the isometric view to those on the missing view were produced in green, while the other lines were produced in magenta. Figure 8 shows what the fourth screen would look like.

The student was given five attempts on each problem before going on to the next. The final screen actually provided the student with the correct missing view. The student was allowed to study it and then the correct solution was removed by pressing the return key. The student was then instructed to complete the view. If the final attempt was incorrect, after seeing the correct solution, additional attempts would serve no useful purpose in this researcher's opinion. A sample of the final screen can be observed in Figure 9.

Upon completion of the six problems, the students' scores were
Use the projection lines to solve this problem.

Figure 7. Simulation lesson screen 3

Study the green lines on the isometric projection.

Figure 8. Simulation lesson screen 4
This is the correct solution, study it. This is your last attempt.

Figure 9. Simulation lesson screen 5

The key you have entered is not an operation, accepted key commands are:
- "C" = To check a solution.
- "H" = To remove the previous line.
- "R" = To refresh the dots.
- "S" = To start a line.
- "V" = To draw a visible line.

Please complete the front view of this object.

Figure 10. Simulation lesson error message
presented to them. This was done in the same manner as the drill and practice lesson. The computer also recorded the percentage score and the number of correct solutions on the first attempt for each student. Although this is the same type of data which was recorded for the drill and practice lesson, there is really no meaningful way to compare these lessons based upon these scores.

During the development of this lesson, the researcher attempted to make the lesson as user friendly as possible. To accomplish this required the development of error messages which would inform the students when they had incorrectly interacted with the lesson. Figure 10 shows one possible error message. The error messages were placed in the upper right hand corner of the screen. This was the only available space on the screen. Table 2 lists possible incorrect student interactions and the resulting error message.

Research Procedure

The study was completed during a seven-week period beginning January 19, 1984. The first two sections of freshman Engineering 166X met at 8:00 a.m., and the other sections met at 2:10 p.m. First, the GEFT was administered. This was done by the researcher thirty minutes after the start of class for all sections. This was done to insure all students would be in class by this time. To insure anonymity, all names from this and all other measures were removed once all the data had been collected. After the GEFT had been administered, test eight of the MAT was completed. The biographic information was completed
Table 2. Possible incorrect student interactions with simulation lesson and resulting error message

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Error message</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the student attempted to start without first identifying the starting location of a line.</td>
<td>To begin a line, you must move the cursor to a starting location using the arrow keys and press &quot;S&quot; key. Please press return.</td>
</tr>
<tr>
<td>When the student continued to press the delete key after all lines had been removed.</td>
<td>You have deleted all of the lines which were previously drawn. To begin again, move the cursor to a starting location using the arrow keys and press the &quot;S&quot; key. Please press return.</td>
</tr>
<tr>
<td>The student attempted to draw a line outside the dot grid provided for the solution.</td>
<td>The location of the cursor is not within the limits of the solution for this problem. The cursor must be on a dot for the solution to be correct. Please press return.</td>
</tr>
<tr>
<td>When the student tries entering any key other than those specified for the lesson.</td>
<td>The key you have entered is not an operation accepted key, commands are: C = to check a solution Delete = to remove the previous line H = to draw a hidden line R = to refresh the dots S = to start a line V = to draw a visible line. Please press return.</td>
</tr>
</tbody>
</table>

after the time had expired for the completion of test eight of the MAT. This required approximately forty-five minutes for all sections. These instruments were then scored by the researcher.

Students from all four sections were now pooled together and randomly assigned to either the drill and practice lesson or the simulation lesson. The researcher then received from the ISU computational
center two sets of VAX user numbers and passwords, one set for those students assigned to the drill and practice lesson and the other for the simulation lesson group. Each student received a user number and password when the assignment was made, which directed him/her to the appropriate lesson. Directing the student was accomplished by using the courseware authoring system (CAS). CAS is a courseware management system developed by Digital Equipment Corporation. To use this system, the researcher made the specific assignment of either the drill and practice lesson or the simulation lesson to the specific group. These assigned lessons had previously been published in CAS. The lessons were restricted to students only in the specifically assigned groups. This was done to insure students completed only the lesson they had been assigned. When a student logged-on to complete their assigned lesson, they were first required to register for identification purposes. This basically consisted of their name and social security number. CAS then directed the student to the specific lesson. After completion of the lesson, CAS recorded information such as response time, raw score, etc. Additional information was also stored upon completion of the lesson.

Four class periods prior to making the orthographic projection CAI lesson, the freshman Engineering 166X instructors began lecturing on the topic of orthographic projections. This provided the student with an introduction to the concepts of orthographic projections. On the day the assignment was made, each student received an assignment guide and a VAX user number with password. The students were allowed
ten days to complete the assignment. A copy of the assignment guide can be observed in Appendix G. All students completed the assignment within the allotted time.

The assignment was completed as an out-of-class exercise. Instructors did not assist students in solving specific problems. The students were required to do this on their own. At this stage in the semester, each student was familiar with the operation of the computing system. Instructors did provide assistance to students relative to using the computing system if needed.

The posttest was administered one class period after the due date of the CAI orthographic projection lessons. This concluded the data collection phase of this study.

Treatment of Data

The data for this study came from the four instruments which were described earlier. They were the GEFT, test eight and nine of the MAT and the biographic information form. All instruments were evaluated by the researcher and coded on summary sheets. The initial sample size for this study was ninety five students. This was reduced to eighty-four students, resulting from eleven students dropping the course before the posttest administration. To insure complete data on the remaining eighty-four subjects, the researcher found it necessary to follow-up several students to clarify either incomplete or unclear data. This was accomplished over the telephone in most instances. Only those cases where complete data were available were used for the analysis.
The computer software package used to analyze the data was the statistical analysis system (SAS, 1982). Multiple regression techniques were used to analyze the data in the present study. The full regression model contained three main factors: treatment, GEFT score and sex. Two covariates were also included: past orthographic exposure and class rank. In addition, three interactions completed the full model. They were treatment by GEFT score, treatment by sex and treatment by GEFT score by sex.

Hypotheses of the Study

The hypotheses of the study were as follows:

(1) There is no significant difference of scores on the MAT test 9 between students experiencing a Computer Assisted Instructional (CAI) drill and practice orthographic projection lesson and students experiencing a CAI simulation orthographic projection lesson.

(2) There is no significant difference of scores on the achievement posttest between male and female students.

(3) There is no significant interaction between CAI strategy and degree of field dependence independence in relation to a student's score on the MAT test 9.

(4) There is no significant interaction between CAI instructional strategy and sex in relation to a student's score on the MAT test 9.

(5) There is no significant interaction between CAI strategy,
student sex, and degree of field dependence independence in relation to a student's score on the MAT test 9.
CHAPTER 4. PRESENTATION OF DATA

In this chapter, the results of the study are presented. Each of the null hypotheses listed in Chapter 3 was tested at the ninety-five percent confidence level. The chapter begins with descriptive data concerning the subjects of the study, the regression model is presented next, and the chapter concludes with testing of the hypotheses.

Descriptive Data

The average age of the subjects for the study was 18.8 years with a standard deviation of 1.6 years. Sixty-eight males and sixteen females participated in the study. Seventy-four of these students indicated their present class standing was freshman, while seven were sophomores and three were juniors. The average rank of each student when they graduated from high school was 10.4 percent, with a standard deviation of 9.7 percent. Hence, most students of this study were within the top 20 percent of their respective graduating high school class.

Twenty-three students, or 27.4 percent of those who participated in the study, indicated they owned a microcomputer. Eighty-eight percent said they had had previous course instruction concerning the use of computers. Thirty-three of the students, or 39.3 percent, had at least one semester or more of previous coursework in mechanical drawing, architectural drawing, etc.

Only nine students, or 10.7 percent of the subjects, had visual problems such as color blindness, etc. The same percentage had work experience using industrial machines or graphic communication equipment.
Those students with visual problems were not necessarily the same students with work experience.

Table 3 presents the descriptive statistics for the dependent and independent tests for the study. Included are the means and standard deviations of all tests for both treatment groups. Across each treatment group, t-test results showed no significant difference between means on any of the tests. Test 8 was used for this study as a pre-test measure or more accurately to evaluate the student's spatial relations ability at the beginning of the course. This was a two dimensional test described in Chapter 3. Test 9 was the posttest measure. This test was used as a measure of spatial relations; this time,

### Table 3. Descriptive statistics for tests of dependent and independent variables

<table>
<thead>
<tr>
<th>Test</th>
<th>Maximum score</th>
<th>Treatment groups</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>N</td>
</tr>
<tr>
<td>Independent variable test measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEFT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.0</td>
<td>15.81</td>
<td>2.77</td>
</tr>
<tr>
<td>MAT&lt;sup&gt;b&lt;/sup&gt; test 8</td>
<td>25.0</td>
<td>18.93</td>
<td>5.36</td>
</tr>
<tr>
<td>Dependent variable test measure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAT test 9</td>
<td>24.0</td>
<td>19.05</td>
<td>2.77</td>
</tr>
</tbody>
</table>

<sup>a</sup>GEFT = Group Embedded Figures Test.

<sup>b</sup>MAT = Multiple Aptitude Test.
though, it was a three dimensional test. Figure 11 is a scatterplot of test 8 against test 9. The scatterplot suggests some of the scores on MAT test 8 are random or outlier values. This suggests MAT test 8 may be appropriately excluded from the original model because of a large number of extraneous observations. Since test 8 correlated very low (.16) with the criterion, the decision was made to drop it from the analysis. Correlation coefficients between all measures, including the MAT test 8 scores, administered in the study are shown in Table 4.

Table 4. Correlation coefficients for all measurements

<table>
<thead>
<tr>
<th>Measure</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3</td>
</tr>
<tr>
<td>1. MAT test 9</td>
<td>1.00</td>
</tr>
<tr>
<td>2. MAT test 8</td>
<td>1.00 .16</td>
</tr>
<tr>
<td>3. Treatment</td>
<td>1.00 -.18</td>
</tr>
<tr>
<td>4. GEFT</td>
<td>1.00 .10</td>
</tr>
<tr>
<td>5. SEX</td>
<td>1.00 -.24*</td>
</tr>
<tr>
<td>6. Previous exposure</td>
<td>1.00 -.10</td>
</tr>
<tr>
<td>7. H.S. rank</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*P ≤ .05.

**P ≤ .01.

Testing of the Hypotheses

In the following paragraphs, results are presented as they relate to each hypothesis in the study.

Hypothesis 1: There is no significant difference of scores on the MAT test 9 between students experiencing a Computer-Assisted Instructional (CAI) drill and practice
Figure 11. Scatterplot of MAT test 8 versus MAT test 9

A = 1 observation, B = 2 observations, etc.
orthographic projection lesson and students experiencing a CAI simulation orthographic projection lesson.

In Table 5, the results of the multiple regression analysis are presented. Hypothesis 1 cannot be rejected based upon this analysis.

Table 5. Results of regression analysis and significance tests for MAT test 9

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>R² for full model</th>
<th>Independent variables</th>
<th>Sums of squaresᵃ</th>
<th>F-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT test 9</td>
<td>.39</td>
<td>Treatment</td>
<td>1.16</td>
<td>.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GEFT</td>
<td>2.39</td>
<td>.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEX</td>
<td>4.93</td>
<td>.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Past exposure</td>
<td>9.77</td>
<td>1.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H.S. rank</td>
<td>2.87</td>
<td>.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treat by GEFT</td>
<td>2.40</td>
<td>.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treat by SEX</td>
<td>29.59</td>
<td>4.45*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment by GEFT by SEX</td>
<td>30.52</td>
<td>4.59*</td>
</tr>
</tbody>
</table>

ᵃType III sums of squares.

*P < .05.

The results suggest there is no difference between the two CAI instructional strategies of this study in producing significantly different scores on MAT test 9. By examining Table 3, the means and standard deviations for the MAT test 9 scores for the two treatment groups can be observed. The mean for the simulation treatment is lower than that for the
drill and practice treatment. A t-test between these groups resulted in a $t_{84} = 1.66$, $p < .1008$.

Hypothesis 2: There is no significant difference of scores on the achievement posttest between male and female students.

The multiple regression analysis and t-test results do not allow the rejection of this hypothesis. The males and females who participated in this study did not differ significantly on the MAT test 9 scores. The mean value on the MAT test 9 for males was 18.63, while the mean score for females was 17.81. A t-test was done resulting in a $t_{84} = .7894$, $p < .44$.

Hypothesis 3: There is no significant interaction between CAI instructional strategy and degree of field dependence independence in relation to a student's score on the MAT test 9.

The multiple regression analysis does not allow the rejection of this two-way interaction hypothesis. This suggests that there is no difference between the scores achieved on the MAT test 9 for students who are field dependent independent and the CAI lesson strategy they completed. Figure 12 shows a graph of this two-way interaction. The students were grouped for this figure by a GEFT score less than or equal to 16 as field dependent and a GEFT score greater than 16 classified as field independent.

Hypothesis 4: There is no significant interaction between CAI instructional strategy and sex in relation to
Figure 12. Interaction of field dependence independence by CAI strategy on MAT test 9

x = drill and practice, o = simulation
student's score on the MAT test 9.

The regression analysis for the full model allows the rejection of this hypothesis. This suggests there is a significant difference between the scores on the MAT test 9 of males and females dependent upon the CAI instructional strategy they were assigned. Figure 13 is a graphic representation of this significant interaction. Those students who completed the drill and practice CAI strategy, of both sexes, achieved very similar scores on the achievement test. For those students assigned to the simulation CAI strategy, females scored lower than males on the MAT test 9.

Hypothesis 5: There is no significant interaction between CAI instructional strategy, student sex and degree of field dependence independence in relation to a student's score on the MAT test 9.

Based upon the regression analysis for the full model, the probability level for this interaction effect allows the rejection of the stated hypothesis. A graphic presentation of the significant three-way interaction is presented in Figure 14. For this graph, students have also been classified as field dependent and field independent. Students who scored 16 or less on the GEFT were classified as field independent. This classification was used for graphic representation only and was not used for the regression analysis.

Those students who are field independent score about the same on the MAT test 9 regardless of their sex or the CAI instructional strategy they were assigned. This is not the case for those students who were
Figure 13. Interaction of sex by CAI strategy on MAT test 9

x = drill and practice, o = simulation
Figure 14. Interaction of sex by CAI strategy by field dependence independence on MAT test 9

**x** = drill and practice, **o** = simulation

--- field dependent, ____ field independent
identified as being field dependent. The field dependent female students achieved lower MAT test 9 scores than the male field dependent students. In addition, those field dependent female students assigned to the simulation strategy had the lowest MAT test 9 scores of any group.

This suggests the students, male or female, who are field independent, achieve similar scores on the MAT test 9 regardless of CAI instructional strategy. The MAT test 9 score of those students who are field dependent, though, are influenced by their sex and the CAI instructional strategy they were assigned.

The above results should be interpreted given the fact that equal or proportional sample sizes were not present for the combination of the three main effects present in this study. As a consequence, the main effects and interactions studied are not mutually independent components of the MAT test 9 variance.
CHAPTER 5. SUMMARY, DISCUSSION AND RECOMMENDATIONS

Summary

The purpose of this study was to compare the learning outcomes of two CAI instructional strategies: drill and practice and simulation. These instructional strategies related specifically to an orthographic projection lesson. The drill and practice strategy required the student to identify the correct missing view of an object from four alternative views. The students would continue until they had identified the correct view and then proceed to the next problem until all of the problems had been completed. For the simulation strategy, the student was required to actually produce the missing view using a GIGI microcomputer terminal. The student's solution would then be evaluated for correctness. If the solution was correct, the next problem was presented. If the solution was evaluated incorrect, the same problem was presented, with hints or cues to aid in arriving at the correct solution. This continued for five attempts with the correct solution being presented on the last attempt. The student was then required to generate the correct solution on the last attempt even though he/she had been presented the correct solution.

The students enrolled in the four sections of freshman Engineering 166X during the Spring semester 1984 at Iowa State University were the subjects for the study. These students were pooled together and randomly assigned to either the drill and practice CAI strategy or the simulation CAI strategy. These lessons were completed by the students as part
of their regular course work. The lessons were completed when the topic of orthographic projections was being discussed in their classes.

On the first day of class, the researcher administered three measures which were used as part of the study. These were the MAT test 8, the GEFT and a biographic information form. During the sixth week of the semester, the CAI strategies were assigned to the students. Each student was allowed ten days to complete the CAI lesson. During the first class period of eighth week of the course, the MAT test 9 was administered as a posttest achievement measure.

The cognitive learning style of field dependence independence was also examined in this study. This cognitive style was investigated through the data obtained from the GEFT. Field dependence independence originally dealt with the process of visual perception but was later extended to include the processes of problem solving. Orthographic projections deal with problem solving related to visual perception. The GEFT, therefore, seems to be appropriate for the present study. It is theorized that individuals who are field dependent have difficulty imposing structure on an unorganized perceptual field. Therefore, by providing these students with a more structured learning environment, through the use of cues or hints, structure could be introduced to the learning situation. It is conjectured this process would eliminate any difference between field dependent and field independent individuals in their ability to solve visual perceptual problems.

Five hypotheses were developed and tested. One of the hypotheses compared the posttest achievement scores of the students in the two
Another hypothesis compared the posttest achievement scores of male and female students of the study. The final three hypotheses dealt with the interactions between CAI strategy (treatment), student's sex and cognitive style (field dependence independence).

The results were:

1. There was no significant difference on the posttest achievement scores of the MAT test 9 between students receiving the drill and practice CAI strategy and those students who received the simulation CAI strategy. One CAI strategy did not result in MAT test 9 scores being superior to scores on the other CAI strategy.

2. Posttest achievement scores did not differ significantly for males and females who participated in this study. One sex was not superior to the other with respect to their scores on the MAT test 9.

3. There was no significant interaction between CAI strategy and cognitive learning style (field dependence independence) on the MAT test 9 as determined by the multiple regression analysis.

4. There was a significant interaction between CAI strategy and sex as determined by the multiple regression analysis. The scores on the MAT test 9 for males and females who completed the drill and practice CAI strategy were very similar. For those students who completed the simulation CAI strategy, females scored lower than the males on the MAT
test 9. Although the MAT test 9 scores for those students completing the simulation strategy were lower for both males and females than those completing the other treatment, the difference between strategies alone was not significant.

(5) There was a significant three-way interaction between sex, CAI strategy and cognitive learning style (field dependence independence) on the posttest achievement measure (MAT test 9) as determined by the multiple-regression analysis. This interaction indicates that female students, who are field dependent, achieved lower scores on the MAT test 9 than their male counterparts for both CAI strategy. Students who were identified as field independent had similar scores on the MAT regardless of sex or CAI strategy.

Discussion

A great deal of research has been done based upon Witkins' cognitive learning style theory of field dependence independence. Witkins' theory and subsequent research findings suggest field dependent learners achieve best under a high-structure learning environment. Furthermore, the theory suggests field independent learners can achieve without a high-structure. It has even been suggested that field independent learners will achieve better under less structured learning situations.

In a study conducted by Boysen (1980), this theory is refuted. Boysen actually found field independent subjects achieved better under
a high-structure explicit feedback CAI strategy and field dependent subjects performed better under a low-structure implicit CAI strategy. This result was found for both adolescent and adult samples. Boysen suggests this unexpected finding may be attributed to a sequencing variable. The expected outcome may have occurred had the less-structured feedback program been used before, rather than after classroom instruction.

Hooper (1982), in another study which addressed the aspect of sequencing, found the interactions between cognitive style and environmental structure to be consistent with Boysen's original predictions. This is supported by other research on this topic too. Hooper found field dependent students performed better when provided a more structured environment and field independent students performed better under a less structured environment.

For the present study, two CAI strategies were developed. One was a drill and practice CAI lesson, while the other was a simulation CAI lesson. The drill and practice CAI strategy was designed to be a structured CAI lesson. The student solved problems presented by the computer by selecting one of four possible views. Visualization was necessary, but in a structured way, because the student had only to identify the missing view from the alternatives.

The simulation CAI strategy was substantially less structured. An attempt was made in the design of this lesson to help the field dependent learner solve problems with less structure by cueing them to the correct solution. In other words, an attempt was made to help field
dependent students structure an unstructured learning experience. The simulation CAI strategy required the student to produce this missing view of an orthographic projection. This would, therefore, be a less structured learning environment. The attempt to teach the field dependent student how to structure came when their solutions were evaluated incorrect. When this occurred, the program was designed to help the student solve the problem by cueing them how to structure the problem. This process might be viewed as teaching or assisting the field dependent students to behave as though they were field independent.

Hypothesis 3 for the study tests the interaction of cognitive style and CAI strategy. This hypothesis suggests there is not a significant interaction between CAI strategy and field dependence independence. Initially, this appears to support the researcher's original attempt to equalize field dependent independent students by cueing them how to structure the unstructured learning environment. It should be noted that if the significance level for this study had been established at the .10 level, this aptitude treatment interaction hypothesis would have been significant.

An examination of hypothesis 4 reveals a significant interaction between CAI strategy and sex. The students completing the simulation strategy, particularly the female students, had lower MAT test 9 scores. There was also a larger difference between MAT test 9 scores for females on the two CAI strategies than for the male students. This suggests the researcher may not have been as successful at cueing the field dependent female students who completed the simulation strategy as
initially thought.

Examining the final hypothesis, which was also significant, the greatest amount of information relative to the study is provided. In Figure 14, we can observe the field independent students' achievement scores on the MAT test 9, for both sexes and CAI strategy, were quite similar. This tends to support the theory that field independent students will perform better under less structure. Even though the structure of the two lessons is different, both required some structuring on the learner's part with respect to visualization. The structuring cues of the simulation exercise were most likely never utilized by the field independent students resulting in similar MAT test 9 scores for both CAI strategies.

By examining Figure 14, it can be observed that the female field dependent learners who completed the simulation lesson achieved lower scores on the MAT test 9 than the field independent female students assigned to the simulation lesson. This is contrary to the researcher's original expectations involving the development of the simulation CAI strategy. An explanation of this result relates to the development of the simulation CAI strategy. Although an attempt was made to produce a user friendly instructional program, the attempt may not have been as successful as desired for all students. This would account for the fact that the female field dependent students assigned the simulation lesson did not perform on the MAT test 9 as the field independent females assigned the same lesson. Those field dependent female students assigned to the simulation CAI strategy may not have grasped the
directions on how to use the GIGI microcomputer to solve the problems. The directions for using the GIGI microcomputer terminal for the simulation lesson may not have been structured enough. It is speculated that these students spent most of their time learning how to use the instructional hardware and did not get to the program content, which was the visualization of orthographic projections.

The interaction effect of sex is most prevalent with the field dependent subjects. The field dependent females appeared to have achieved lower MAT test 9 scores than the male field dependent subjects. Some literature suggests females may be more field dependent than males. This is not supported by this research because the females' scores on the GEFT did not differ significantly from the males' GEFT scores. There is an indication that females who are field dependent may have more difficulty with structured learning than the males who are field dependent. This would contribute to the significant sex interaction. The small sample size of females in this study suggests additional study needs to be done relative to sex differences on the cognitive style of field dependence independence.

Recommendations

Based upon the results of this study, some additional observations have been made by the researcher. The attempt to assist field dependent individuals overcome their inability to structure their learning environment was apparently only partially successful. Given the amount of time and effort required to develop the simulation CAI strategy,
careful consideration must be given when making the decision to develop CAI materials. This is especially important, given the apparent lack of difference between the MAT test 9 scores for the field independent students.

One possible solution to the user friendly aspect of the simulation CAI strategy would be to provide an in-class demonstration. More orthographic projection problems could then be used in the simulation lesson because less time would be needed to learn how the program worked. Because of the additional time required for the simulation lessons' directions, these students completed only six problems compared to the twenty problems completed by the students who were assigned the drill and practice lesson. This was necessary to equate the time spent completing the lesson. It is, therefore, recommended that this study be replicated, giving the students assigned to the simulation lesson a demonstration on how to use the program. In addition, the number of orthographic projection problems should be increased to become more equitable with the drill and practice lesson.

The topic of spatial visualization is also one which needs additional investigation. It has been observed that students from different age groups and cultures have differing abilities in performing this task. The advent of Computer Aided Design (CAD) systems and other systems used in industry has also contributed to the importance of this ability. The problem of spatial visualization has received extensive theoretical analysis and speculation. This theorizing has yet to make a contribution to educational practice. Additional
study needs to be done in relation to the phenomenon of spatial visualization and the implications for educational practice. The question arises, is the phenomenon of spatial perception amenable to instruction or is this trait more stable over time? If the trait is changeable, at what age level are the largest gains made and is there a difference between the gains made at different age levels? Effectiveness of different instructional strategies also needs more investigation relative to spatial visualization.

It has been observed that some individuals have greater spatial visualization abilities than other individuals. Study should also be done to determine if these individuals with greater visualization abilities have had experiences which contribute to this ability. This investigation should include collection of data from persons of diverse backgrounds with a variety of experiences. This may provide insight into the phenomenon of spatial perception and what contributes to this ability.

The students utilized in this study were assigned to treatment groups on a random basis. A replication of this study could also be conducted with the assignment to treatment groups based upon the GEFT scores. This would allow for proportional assignment of subjects to the treatment groups and insure both field dependent and field independent subjects are assigned to the various treatments.

A final recommendation concerns the use of a more representative cross section of students. Only freshman Engineering students during the Spring semester, 1984, at Iowa State University were used. The
CAI lessons of this study would apply equally to high school courses in mechanical drawing and many courses taught at the post-secondary level. It is recommended that this study be conducted with samples of high school students, two year technical school students and students from various curricula throughout the university structure. This would provide a more representative sample to determine the effectiveness of these CAI strategies.


Papert, Seymour. New cultures from new technologies. BYTE, 1980, 5(9), 230-240. (b)


Segel, David, & Raskin, Evelyn. Technical report on the multiple aptitude tests. Monterey, California: California Test Bureau, 1959. (b)


ACKNOWLEDGMENTS

The completion of a project such as this cannot be accomplished without the dedication and assistance of many people. I am taking this opportunity to express my sincere appreciation and to thank some of these individuals: First, Dr. William Miller who has supported and given me guidance throughout the writing of this paper and my graduate studies at ISU; second, the members of my graduate committee—Dr. LeRoy Wolins, Dr. William Wolansky, Dr. William Paige, and Dr. Clifford Smith—for serving on my graduate committee and providing me challenge and assistance which have helped me grow as a person.

Special appreciation is extended to Dr. Rex Thomas, Dr. Pete Boysen and Elizabeth Hooper. The comments and assistance of these individuals provided during the development of the CAI lessons was indispensable. I would also like to express my gratitude to the faculty and students of Freshman engineering 166X for their participation in this study. Professor Roland Jenison deserves a special acknowledgment for the assistance and coordination he provided to insure this study was successfully implemented.

Finally, I would like to thank my wife, Debra, for her encouragement and assistance during the preparation of this dissertation.
APPENDIX A. STUDY DESCRIPTION READ TO SUBJECTS

The following is to be read by the test administrator as the introduction to the spatial visualization test, biographical information form, and GEFT.

As part of this course, you are being asked to complete several inventory forms. These forms relate to spatial perceptual abilities, cognitive learning style and subject biographical information. This is all part of a study to investigate the effectiveness of computer-assisted instruction. Your cooperation by accurately completing these forms will help determine the effectiveness of computer-assisted instruction for this course. The responses from these forms will be tabulated and reported on a group basis only. The individual responses will not be available to anyone but the primary investigator. Although your name is important at this point for identification of future parts of this study, it will be removed as soon as all parts have been completed.
APPENDIX B. HUMAN SUBJECTS FORM
INFORMATION ON THE USE OF HUMAN SUBJECTS IN RESEARCH
IOWA STATE UNIVERSITY
(Please follow the accompanying Instructions for completing this form.)

1. Title of project (please type): Interaction of field dependence/independence with computer-assisted instruction structure in an orthographic project lesson.

2. I agree to provide the proper surveillance of this project to ensure 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.

Ronald D. Dahl 8/23/83
Typed Name of Principal Investigator Date Signature of Principal Investigator

215 Ind. Ed. II 292-5739
Campus Address Campus Telephone

3. Signatures of others (if any) Date Relationship to Principal Investigator

William J. Miller 8/26/83 Committee Chair

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:

7. If Applicable: Anticipated date on which audio or visual tapes will be erased and/or identifiers will be removed from completed survey instruments:

Month Day Year

8. Signature of Head or Chairperson Date Department or Administrative Unit

9. Decision of the University Committee on the Use of Human Subjects in Research:

☒ Project Approved ☐ Project not approved ☐ No action required

George G. Karas 9/1/83
Name of Committee Chairperson Date Signature of Committee Chairperson

Revised 5/78
APPENDIX C. MAT REPRODUCTION PERMISSION LETTER
October 4, 1983

Ron Dahl
1366 Hawthorne Court
Ames, Iowa 50010

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Sincerely yours,

Phyllis O'Donovan, Editor
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APPENDIX D. SAMPLE TEST ITEMS FROM MULTIPLE APTITUDE TEST
TEST 8
APPENDIX E. SAMPLE TEST ITEMS FROM MULTIPLE APTITUDE TEST

TEST 9
APPENDIX F. BIOGRAPHIC INFORMATION FORM
BIOGRAPHIC INFORMATION
(All Responses Will Be Kept In Strict Confidence)

Please answer the following questions with an "X" or a response in the space provided.

1. How many semesters of mechanical drawing, architectural drawing, etc. did you have in grades 9 through 12? ______

2. How many semesters of mechanical drawing, architectural drawing, etc. have you had in college? ______

3. What is your grade point average in mechanical drawing, architectural drawing, etc. at the college level?
   G.P.A. ______ ( ) does not apply

4. Approximately how many hours experience do you have playing video games? ______

5. What was your class rank when you graduated from high school? ______

6. What was your high school graduating class size? ______

7. What is your sex?
   ( ) female ( ) male

8. What time does this course meet?
   ( ) morning ( ) afternoon

9. What is your present student classification?
   ( ) freshman ( ) sophomore ( ) junior ( ) senior

10. Have you had any previous course instruction on using computers?
    ( ) yes ( ) no

11. Do you own a micro-computer?
    ( ) yes ( ) no

12. Are you aware of any uncorrectable visual problem you might have such as color blindness?
    ( ) yes ( ) no

13. Have you ever been employed where you used industrial machines or graphic communication equipment?
    ( ) yes ( ) no
APPENDIX G. STUDENT ASSIGNMENT SHEET
INTRODUCTION:

This assignment will provide you with an opportunity to improve your visualizing ability of orthographic projections. The entire assignment will be completed on "VAX C" at Iowa State University. The use of the "GIGI" terminal is also required for this assignment. To complete the assignment log-in with the appropriate user number and password and answer the appropriate questions.

PROCEDURE:

The following steps will assist you in completing this assignment.

1. Turn on the monitor and GIGI terminal.
2. Log-in on VAX C (user number and password).
3. Answer the registration question with the correct responses.
4. Execute the assignment. This is accomplished by moving the overlay with the up and down arrows over the words: "ASSIGNMENTS do assignments" and press the return key.
5. The assignment list will now appear, simply press the return key to begin the assignment.
6. You should now see "starting lesson ..."
7. Now read the directions and complete the assignment.
8. At the end of the lesson record your score in the appropriate blank at the top of this sheet. Although this is recorded in the system variables, please write your score on this sheet also.
9. After pressing return when "BYE" is on the screen you will be returned to the "assignment list". Press the "PF4" key at this time. (Located on the upper right-hand of the GIGI terminal.)
10. You should now be at the student menu, press the "PF4" key again.
11. You should not be logged-off the system.
12. Turn off the monitor and "GIGI" terminal and turn in this assignment sheet to your instructor.

PRECAUTIONS:

1. The response time on the VAX system is a function of the number of users on the system at anytime. This will cause the system to slow down considerably during certain times of the day. Wait for the appropriate prompts, DO NOT begin depressing keys at random as this may cause undesired results. Reset the system ONLY if you are certain an error has occurred in the system!!
2. This assignment is planned to be completed in a single session. The lesson should not require more than one hour to complete, so allow yourself ample time before you begin the assignment.
3. Do not leave a terminal without logging-off as this will allow access to your personal file by unauthorized individuals.
4. If you are in the locator mode (used by one-half the class), and the cursor disappears for several seconds, try pressing one or more of the arrow keys to bring it back.
APPENDIX H. SAMPLE TEST ITEMS FROM THE GEFT AND SIMPLE FORMS
Find Simple Form "A"

Find Simple Form "C"

Go on to the next page
SIMPLE FORMS

A

B

C

D

E

F

G

H
APPENDIX I. DRILL AND PRACTICE CAI LESSON SOURCE CODE
LESSON TREAT1
SCORE FALSE
DEFINE C,I: INTEGER
DEFINE NUMPOOL 20 : BOOLEAN
DEFINE RANDP: INTEGER, FUNCTION
DEFINE ANSWER 20 : STRING
DEFINE COUNTER, PERCENT : INTEGER
DEFINE yes : BOOLEAN, FUNCTION
ASSIGN COUNTER := 0
ASSIGN ANSWER 1 := "A"
ASSIGN ANSWER 2 := "C"
ASSIGN ANSWER 3 := "B"
ASSIGN ANSWER 4 := "A"
ASSIGN ANSWER 5 := "C"
ASSIGN ANSWER 6 := "A"
ASSIGN ANSWER 7 := "B"
ASSIGN ANSWER 8 := "A"
ASSIGN ANSWER 9 := "D"
ASSIGN ANSWER 10 := "B"
ASSIGN ANSWER 11 := "D"
ASSIGN ANSWER 12 := "A"
ASSIGN ANSWER 13 := "B"
ASSIGN ANSWER 14 := "D"
ASSIGN ANSWER 15 := "A"
ASSIGN ANSWER 16 := "C"
ASSIGN ANSWER 17 := "A"
ASSIGN ANSWER 18 := "B"
ASSIGN ANSWER 19 := "D"
ASSIGN ANSWER 20 := "C"
FCOLOR CYAN
ERASE BOX 0.0; 0.999, 0.999; -15
AT 510 SIZE 2
FCOLOR CYAN
WRITE This lesson lets you practice identification of the third view of an orthographic projection given two views.
SIZE 1 AT 1825 FCOLOR RED
WRITE Press RETURN to continue.
PAUSE
DO INTRO
UNIT PRAC
ERASE DO SETPERM(NUMPOOL)
FOR C := 1, 20
  ASSIGN 1 := RANDP(NUMPOOL, 1, 20)
  SLIDE "FIG" + STRING(1) + "\h.PIC"
  AT 10, 430
  FCOLOR RED
  SIZE 1
  WRITE Which right side view should be used with the given views?
  AT 400, 430
  FCOLOR WHITE
  WRITE Enter either A, B, C, or D
For this lesson you will be presented with the top and front views of an object. Four alternative right side views will also be presented. You must select which right side view is correct for the top and front views.

Press RETURN to continue.

To select the appropriate right side view enter either A, B, C, or D. Your response will be evaluated and you will be instructed what to do next.

This lesson requires that you complete all twenty problems before the lesson can be terminated. The time required to complete the lesson is from 30 to 45 minutes.

Allow yourself sufficient time to complete the entire lesson!
DO PRAC

ELSE

SIZE 1

DO QUIT

ENDIF

UNIT SHOSCORE(_PERCENT)
DEFINE PERCENT:INTEGER
ERASE PATTERN SOLID
FCOLOR YELLOW
BOX 0,0;0.999,0.999:-15
FCOLOR RED
SIZE 2
AT 1215
TEST PERCENT $SCORE FOR SET OF TWENTY PROBLEMS.
VALUE 100 $ALL RIGHT
WRITE VERY GOOD
YOU GOT THEM ALL RIGHT!
VALUE 89..99
WRITE NOT BAD
YOUR SCORE IS <<S,INT(PERCENT)>> %
VALUE 80..88
WRITE GOOD
YOUR SCORE IS <<S,INT(PERCENT)>> %
VALUE 25..79
WRITE YOU NEED ADDITIONAL PRACTICE.
YOU NEED ADDITIONAL PRACTICE.
YOUR SCORE IS <<S,INT(PERCENT)>> %
ENDTEST
AT 1825
SIZE 1
FCOLOR WHITE
WRITE Press RETURN to continue.
DO UNIT1(_PERCENT)

UNIT UNIT1(_PERCENT)
SCORE TRUE
DEFINE PERCENT:INTEGER
MODE ERASE
QUERY 510
RIGHT WEIGHT PERCENT
ENDQ MODE OVERLAY

UNIT QUIT
ERASE PATTERN SOLID
FCOLOR RED
BOX 0,0;0.999,0.999:-15
AT 620
APPENDIX J. SIMULATION CAI LESSON SOURCE CODE
LESSON TREAT2

DEFINE SOLINE 200, SLINE 200, LINES 100 : STRING
DEFINE NUMTRY, I, J, X, Y, NUMP, TEMP, COUNT, C, D, INCREM, FLAG, XO, YO, ENDKEY : INTEGER
DEFINE NUMLINES, percent : INTEGER
DEFINE INCORR, COUNTIN : BOOLEAN
DEFINE YES : BOOLEAN, FUNCTION

define firsttry 6 : boolean

ASSIGN XO := 50
ASSIGN YO := 270
ASSIGN NUMTRY := 0
ASSIGN NUMP := 1
DO KEYCHAR("LOAD")
DO TITLE

ERASE SIZE 1, 2
FCOLOR WHITE
AT 2225
WRITE To continue press
FCOLOR RED
DO KEYCHAR("RETURN")
FCOLOR CYAN
AT 310
IF YES("Do you want to review the directions ? ")
  DO INSTRUC
  ERASE 110; 2182
  AT 310
  IF YES("Do you wish to review the directions again ? ")
    DO INSTRUC
  ENDIF
ENDERASE

WRITE This assignment will require about 30-45 minutes to complete. Allow yourself sufficient time to complete the entire lesson.

SIZE 1, 2
FCOLOR CYAN
AT 310
IF YES("Do you want to continue ? ")
  FOR i := 1, 6
    assign firsttry i := true
  ENDFOR
  SIZE 1, 2
  LOOP NUMP <= 6
    ASSIGN FLAG := 1
    ASSIGN INCORR := TRUE
    LOOP INCORR
      DO EXERCISE(LINES, NUMLINES, INCORR, FLAG)
      DO ARRANG(LINES, NUMLINES, INCORR, SLINE)
      DO SORT(SLINE, INCREM, SOLINE)
      DO CHECK(SOLINE, INCREM, FLAG, INCORR, NUMP)
    ENDLOOP
    ASSIGN NUMTRY := NUMTRY + 1
  ENDLOOP
  ASSIGN NUMP := NUMP + 1
  ENDLOOP
  DO SHOSCORE(NUMTRY)
  DO QUIT
ELSE
  SIZE 1, 2
  DO QUIT
UNIT INSTRUCT
DEFINE i, j, x, y: INTEGER
SIZE 1, 2
ERASE
FCOLOR MAGENTA
BOX 0, 0; 0.999, 0.999; -15
FCOLOR CYAN
AT 310
WRITE This lesson lets you generate the missing view of an orthographic projection given two views.
FCOLOR WHITE
AT 2225
WRITE To continue press
FCOLOR RED
DO KEYCHAR("RETURN")
FCOLOR CYAN
PAUSE
AT 610
WRITE For this lesson you will be presented with the top and right side views of an object. The objective is to produce, through cursor movement, the missing front view. Once the missing view has been generated the solution will be evaluated to determine if the solution is correct.
PAUSE
AT 1110
WRITE Once the solution has been evaluated the correctness of the solution will be indicated. If the solution is correct the next problem will be presented. If the solution is incorrect, the same problem will be presented again. Each time a problem is represented additional assistance will be provided. This will continue until all problems have been completed.
PAUSE
ERASE 110: 2182
AT 310
WRITE For this lesson you will use the "GIGI" terminal to produce the desired missing view. The arrow keys and five other keys are all that are required. The
FCOLOR RED
DO KEYCHAR("RETURN")
FCOLOR CYAN
WRITE key will also be required when requested by the
AT 610
WRITE lesson just as your using it here.
Now let's review the keys which will be required.

The **GREEN KEY** is used when you want the solution you have generated to be checked. This stands for "CHECK SOLUTION".

The **GREEN KEY** is used to remove lines which were produced incorrectly. The most recently produced line is removed first, one line at a time, until all lines have been deleted.

The **GREEN "H" KEY** is used to produce a hidden line. The line will be produced from the current cursor location to the most recent cursor position.

The **GREEN "R" KEY** is used to restore the dots. Each time a problem is presented a grid of dots such as those below will be presented. When lines are deleted the dots at those locations are too. You may wish to restore these dots occasionally.

```
FOR I:=100,300,25
  FOR J:=270,395,25
    DOT I,J
  ENDFOR
ENDFOR
```

The flashing object below is the cursor. You can move it with the arrow keys. TRY IT NOW! To continue you will need to press **RED KEY**. You can move the cursor anywhere on the screen, but the correct solution will have intersecting lines at dot locations only!!
The "S" key is used to start a new line. Simply move the cursor to the desired starting location and press the "S" key. Then move to the end location of a line and press either "H" for a hidden line or "V" for a visible line.

If the end points of two lines are connected, you can proceed from one line to the next without the "S" key. But if the end points do not connect you must use the "S" key to start the next line.

The final key is the "V" key. This key is used to produce visible lines just as the "H" key is used to produce hidden lines.

You should now be ready to complete this lesson. Prompts are provided throughout the lesson to assist you. If you enter information incorrectly you will be informed how to correct the problem.

Simply follow the written directions and you should not encounter any difficulty completing this lesson.
Some problems do have multiple correct solutions. For these exercises there is only one correct solution which will be scored correct. If you feel your solution is correct but it was evaluated incorrect, study the additional prompts to arrive at the desired correct solution.

REMEMBER: to move the cursor use the arrow keys of the "GIGI" terminal. A correct solution can only be arrived at when intersecting lines meet at a dot location.

Please complete the front view of this object. The intersection of lines will occur only at the dot locations. Use the projection lines to solve this problem. Study the green lines on the isometric projection. This is the correct solution, study it. This is your last attempt.

Now complete the correct solution. To continue press RED KEYCHAR{"RETURN"}

END TEST

IF FLAG = 1
  FOR C:=50,250,25
    FOR D:=270,395,25
      DOT C,D
    END FOR
  END FOR
ELSE
  END FOR
END IF

ASSIGN NUMLINES:=0
ASSIGN COUNT:=0
ASSIGN COUNTIN:=TRUE
LOOP COUNTIN
  IF COUNT < 0
    ASSIGN COUNT:=0
  ENDIF
  IF X=0
    ASSIGN X:=250
    ASSIGN Y:=270
  ENDIF
  FCOLOR WHITE
  DO LOCATOR(X,Y,25,25,ENDKEY)
    IF ENDKEY=115
      ASSIGN ENDKEY:=83
    ENDIF
    IF ENDKEY=114
      ASSIGN ENDKEY:=82
    ENDIF
    IF (COUNT=0) AND (ENDKEY <> 83)
      IF (ENDKEY <> 82)
        ASSIGN ENDKEY:=2
      ENDIF
    ENDIF
  ENDIF
  IF (COUNT=1) AND (ENDKEY=127)
    ASSIGN COUNT:=COUNT-1
    ASSIGN ENDKEY:=3
  ENDIF
  IF (NUMLINES (= 0) AND (ENDKEY=127)
    ASSIGN ENDKEY:=3
  ENDIF
  IF (50 <= X AND X <= 250) AND (270 <= Y AND Y <= 395)
    ELSE
      ASSIGN ENDKEY:=1
  ENDIF
TEST
END KEY
VALUE 2
  ERASE 350,30;755,215
  AT 350,30
  FCOLOR CYAN
  WRITE To begin a line you must move the cursor
to a starting location using the arrow
  keys and press the "S" key.
  PLEASE PRESS
    FCOLOR RED
    DO KEYCHAR("RETURN")
    PAUSE
    FCOLOR WHITE
    ERASE 350,30;755,180
    ASSIGN X:=250
    ASSIGN Y:=270
VALUE 3
  ERASE 350,30;755,215
  AT 350,30
  FCOLOR CYAN
  WRITE You have deleted all of the lines
  which were previously drawn. To
  begin again move the cursor to a
  starting location using the arrow
  keys and press the "S" key.
PLEASE PRESS

FCOLOR RED
DO KEYCHAR("RETURN")
PAUSE
FCOLOR WHITE
ERASE 350,30;755,180
ASSIGN X:=250
ASSIGN Y:=270
VALUE 83,115
WRITE <<S,CHAR(7)>>
ASSIGN COUNT:=COUNT + 1
ASSIGN XL COUNT :=X
ASSIGN YL COUNT :=Y
VALUE 86,118
ASSIGN NUMLINES:=NUMLINES + 1
PATTERN SOLID
ASSIGN COUNT:=COUNT + 1
ASSIGN XL COUNT :=X
ASSIGN YL COUNT :=Y
LINE XL COUNT-1 ,YL COUNT-1 ;XL COUNT ,YL COUNT
ASSIGN POINT COUNT :=9*INT((YL COUNT -YO)/25)+INT((XL COUNT
-XO)/25)+1
ASSIGN POINT COUNT-1 :=9*INT((YL COUNT-1 -YO)/25)
+INT((XL COUNT-1 -XO)/25)+1
IF POINT COUNT <POINT COUNT-1
.. AS SIGN TEMP:=POINT COUNT-1
.. AS S IGN POINT COUNT-1 :=POINT COUNT
.. AS S IGN POINT COUNT :=TEMP
.. ELSE
.. ENDIF
ASSIGN LINES NUMLINES :=STRING(POINT COUNT ) + " "
VALUE 72,104
ASSIGN NUMLINES:=NUMLINES + 1
PATTERN DASH
ASSIGN COUNT:=COUNT + 1
ASSIGN XL COUNT :=X
ASSIGN YL COUNT :=Y
LINE XL COUNT-1 ,YL COUNT-1 ;XL COUNT ,YL COUNT
ASSIGN POINT COUNT :=9*INT((YL COUNT -YO)/25)+INT((XL COUNT
-XO)/25)+1
ASSIGN POINT COUNT-1 :=9*INT((YL COUNT-1 -YO)/25)
+INT((XL COUNT-1 -XO)/25)+1
IF POINT COUNT <POINT COUNT-1
.. AS S IGN TEMP:=POINT COUNT-1
.. AS S IGN POINT COUNT-1 :=POINT COUNT
.. AS S IGN POINT COUNT :=TEMP
.. ELSE
.. ENDIF
ASSIGN LINES NUMLINES :=STRING(POINT COUNT ) + " "
VALUE 127
.. MODE ERASE
.. PATTERN SOLID
.. ASSIGN XL COUNT :=X
.. ASSIGN YL COUNT :=Y
.. LINE XL COUNT-1 ,YL COUNT-1 ;XL COUNT ,YL COUNT
.. ASSIGN LINES NUMLINES := "O" + " " + "O" + " " + "O"
.. ASSIGN X:=XL COUNT-1
.. ASSIGN Y:=YL COUNT-1
109

MODE REPLACE
ASSIGN NUMLINES:=NUMLINES - 1
ASSIGN COUNT:=COUNT-1
VALUE 1
ERASE 350,30;755,215
WRITE <<5,CHAR(7)>>
AT 350,30
FCOLOR CYAN
WRITE The location of the cursor is not within the limits of the solution for this problem. The cursor must be on a dot for the solution to be correct. Please press
FCOLOR RED
DO KEYCHAR("RETURN")
FCOLOR WHITE
IF COUNT=0
  ASSIGN X:=250
ELSE
  ASSIGN X:=XL"COUNT"
  ASSIGN Y:=YL COUNT
ENDIF
PAUSE
ERASE 67,99
ASSIGN COUNTIN:=FALSE
VALUE 82,114
FCOLOR WHITE
IF (COUNT = 0)
  ASSIGN X:=250
ELSE
  ASSIGN X:=XL COUNT
  ASSIGN Y:=YL COUNT
ENDIF
IF FLAG=1
  FOR C:=50,250,25 FOR D:=270,395,25 DOT C,D
  ENDFOR
ELSE
  DO DOTS(NUMP)
ENDIF
END

OTHER
ERASE 350,30;755,215
AT 350,30
FCOLOR CYAN
WRITE The key you have entered is not an operation, accepted key commands are:
FCOLOR GREEN
AT 350,70
WRITE "C" = To check a solution.
AT 380,90
DO KEYCHAR("DELETE")
AT 440,90
WRITE = To remove the previous line.
AT 350,110
WRITE "H" = To draw a hidden line.
    "R" = To refresh the dots.
    "S" = To start a line.
    "V" = To draw a visible line.

FCOLOR CYAN
AT 350,190
WRITE PLEASE PRESS
    FCOLOR RED
    DO KEYCHAR("RETURN")
    PAUSE
    FCOLOR WHITE
    ERASE 350,30;755,215
    ASSIGN X:=XL COUNT
    ASSIGN Y:=YL COUNT
ENDTEST
ENDLOOP
ERASE 0,450;767,479
DO PRESSRET
ASSIGN COUNT:=COUNT-1
UNIT DOTS(NUMP)
DEFINE NUMP: INTEGER
TEST VALUE 1
    DOT 50,270.
    DOT 50,320
    DOT 50,395
    DOT 150,270
    DOT 150,320
    DOT 150,395
    DOT 250,270
    DOT 250,320
    DOT 250,395
VALUE 7
    DOT 50,270
    DOT 50,395
    DOT 75,270
    DOT 150,395
    DOT 200,270
    DOT 250,270
    DOT 250,370
    DOT 250,395
VALUE 3
    DOT 50,270
    DOT 50,320
    DOT 50,395
    DOT 150,270
    DOT 150,320
    DOT 150,395
    DOT 250,270
    DOT 250,395
VALUE 4
    DOT 50,270
    DOT 50,395
    DOT 75,270
    DOT 125,295
    DOT 250,295
    DOT 250,370
    DOT 250,395
VALUE 10
  DOT 50,270
  DOT 50,320
  DOT 50,395
  DOT 125,270
  DOT 125,320
  DOT 175,320
  DOT 175,395
  DOT 250,270
  DOT 250,320
VALUE 6
  DOT 50,270
  DOT 50,320
  DOT 50,345
  DOT 50,395
  DOT 100,270
  DOT 100,320
  DOT 175,320
  DOT 175,345
  DOT 250,345
  DOT 250,395
VALUE 2
  DOT 50,270
  DOT 50,345
  DOT 50,395
  DOT 175,345
  DOT 250,395
VALUE 8
  DOT 50,270
  DOT 50,395
  DOT 250,270
  DOT 250,395
VALUE 9
  DOT 50,270
  DOT 50,345
  DOT 50,395
  DOT 125,270
  DOT 125,345
  DOT 125,395
  DOT 150,270
  DOT 250,320
  DOT 250,345
  DOT 250,395
VALUE 5
  DOT 50,270
  DOT 50,320
  DOT 50,395
  DOT 125,270
  DOT 125,345
  DOT 125,395
  DOT 175,345
  DOT 175,395
  DOT 250,320
  DOT 250,395
ENDTEST

UNIT SORT(SLINE, INCREM, SOLINE)
DEFINE J, I, INCREM: INTEGER
DEFINE TEMP, SOLINE ?, SLINE ?: STRING
FOR J:=INCREM,2,-1
  FOR I:=1, J-1
    IF SOLINE I < SOLINE I+1
      ASSIGN TEMP := SOLINE I
      ASSIGN SOLINE I := SOLINE I+1
      ASSIGN SOLINE I+1 := TEMP
  ENDFOR
ENDFOR
ASSIGN J:=1
ASSIGN I:=1
LOOP J <= INCREM
  LOOP SOLINE J = SOLINE J+1
    ASSIGN J:=J+1
  ENDLOOP
  ASSIGN TEMP := SOLINE J
  ASSIGN SOLINE I := TEMP
  ASSIGN I:=I+1
ENDLOOP
ASSIGN INCREM:=1-1

UNIT ARRANG(SLINE, COUNT, INCREM, SOLINE)
DEFINE SLINE ?, POINT, VALUE3, SOLINE ?: STRING
DEFINE M, N, J, DIFFER, I, INCREM, COUNT, END, VALUE1, VALUE2, REMAIN, CONST: INTEGER
ASSIGN INCREM:=0
ASSIGN CONST:=9
ERASE 0.450:767, 479
AT 30.460
WRITE Checking your solution ...
FOR I:=1, COUNT
  ASSIGN VALUE1:= INT(NUMBER(WORD(1, SLINE )))
  ASSIGN VALUE2:= INT(NUMBER(WORD(2, SLINE )))
  ASSIGN VALUE3:= WORD(3, SLINE )
  ASSIGN DIFFER:= VALUE1-VALUE2
  IF DIFFER >= 9
    ASSIGN REMAIN:= DIFFER MOD CONST
    IF REMAIN <> 0
      ASSIGN INCREM:= INCREM+1
      DO LINE(INCREM, VALUE1, VALUE2, VALUE3, SLINE)
    ELSE
      ASSIGN END:= DIFFER/CONST
      FOR M:=1, END
      . ASSIGN VALUE2:= VALUE1-9
      . ASSIGN INCREM:= INCREM+1
      . DO LINE(INCREM, VALUE1, VALUE2, VALUE3, SLINE)
    ENDFOR
  ELSE
    . ASSIGN VALUE1:= VALUE1-9
    . ASSIGN INCREM:= INCREM+1
    . DO LINE(INCREM, VALUE1, VALUE2, VALUE3, SLINE)
  ENDIF
ELSE
  FOR N:=1, DIFFER
    . ASSIGN INCREM:= INCREM+1
    . ASSIGN VALUE2:= VALUE1-1
    . DO LINE(INCREM, VALUE1, VALUE2, VALUE3, SLINE)
  ENDFOR
  ASSIGN VALUE1:= VALUE1-1
  ENDIF
DEFINE INCREM, VALUE1, VALUE2: INTEGER
DEFINE POINT1, POINT2, SOLINE ?, VALUE3: STRING
IF VALUE1 < 10
  ASSIGN POINT1:=" " + STRING(VALUE1)
ELSE
  ASSIGN POINT1:=STRING(VALUE1)
ENDIF
IF VALUE2 < 10
  ASSIGN POINT2:=" " + STRING(VALUE2)
ELSE
  ASSIGN POINT2:=STRING(VALUE2)
ENDIF
ASSIGN SOLINE INCREM := POINT1 + " " + POINT2 + " " + VALUE3
UNIT CHECK(SOLINE, INCREM, FLAG, INCORR, nump)
DEFINE INCORR: BOOLEAN
DEFINE CLINE, SOLINE ?, CSOLUTION 200: STRING
DEFINE Firsttry6: BOOLEAN
DEFINE ENUMER: BOOLEAN
DEFINE N, FLAG, INCREM, I: INTEGER
ASSIGN ENUMER:=TRUE
OPEN "ANSW" + STRING(NUMP) + ".DAT", 1, READ
IF IORESULT <> 1
  at 1560
  WRITE Error 1, please report to instructor. <<s, ioresult>>
ENDIF
ASSIGN N:=0
LOOP
  IF EOF(1)=0
     GET 1, CLINE
     ASSIGN N:=N+1
     ASSIGN CSOLUTION N:=CLINE
  ELSE
     WRITE Your final attempt at this problem is not correct!
     WRITE Your solution is not the desired solution! Try again!!
     ENDIF
  ENDIF
  WRITE Your final attempt at this problem is not correct!
  WRITE Your solution is not the desired solution! Try again!!
  ENDIF
  DO PRESSRET
     ASSIGN FLAG:=FLAG + 1
     FCOLOR WHITE
     SIZE 1, 2
  ELSE
     ASSIGN I:=0
     ASSIGN ENUMER:=TRUE
  ENDIF
  WRITE
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LOOP ENUMER
  IF CSOLUT 1+1 =SOLINE 1+1
  ASSIGN 1:=1 + 1
  ELSE
    assign firstrynump :=false
    ERASE
    AT 100,100
    FCOLOR RED
    SIZE 3
    IF FLAG=5
      WRITE Your final attempt
      at this problem
      is not correct!
    ELSE
      WRITE Your solution is
      not the desired
      solution!
      Try again!!
    ENDIF
    DO PRESSRET
    ASSIGN FLAG:=FLAG + 1
    SIZE 1,2
    FCOLOR WHITE
    ASSIGN ENUMER:=FALSE
  ENDIF
  IF (N-1)=1
    ERASE
    AT 50,150
    FCOLOR MAGENTA
    SIZE 3
    WRITE Congratulations,
    your solution is correct!!
    FCOLOR WHITE
    SIZE 1,2
    ASSIGN ENUMER:=FALSE
    DO PRESSRET
    ASSIGN INCORR:=FALSE
  ENDIF
ENDLOOP
ENDIF
IF FLAG=6
  ASSIGN INCORR:=FALSE
ENDIF
UNIT SHOSCORE(NUMTRY)
SCORE TRUE
DEFINE PERCENT,NUMTRY:INTEGER
ASSIGN PERCENT:=100*(6/NUMTRY)
ERASE
PATTERN DASH
FCOLOR YELLOW
BOX 0.0:0.999,0.999:-15
PATTERN SOLID
FCOLOR RED
SIZE 2
AT 1215
TEST PERCENT
VALUE 100
  WRITE Very Good!
  You got them all right.
VALUE 83.99
  WRITE Not bad,
  your score is "<<s,int(percent)>> %.
VALUE 70.82
  WRITE Good,
  your score is "<<s,int(percent)>> %.
VALUE 55.69
  WRITE Fair,
  your score is "<<s,int(percent)>> %.
OTHER
  WRITE You need additional practice,
  your score is "<<s,int(percent)>> %.
ENDESTOP
AT 1825
SIZE 1,2
FCOLOR WHITE
WRITE To continue press
FCOLOR RED
DO KEYCHAR("RETURN")
DO UNITI(percent)
UNIT UNITI(percent)
define percent:integer
MODE ERASE
QUERY 510
RIGHT
ENDQ
MODE OVERLAY
UNIT QUIT
define PERCENT,i,try:integer
define record:string
assign try:=0
for i:=1,6
  if firstry
    assign try:=try+1
  endif
open "treat2.log",5,write
test i oresult
value 1
value 8
other 8
erase
  fcolor red
  at 410
  write Error opening file. Data not stored.
  Please report this to your instructor.
  stop
endtest
assign record:=acccname
put 5,record
assign record:="Correct first try = "+string(try)
put 5,record
assign record:="Percent = "+string(percent)
put 5,record
close 5
ERASE